

Book of Abstracts

November 8–11, 2026

Hilton Waikoloa Village

Waikoloa, Hawaii, USA

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Plenary Session 1. Health and Wellness
Monarchy Ballroom

Monday, November 9, 2026

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8:35-9:05

From Better-for-You to Built-for-Wellness:

How Health and Wellness Is Reshaping Food Innovation and Food Engineering

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ABSTRACT

Health and wellness expectations are reshaping the food industry from the inside out. Consumers are no longer just asking for less sugar, sodium, fat, or artificial ingredients — they want foods that actively deliver protein, fiber, gut health, metabolic support, healthy aging, and sustained energy. That shift moves health and wellness out of marketing and formulation and into a broader food engineering challenge: not just what goes into a product, but how it is processed, packaged, and manufactured at scale. Reformulation, functional nutrition, Food as Medicine, and digital health tracking are pulling companies in the same direction, even as cost, accessibility, taste, shelf life, safety, sustainability, and regulatory approval all still must be satisfied at once.

Delivering on that promise falls largely to food engineering. Heat-sensitive nutrients and bioactives need protection from degradation due to processing. Protein- and fiber-enriched systems need to be able to be processed while still delivering the desired finished product texture and flavor. Sodium and artificial additives need to be removed from recipes without losing the product's consumer acceptability. None of this happens without better processes — advanced thermal and non-thermal treatments, precision drying, fermentation, digital monitoring, AI-enabled formulation, and smart packaging. Commercial food systems will be used to illustrate what is already working on an industrial scale, where gaps remain, and what it will take to close them.

This presentation treats health and wellness as a system-level engineering problem. It looks at how consumer expectations are shifting and what that means for the way foods are designed and manufactured. The goal is to show where food engineers can turn "better-for-you" goals into products that are actually scalable, safe, affordable, and consumer-preferred over the next decade.

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9:05-9:35

Dispelling the Myth of Ultra Processed Foods

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ABSTRACT

The concept of ultra processed foods calls for serious misinterpretations of the role of food processing in human health. Numerous articles and scientific publications report food processing as a factor leading to adverse dietary outcomes and public health problems. The serious simplification of food classification at a binary level in published studies to foods and ultra processed foods is purporting the misinformation of food processing as the danger to public health and even as a cause of mortality. Obviously, such relationships are overstated and must be corrected. Firstly, it must be recognised that food processing is very different in its meaning from processed food. Secondly, when the extent of processing is reported as a health contributing factor or included in nutritional guidance, the levels of food processing, separate from food formulation, must be shown on an ordinal scale. Thirly, unprocessed foods are an exception rather than the norm and as such they may be a risky alternative to common diets. Fourtly, the modern food systems and societies may not be able to function without access to processed foods. Furthermore, using processing as a nutritional parameter requires means to measure exposures to processing from foods, meals and diets before processing vs. health relationships are established. Food processing needs may also be described by legislation to ensure food safety besides rigid, scientific data -based regulations controlling ingredients and additives use in food formulations. A robust food classification system that recognises processing and formulation as individual contributors to food properties is required to show whether food processing *per se* or chosen food formulation ingredients of processed foods cause adverse health outcomes. Besides well-defined processing terminology being essential, no food classification or nutritional guidance should compromise the robust scientific risk assessment and regulatory frameworks governing food processing and formulation or the overall food safety and quality.

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Oral Session 1: Emerging Technologies in Food Processing

Monday, November 9, 2026

Co-chairs: Hao Feng/Yi-Cheng Wang. 10:20 am-12:00 pm. Queen 4

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Abstract 686 | 10:20-10:40

Laser Photobiomodulation Enhances Growth, Bioactive Compounds, and Physical Quality of Brassica Sprouts

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ABSTRACT

Brassica sprouts are nutrient-rich fresh foods, but conventional germination may not fully activate their biochemical potential. Blue-laser photobiomodulation offers a chemical-free, low-energy approach for improving sprout growth and phytonutrient profile. However, comprehensive characterization of how laser treatment affects both bioactive and processing-relevant properties across sprout species remains unexplored. This study aimed to determine the effects of 450-nm blue-laser treatment on germination, growth, bioactive compounds, metabolomic profiles, and physical properties of broccoli, radish, and kale sprouts. Seeds were exposed to an 85-mW blue laser for 0, 60, 120, 180, 240, or 300 s using 1-s on/off cycles, then germinated at 25°C for 120 h. Germination rate, sprout length, and fresh weight were measured. Freeze-dried sprouts were analyzed for total phenolic content (TPC), total flavonoid content (TFC), DPPH antioxidant activity, γ-aminobutyric acid (GABA) content, phenylalanine ammonia-lyase (PAL) activity, color, compressibility, microstructure, and thermal properties. Untargeted UHPLC-HRMS metabolomics characterized treatment-induced metabolic changes. The 180-s treatment produced the most consistent improvements. Germination reached 100% for broccoli and radish and 93.3% for kale, while sprout lengths reached 5, 8, and 5 cm, respectively. At 180 s, TPC reached 22.6, 25.2, and 27.8 mg GAE/g; TFC reached 42.7, 53.4, and 54.4 mg QE/g; and DPPH activity reached 10.95, 20.68, and 25.09 μmol TE/g for broccoli, radish, and kale, respectively. GABA content and PAL activity also increased. Metabolomics showed species-specific enrichment of glucosinolates and flavonoids, with glucoraphanin emerging as a key differential metabolite. Laser treatment increased brightness, greenness, and surface roughness; raised denaturation temperatures by 6-8°C; and reduced powder compressibility by approximately 16-19%. Overall, moderate blue-laser exposure enhanced growth, biochemical composition, and functional powder properties. Blue-laser seed treatment provides a sustainable, scalable strategy for producing Brassica sprouts and functional sprout powders with improved nutritional quality and processing performance.

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Abstract 931 | 10:40-11:00

Inactivation of Polyphenol Oxidase by 222-nm Far-UVC: Effects of pH, Sugars, and Turbidity

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ABSTRACT

An important contributor to the enzymatic browning of fruits and vegetables is polyphenol oxidase (PPO), a copper-containing enzyme that catalyzes the oxidation of phenolic compounds to quinones. Because browning can reduce not only consumer acceptance but also nutritional quality, safe and effective methods for inactivating PPO during food processing and storage are needed. This study therefore evaluated how effectively various doses of microplasma-based 222 nm far-ultraviolet C (far-UVC) light inactivated PPO in a liquid-buffer system. Compared with conventional 254 nm UVC, far-UVC has limited penetration into human tissues, potentially offering safety advantages for applications involving human exposure. After treating mushroom PPO solutions with far-UVC generated by a KrCl excimer lamp, the researchers quantified PPO activity using a catechol-based spectrophotometric assay and ascertained residual activity relative to untreated controls. The influence of food-relevant matrix factors including pH, sugars, and turbidity on far-UVC-induced PPO inactivation was also investigated, and matrix absorbance at 222 nm was measured to evaluate its potential influence on treatment efficacy. All experiments were performed in triplicate. Far-UVC treatment progressively inactivated PPO as the dose increased, whereas ambient light produced only a modest reduction in activity. PPO inactivation was enhanced under acidic conditions and in the presence of fructose. In contrast, turbidity strongly reduced PPO inactivation, demonstrating that food-relevant matrix properties can substantially influence the efficacy of the proposed treatment. Overall, these findings highlight 222 nm far-UVC's potential as a nonthermal strategy for controlling PPO activity, and the strong influence of turbidity underscores the importance of optimizing far-UVC delivery when dealing with complex food systems.

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Abstract 814 | 11:00-11:20

Mechanically Flexible Devices and Elastic Robots for Food Packaging, Processing, and Safety

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ABSTRACT

This presentation will describe two classes of emerging technologies for food packaging, processing, and safety: mechanically flexible cold plasma devices and elastic robotic scrubbers for surface cleaning. Mechanically flexible devices made of metallized paper or layered sheets of aluminum and plastic use surface dielectric barrier discharge (SDBD) to produce ozone and other reactive species that inactivate bacteria up to 6 log colony-forming units (CFUs) within minutes of treatment. Collaboration with food scientists to treat fresh produce and other food products is advancing understanding of how plasma generated by SDBD interacts with complex substrates. Plasma, surface properties, and chemistry affect the degree of bacterial inactivation (log reduction in CFUs) and impact food quality. Our team is also working to understand how these devices might be patterned, bent, and shaped to accommodate food packaging layouts that might enable intermittent or futuristic treatments immediately before consumption.

The second topic of this talk will focus on elastic robots for scrubbing and cleaning surfaces stained by food. This work embeds elasticity in the design of the robotic links and joints to control the application of normal force during scrubbing passes. With less than 10 N of normal force, the robotic scrubbers can remove low-adhesion stains. To understand the required applied loads, our group runs experiments and uses discrete element modeling to simulate the balance between adhesion and cohesion forces. The resulting simulations can illuminate considerations for the design of future robots with appropriate dynamics and controls for cleaning stained surfaces.

Cleaning and sanitizing products, packaging, and processing areas are necessary to ensure food safety and quality. Ensuring food safety and quality requires water, cleaning reagents, and labor. In these examples, our group is exploring methods to reduce the use of reagents and advance robotic automation to improve efficiency in food processing and manufacturing.

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Abstract 840 | 11:20-11:40

Development of a Continuous-Flow Thermo-Ultrasonic System for Liquid Pasteurization

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ABSTRACT

Objectives

Ultrasound can effectively inactivate microorganisms in liquid foods while causing less damage to sensory and nutritional quality than conventional thermal processing. However, existing batch and continuous ultrasonic reactors often require several minutes to achieve a 5-log microbial reduction, limiting industrial throughput. This study aimed to develop a continuous-flow, high-intensity thermo-ultrasonic pasteurization system capable of rapidly inactivating target microorganisms while maintaining product quality and increasing processing capacity.

Methods

A prototype continuous-flow thermo-ultrasonic system consisting of pre-treatment, ultrasonic treatment, and post-treatment sections was developed. The ultrasonic flow cell was optimized to improve microbial inactivation. *Escherichia coli*, *Listeria monocytogenes*, and a surrogate for psychrotrophic *Clostridium botulinum* spores were evaluated in apple, watermelon, and carrot juices. Effects of thermosonication on color, antioxidant activity, total phenolic content, and total plate count were assessed. Treated juices were stored at 4 °C for 28 days to evaluate quality changes and shelf life.

Results

Thermosonication achieved rapid microbial inactivation, with most 5-log reduction times below 20 s. The treatment caused no significant changes in juice quality, while significantly reducing total plate counts and extending shelf life. The continuous-flow high-intensity thermo-ultrasonic system therefore enables microbial inactivation within seconds while preserving product quality. These results demonstrate its potential as a rapid, efficient, and scalable pasteurization technology for liquid foods.

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Abstract 835 | 11:40-12:00

High-Pressure Processing of Poi: Applied Research and a Pathway for HPP Adoption in Hawai‘i’s Food Industry

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ABSTRACT

Poi, a traditional Hawaiian staple produced from cooked and pounded kalo (taro; Colocasia esculenta), has a limited refrigerated shelf life and undergoes textural changes associated with starch retrogradation. These characteristics constrain the distribution and market reach of fresh Hawai‘i-produced poi. High-pressure processing (HPP) offers a nonthermal preservation approach with potential to extend refrigerated shelf life while maintaining product quality.

This study evaluates the effects of HPP pressure, kalo variety, and water concentration on fresh poi to identify processing conditions that delay textural changes associated with starch retrogradation, extend refrigerated shelf life, and maintain sensory quality.

Fresh poi representing selected kalo varieties is prepared with Hawai‘i poi processors at three commercially relevant water-addition levels. Samples are untreated or processed at 400, 500, or 600 MPa for 3 min and stored at 4°C for up to 28 days. Samples are evaluated at defined intervals for pH, water activity, moisture/total solids, instrumental texture or rheological properties, microbial quality, and sensory attributes. Treatment effects are compared across variety, water concentration, HPP pressure, and storage time. Preliminary sensory evaluation immediately following HPP treatment (Day 0) identified no apparent adverse changes in sensory characteristics compared with untreated poi. Ongoing trials will evaluate treatment effects on texture, sensory quality, and shelf life; results will be presented.

This research is part of WVAPDC’s broader HPP program integrating applied research, pilot-scale processing, product characterization, shelf-life and sensory evaluation, microbial validation, producer education, and commercialization support. Establishing science-based HPP applications for poi could expand the geographic reach and value of Hawai‘i-produced poi while reducing barriers to HPP adoption by local processors. More broadly, this work demonstrates how emerging processing technologies can be adapted to traditional foods while addressing quality, food safety, cultural relevance, and commercial feasibility.

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Oral Session 2: Sustainable Food Design

Monday, November 9, 2026

Co-chairs: Alain Le Bail/Ferruh Erdogdu. 10:20 am-12:00 pm. Queen 5

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Abstract 595 | 10:20-10:40

Microwave and baking; an overview of possible applications

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ABSTRACT

MW baking yielded numerous publications; this contribution concerns industry applications.

Bread baking with MW was adopted by two industries (crustless-bread), with two patents which both concern depaning; JACQUET-BROSSARD(France)/Patent EP2138-285B1(May-2009) and BIMBO(Spain) with EP2204-096-B1(Dec-2009), which will be detailled. MW is also associated with risks of tough texture named the HIGO effect (HIGO&NOGUCHI,1987), which will be explained. Hardening of the crumb texture can be overcome through control of the baking curve for example.

A second application concerns biscuit baking, which is not yet adopted in the industry. Baking tests were done in a conveyor oven. Overrun was observed with internal bubbling revealing the challenges of such technology. Also, a second conventional baking was needed to complete the final drying and colouring.

A third application concerns the mitigation of biscuits cracking caused by hydromechanical stresses, which is used by Arnott's Biscuits(AUS). The concept is based on applying a short MW treatment to cross the glass transition for ca. 1min), allowing enough time for equilibration of the water content. CFD modelling showed that stress accumulates around crumb's cells; application were done with biscuits, rusks and crackers.

The authors were involved in 3 major industry and academic projects in the field, giving credit to this contribution, which will contain a lot of technical information and scientific results.

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Abstract 635 | 11:20-11:40

Food Process Innovation for Sustainability:

Simulations for Industrial Scale Infrared, Microwave and Radio Frequency Applications

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ABSTRACT

UN-2030 Sustainable Development Goals and European Green Deal aim for clean energy in food processing. This is important in food manufacturing since conventional thermal processing depends upon fossil fuels and still holds significant proportion in the industry. Using electrified processing technologies as novel approaches, however, is a recent trend to apply in the industrial process lines. Among the electrified technologies, infrared, microwave, and radio frequency have been gaining industrial preference. While the objectives are for efficient processing and reduced energy use for improved quality and safety, satisfying these challenges is mostly based on experimental trial and error approaches. Hence, industrial adoption of these so-called eco-friendly technologies is rather challenging. Due to the required knowledge for physical and mathematical background for the process, manufacturing does not demonstrate the expected efficiency while the same systems are preferred to use for different purposes with minor changes in the process design conditions. Within the last decade(s), introducing computational-digital design for sustainable manufacturing has become an important concern, and digital technologies supported with the computational (mathematical modelling) approaches are to be the efficient solutions for these required advances.

The objective of this study is therefore to present computational designs of electrified technologies and demonstrate the computational manufacturing approach for advances in industrial processing. For this purpose, various industrial designs (thawing of frozen products, surface pasteurization of agricultural commodities, pasteurization of liquid food products) are presented for safe and eco-friendly sustainable processing. With the introduction of Industry 5.0 and beyond Industry x.0, combining digitalization with mathematical modelling-based virtualization background will also be more significant. Therefore, a futuristic example of a complete computational process supported with digital technologies (digital twin approach) for data flow, process control, design and optimization feature with a (hypothetical) digital twin for a conventional process will also be demonstrated.

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Abstract 751 | 11:00-11:20

From Food Structure Design to Industrial and AI-Driven Innovation

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ABSTRACT

Food innovation requires translating a fundamental understanding of process–structure–function relationships into technologies that can be implemented at industrial scale and respond to emerging consumer and sustainability demands. This contribution presents an innovation pathway built on the controlled design of food structures, illustrating how scientific understanding can progressively inform process development, prototyping, scale-up, and industrial implementation. The approach integrates formulation and processing conditions with rheological, microstructural, and functional characterization to understand how structures develop during food processing and how they determine texture, stability, digestibility, and nutritional performance. Examples include extrusion-based food structuring, the development of third-generation snacks, and alternative frying technologies aimed at producing foods with improved nutritional profiles. Advanced microscopy and quantitative image analysis have been central to establishing relationships between processing conditions, microstructure, and macroscopic properties. The translation of these principles from laboratory to pilot and industrial scales is illustrated through the development of a technology for producing low-fat, nutritionally enhanced snack products. This technology ultimately led to its implementation at industrial scale and the creation of a company producing low-fat, nutrient-dense snacks, providing valuable insights into the challenges of translating scientific knowledge and prototypes into scalable processes and market-ready products. More recently, this experience has been extended to data-driven food innovation through NOVA-IA, an industry–academia initiative integrating artificial intelligence into the food sector. Current developments focus on three interconnected challenges: food upcycling, AI-supported consumer and market intelligence, and improved process efficiency and consistency through data-driven approaches. Together, these experiences illustrate how food engineering can evolve from understanding and controlling food structures toward integrated innovation ecosystems that combine mechanistic knowledge, scalable technologies, industrial collaboration, and artificial intelligence.

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Abstract 870 | 11:20-11:40

Process Less and Design More: Emerging Technologies for Plant Proteins and Oils

Professor Roman Buckow, La Trobe Institute of Sustainable Agriculture and Food, La Trobe University, Bundoora, Victoria 3086, Australia.

ABSTRACT

The transition towards more sustainable food systems is creating growing demand for plant-derived proteins and lipids that combine nutritional quality, functionality and consumer appeal. Yet their production often relies on intensive fractionation, extraction and subsequent restructuring, with consequences for functionality, resource use and product quality. Emerging processing technologies, including pulsed electric field (PEF) processing, offer opportunities to rethink this approach by selectively modifying biological structures while preserving desirable functionality.

Research on pulses, particularly faba bean, demonstrates how fractionation routes influence protein composition and techno-functional properties, and how subsequent application of moisture, heat, salts, fermentation and extrusion can transform these ingredients into structures ranging from gels and tofu-like matrices to meat and seafood analogues. Hemp seed provides a complementary example of a protein- and oil-rich raw material with opportunities for integrated ingredient production. Beyond protein recovery, gentle processing can retain oleosomes providing functional lipid ingredients without first extracting oil and subsequently rebuilding an emulsion.

These examples point towards a broader opportunity for food engineering by moving from maximising extraction and purity towards selectively preserving, releasing and restructuring components at different length scales. PEF processing is particularly intriguing in this context. PEF can enhance mass transfer and facilitate the release of intracellular components, creating opportunities for more targeted fractionation while potentially reducing the mechanical and thermal intensity of processing.

Drawing on recent research in plant protein fractionation, oleosome recovery, fermentation, gelation and thermomechanical structuring, together with insights from PEF processing, this presentation explores how combining naturally functional structures with selective processing technologies can enable more resource efficient approaches to the next generation of plant-based foods.

Conventional and Emerging Food Processing Technologies

Sustainable and Innovative Food Packaging

Data-Driven and Physics-Based Modeling of Food Processes, Food Quality and Food Safety

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Materials Science for Foods and Food Packaging

Sensors, Biosensors, and Imaging Technologies

Artificial Intelligence, Machine Learning, and Automation in Food Systems

AI: Student fluency and what industry needs!

Plant-Based Proteins, Fungi-Based Foods, and Alternative Meat Innovations

Encapsulation, 3D/4D Printing, and Advanced Delivery Systems

Health Impacts and Nutritional Implications of Processed Foods

Entrepreneurship, Workforce Development, and Food Engineering Education

Educating consumers: What is processing?

Circular Economy: Use of resources for future in mind

Traceability, Sustainability , and Valorization

Cold Chain Technologies and Logistics

Precision Fermentation and Cellular Agriculture

Engineering Innovations for Ethnic, Traditional, and Global Foods

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Abstract 758 | 11:40-12:00

Engineering Stable Low-Temperature Systmes for Food Quality Preservation: Feedback-Controlled Supercooling and Superchilling

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ABSTRACT

Subzero preservation can extend food shelf-life, while limiting the structural damage associated with conventional freezing; however, its industrial application requires precise management of ice nucleation, ice fraction, and temperature fluctuations. This presentation covers an integrated perspective on stable low-temperature food preservation by combining a temperature-feedback-controlled supercooling (TFCS) system with recent advances in superchilling technology. The TFCS system was designed to maintain beef tenderloins in a metastable supercooled state and restore supercooling through immediate micro-thawing after spontaneous ice nucleation. Real-time temperature monitoring was used to identify nucleation events, activate an electric-resistance heater, and reverse incipient freezing. During seven days of storage at -5°C, the system responded successfully to as many as three nucleation events and continuously prolonged the supercooled state. Compared with conventional refrigeration and freezing, TFCS-treated beef showed improved color retention, texture, and microstructural integrity, demonstrating the feasibility of feedback-regulated nucleation management for quality preservation. In parallel, superchilling maintains foods slightly below their initial freezing point (sub-zero temperatures), with approximately 5-30% of tissue water converted to ice. This controlled partial freezing suppresses microbial and biochemical deterioration, while minimizing ice-crystal damage. Current approaches for evaluating and controlling superchilling include thermodynamic and kinetic modeling, differential scanning calorimetry, near-infrared spectroscopy, X-ray micro-computed tomography, and electrical impedance analysis. Evidence across animal-derived muscle foods indicates that superchilling can extend shelf-life by approximately two- to four-fold relative to refrigeration. Emerging combinations with high-voltage electric fields, static magnetic fields, and irradiation may further improve microbial control, ice-crystal stability, and oxidative resistance. Integration with intelligent sensing and adaptive control could enable safer, energy-efficient, and minimally damaging cold storage. Collectively, feedback-controlled supercooling and precisely regulated superchilling provide complementary engineering strategies for next-generation commercial cold-chain preservation.

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Oral Session 3: Novel Technologies for Improving Food Quality

Monday, November 9, 2026

Co-chairs: Tao Wu/Roopesh Syamaladevi. 10:20 am-12:00 pm. Queen 6

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Abstract 824 | 10:20-10:40

Effects of cooling rate, storage time, and thawing rate on ice crystal size in beef

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ABSTRACT

The quality of frozen meat is negatively affected by the formation and growth of ice crystals during freezing, frozen storage, and thawing. Understanding how ice crystal size changes during frozen-meat processing is important for optimizing the processing conditions of frozen meat. In this study, ice crystal size in beef exudate was examined as a function of cooling rate, storage time, and thawing rate. Ice crystal size decreased with increasing cooling rate, which may be caused by faster activation of ice nucleation sites, leading to increased number of smaller crystals. A short-term recrystallization treatment effectively eliminated differences in ice crystal size induced by cooling rate. During frozen storage at -18 ℃, ice crystal size increased with time, with most of the increase occurring within the first 7 days; a subsequent short-term recrystallization treatment increased ice crystal size after 1 and 2 days of storage but did not increase ice crystal size after 7, 14, and 30 days. During thawing, ice crystals grew more rapidly at higher thawing rates due to recrystallization, but the final ice crystal size was smaller because of the shorter thawing duration. Overall, these results demonstrate the important role of recrystallization in governing ice crystal size during freezing, frozen storage, and thawing. All three stages should be investigated to fully evaluate the benefits of novel freezing and thawing technologies.

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Abstract 694 | 10:40-11:00

Cold Plasma technology to Improve the Techno-Functional Properties and 3D Printability of food proteins

M. S. Roopesh, Pauline Chan, Maria Teresa Fernández, Aditya Sukumar Pasagadi, Sreelakshmi Menon, Department of Agricultural, Food & Nutritional Science University of Alberta Edmonton, Alberta, T6G 2P5, Canada

ABSTRACT

Plant proteins offer nutritional and sustainability advantages but frequently exhibit limited solubility, gelation, and shape retention, restricting their application in three-dimensional (3D) food printing. This presentation examines atmospheric cold plasma as a non-thermal approach for tailoring the structure and techno-functional properties of soy, fava bean, and pea protein isolates. Structural changes and related effects on solubility, foaming, water- and oil-holding capacities, gelation, rheology, texture, and 3D-printing performance were evaluated following direct and indirect plasma treatments. These included dielectric barrier discharge plasma, plasma-activated water, and plasma-activated microbubbles generated using air, CO_2, argon, or mixed gases. Treatment outcomes depended strongly on protein source, plasma delivery method, and gas composition. Air plasma increased random-coil content and improved the solubility and foaming properties of soy protein, whereas CO_2 plasma promoted β-sheet formation and enhanced water-holding capacity. Direct plasma and plasma-activated water converted α-helices to β-sheets in fava bean protein, increasing β-sheet content under selected conditions. Plasma-activated microbubbles also enhanced the viscoelastic and mechanical properties of pea protein gels, particularly when produced using argon-air mixtures. The resulting rheological improvements increased extrudability, shape fidelity, structural rigidity, deformation resistance, and storage stability of 3D-printed structures. Complementary treatment of cheese whey achieved microbial reductions while largely preserving protein and lactose contents, demonstrating effective stabilization with minimal quality deterioration. Overall, cold plasma provides a versatile, gas-tunable platform for improving protein functionality and developing customized, structurally stable, high-protein 3D-printed foods with desirable texture.

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Abstract 881 | 11:00-11:20

Integrated Multiphysics and Microbial Kinetics Modeling of Fermentation and Drying of Sausages

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ABSTRACT

Uncooked fermented, dried sausages pose food safety challenges because pathogens may not be adequately inactivated during manufacturing. Studies examining the effects of fermentation and drying on salami products showed that sausage formulation, fermentation and drying duration, terminal pH, and water activity were the most significant drivers of *Salmonella* reduction. However, different products (e.g., with different starter cultures, sausage diameters) dried to the same terminal water activity (aw) did not provide effective assurance that pathogens were sufficiently inactivated (i.e., 5.0 $\log_{10}$-cycle lethality in *Salmonella*). This study developed an integrated multiphysics and microbial kinetic model framework to simulate sausage fermentation and drying, as well as microbial inactivation. The drying of the sausage was simulated by using Fick's Laws of diffusion to model the transport of moisture within the sausage samples with two diameters of 19 mm and 32 mm. Convective mass transfer was used as a boundary condition to simulate moisture transport between the food and the air. A moisture isotherm equation for sausage was obtained from the literature to relate moisture content and water activity. Using collected experimental microbial inactivation data, Weibull models were used to develop microwave inactivation kinetics. The sausage drying and microbial inactivation kinetics were integrated into a multiphysics-kinetics model to simultaneously simulate the coupled drying and microbial inactivation process. The modeling results showed that sausages with larger diameters dried more slowly and non-uniformly, resulting in a lag in pathogen reduction at the center of the product. The modeling framework will be refined to predict the pathogen reductions at various sausage manufacturing conditions.

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Abstract 846 | 11:20-11:40

High-Barrier Food Packaging in Circular Economy: Myths, Facts, and Trade-offs

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ABSTRACT

As the food industry advances its sustainability commitments, packaging decisions are increasingly influenced by circular economy goals, recyclability targets, Extended Producer Responsibility (EPR) schemes, and carbon reduction initiatives. At the same time, food manufacturers continue to face critical challenges related to shelf-life extension, food safety, product quality, packaging efficiency, and total system cost. These competing priorities often create misconceptions about the role of high-barrier packaging in sustainable food systems.

This presentation examines the myths, facts, and trade-offs associated with high-barrier flexible packaging and explores how packaging engineers and sustainability leaders can make informed decisions using a systems-based approach. Through case studies such as potato chips, dry milk, fresh meat, and other comparative analyses, attendees will understand the interactions among barrier performance, package design, recyclability, EPR considerations, and overall environmental impact. Particular attention will be given to recent developments in high-barrier solutions that support circularity objectives while maintaining packaging functionality and commercial viability.

Using innovative barrier technologies, including EVOH and bio-based Plantic materials, the industry can create solutions to improve package sustainability without compromising product protection or processing performance. Examples will illustrate how material selection influences machinability, package weight, shelf life, end-of-life considerations, and total cost across the value chain.

Attendees will gain practical insights into balancing sustainability goals with food protection requirements and learn why the most sustainable package is often determined not by a single metric, but by its ability to optimize the entire system, including regulatory pressures and business performance.

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Abstract 928 | 11:40-12:00

High-Pressure Impregnation of Minerals into Rice

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ABSTRACT

This study evaluated the application of high-pressure liquid infusion concept for impregnating selected minerals into long-grain white Basmati rice. The concept was based on infusion of mineral enriched liquid under high pressure (HP) into grains, and then, post treatment, drying the grains to evaporate the water thereby retaining the infused components within the solid matrix. Initial studies evaluated the level of liquid infusion into various grains and legumes under HP infusion (HPI).

White basmati rice was selected and used next for mineral infusion. Rice was packed along with a mineral solution containing several micro (Zn, B, Se, and Mn) and macro minerals (Ca, Mg, K, and Na) and subjected to HPI treatment under different conditions. Treatment at 100 MPa for 10 min was considered adequate among the conditions tested. Post treatment, the rice was strained to separate the excess solution and then hot-air dried at 60 °C under mild conditions, leaving behind the entrapped minerals. The dried product was evaluated for mineral content and tested for quality after different cooking conditions and analyzed. Elemental concentrations before and after treatment were quantified using inductively coupled plasma mass spectrometry (ICP-MS) following microwave digestion.

Results demonstrated that there was a significant and proportional increase in the mineral concentration in white rice after the HPI. Pressure level was not significant. Compared to untreated control samples, HPI treated rice samples had a large increase in the concentration of all the minerals (820 mg/kg Zn, 3.3 mg/kg Se, 37 mg/kg B, 130 mg/kg Mn, 1180 mg/kg Ca, 390 mg/kg Mg, 13200 mg/kg K, 1630 mg/kg Na). The initial concentration of minerals before treatment was then adjusted to enrich the rice to be in the desired range (~10 times MDA). The cook time for the rice post treatment decreased significantly offering advantages over the control sample. HPI treatment effects on other functional properties of rice were minimal.

Overall, the study demonstrated that HPI can be used to infuse a calculated amount of mineral in to the solid rice matrix for nutrient enrichment along with reduced cooking time. The study can easily be expanded to cover other agricultural products and can help to assist in eradicating the nutrient deficiency problems.

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Oral Session 4: Improving Shelf Life

Monday, November 9, 2026

Co-chairs:Ningjian Liang/Carmen Moraru . 10:20 am-12:00 pm. King 1

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Abstract 937 | 10:20-10:40

Continuous Liquid Phase Plasma Processing Modulates Plasmin Activity and Peptide Profiles in Cheese Ripening

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ABSTRACT

Bitterness in aged cheese significantly impairs product quality and consumer acceptance, largely driven by the accumulation of bitter peptides resulting from casein hydrolysis by the endogenous enzyme plasmin. While standard thermal pasteurization ensures microbiological safety, it promotes proteolysis and bitterness. This occurs because pasteurization degrades heat-sensitive plasminogen activator inhibitors, leading to enhanced plasminogen activation and a subsequent surge in active plasmin during cheese aging.

To mitigate bitterness in cheese without compromising safety, this study aimed at investigating the application of continuous liquid phase plasma processing as an alternative to conventional pasteurization for milk treatment prior to cheesemaking. To evaluate the efficacy of this approach to mitigate the generation of bitter peptides, bovine milk was processed using the continuous liquid phase plasma and subsequently manufactured into Gouda cheese. A control group was the cheese made from milk heat at 72°C for 15 s. Both experimental and control cheeses were aged in a sealed package at 10°C for 3 months. Plasmin was isolated from treated milk and aged cheese and were quantified using spectrophotometry. Peptides were extracted from the cheese, purified using solid-phase extraction C18 cartridges, and subsequently analyzed via liquid chromatography-tandem mass spectrometry-based proteomics.

The results showed that both continuous liquid phase plasma processing and standard pasteurization did not increase plasmin enzyme activity compared to raw milk (43 U/mL). However, during the aging period, cheeses manufactured from milk processed using continuous liquid phase plasma exhibited lower plasmin activity than those produced via standard pasteurization. Furthermore, the peptide profiles of the cheeses different between the two processing methods. Work is currently underway to quantify the specific bitter peptides present in these two groups of cheeses.

In conclusion, continuous liquid phase plasma processing demonstrates significant potential as an innovative method to control plasmin activity and influence peptide formation throughout cheese ripening process.

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Abstract 655 | 10:40-11:00

Gentle processing approaches for improving food shelf life

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ABSTRACT

Food shelf life, the period during which a product retains its defined microbiological, chemical, physical, and sensory integrity is of critical importance for industry and consumers alike. Food shelf life is determined by the interplay of intrinsic factors such as water activity, pH, and composition, with extrinsic drivers including temperature, light, oxygen, and packaging. This talk will present original data illustrating membrane processing-based strategies that extend shelf life by targeting either the microbial load or water activity, while preserving high product quality.

Bacterial contaminants significantly impact the safety and shelf life of liquid foods such as fluid milk and juices. While vegetative cells are inactivated by thermal pasteurization, bacterial spores are not. Microfiltration (MF), a membrane separation process, can remove both vegetative cells and spores from liquid foods. We will demonstrate how MF of 1.4 μm and 1.2 μm pore size can extend the microbial and proteolytic shelf life of fluid milk for up to 90 days at 6 °C, and how a combination of MF and light based treatments can improve the safety and shelf life of juices. The other strategy to increase shelf life is water removal using low temperature reverse osmosis (RO), forward osmosis (FO), or a combination of RO and FO. For milk, concentration levels ~ 40 °Brix were achieved by RO + FO. For strawberry juice, a final concentration of ~ 50 °Brix was achieved by RO + FO, while for red beet juice FO alone achieved ~ 60 °Brix. For all products, the nonthermal processes had no negative impact on the quality, nutritive, and sensory properties of the products.

The factors of influence and limitations for these processes will also be discussed. Overall, this talk will inform scientists and industry practitioners on key aspects of nonthermal processing methods for extending fluid foods shelf life.

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Abstract 779 | 11:00-11:20

Title: Vitamin stability in whey protein and RTM products

ABSTRACT

Consumer demand for high protein dairy products has risen sharply over the past year. Rapid growth of GLP-1 use coupled with intensified interest in nutrition for health and disease-risk is driving vitamin fortification and sales of whey protein isolate (WPI) and ready-to-mix (RTM) drink powders. With these complex matrices, vitamin fortification formulators face challenges assessing long-term vitamin stability and the amount of overage required to meet product shelf life label claims. This presentation will address customized extraction and quantification of water-soluble vitamins C and B5 from WPI and RTM products. The similarities and differences associated with vitamin extraction and quantitation for WPI and RTM product types along with the decline in vitamin quantities during accelerated shelf life testing will be discussed. Results indicate that the higher whey protein content in WPI correlates with a greater amount of protein bound vitamins, translating to lower levels of recovered vitamin in WPI compared to RTM.

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Abstract 837 | 11:20-11:40

Technical Challenges and Analytical Considerations for Creatine and Bioactive Ingredients in Consumer Packaged Foods and Beverages

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ABSTRACT

Introduction: The consumer packaged goods (CPG) industry is saturated with protein-packed RTE foods and RTD beverages. New and established brands seek to differentiate by adding non-essential bioactive ingredients for added health and performance benefits. The demand for convenience foods for on-the-go nutrition is on the rise as consumers display less interest in traditional shelf-stable powdered supplements. Glanbia, the largest producer of American style cheddar cheese and a leading producer of whey protein, is at the forefront of research and development in the bioactive ingredients space. Creatine and peptides are two examples of highly desirable value-add ingredients for protein-enriched packaged goods. The responsible inclusion of these and other bioactives in consumable products requires extensive shelf-life testing and reliable test methods to satisfy product claims and ensure product safety.

Objectives: The objectives of this research were to: (1) Identify stability challenges and solutions in RTD beverage processing (pasteurization, carbonation, pH adjustment, etc), (2) Investigate current risks and opportunities in the analytical testing of creatine and peptides for stability purposes.

Methods: Research methods included use of our pilot plant facilities (microthermics, UHT, hot-fill, hot water bath,) and benchtop formulations to produce shelf-stable and perishable beverages, protein bars, yogurts, gels, gummies, and other prototypes. These prototypes and market samples were subject to real-time ambient or refrigerated storage and regular analytical testing (HPLC, UPLC, amino acid quantification), visual inspections and organoleptic evaluations throughout a 60-365 day shelf-life period.

Results: Our findings suggest superior functionality and stability in our novel creatine ingredient for RTD beverages, yogurts, and gels in the CPG market. Analytical challenges included sample storage conditions (ambient vs refrigerated, pH), analytical test preparations (filter use, pulverization, decarbonation), and ingredient interactions. The addition of bioactive ingredients into protein-enriched foods and beverages requires extensive technical expertise, troubleshooting, and shelf-life monitoring to ensure food safety while maintaining product claims. Furthermore, advancements in robust, affordable analytical methods are essential for supporting the responsible inclusion of bioactive ingredients in RTE foods and RTD beverages.

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Abstract 580 | 11:40-12:00

Energy-Efficient Salmonella Inactivation via Optimized Gas-Liquid Mass Transfer in Dielectric Barrier Discharge Plasma

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ABSTRACT

Salmonella enterica poses persistent challenges to conventional sanitization systems owing to its physiological resilience and capacity for stress adaptation. This study evaluated the operational parameters of a submerged Dielectric Barrier Discharge (DBD) cold plasma system operating directly within the treatment liquid, generating reactive oxygen and nitrogen species (RONS) in situ, targeting a three-strain *Salmonella enterica* cocktail (serovars Enteritidis, Mbandaka, and Tennessee) inoculated onto sand carriers (≈8.25 log CFU/mL). Five voltage conditions (50, 85, 120, 160, and 200 V) were evaluated at fixed discharge frequency (1500 Hz), and airflow rate (1 LPM), with a Bubble-Spark Discharge condition (200 V, 2 LPM, 2500 Hz) included as an external cross-system benchmark. Each condition was characterized through concurrent electrical analysis, physicochemical profiling of the discharge-treated liquid, and microbial inactivation kinetics. Results revealed a non-monotonic relationship between applied voltage and antimicrobial efficacy, termed the Inverse Power-Efficacy Relationship. The 120 V condition (38.7 W) achieved total inactivation of ≈ 7 log CFU/mL within 80 seconds, whilst conditions at ≥ 160 V yielded only ≈ 0.25–1.87 log reductions despite consuming up to 104% more electrical power, attributable to thermal quenching of the primary biocidal species and a shift toward less bactericidal discharge chemistry. The 85 V condition established the lower operational boundary, achieving ≈ 5 log reduction and confirming an effective discharge window spanning 85–120 V. Pearson correlation identified the dominant inactivation driver ($r = 0.98$, $p < 0.01$), while real power was negatively correlated with inactivation efficacy ($r = -0.51$, $p < 0.05$), statistically formalizing the paradox. At a specific energy consumption of 396.9 J/log, the 120 V condition was up to 63.8-fold more energy-efficient than high-voltage configurations. These findings demonstrate that chemical precision within a defined operational window, rather than power maximization, governs both microbiological efficacy and energetic performance in DBD plasma-liquid systems.

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Oral Session 5: Green Extraction and Separation Technologies

Monday, November 9, 2026

Co-chairs: Sergio Martinez-Monteagudo/Felix Schottroff. 10:20 am-12:00 pm. King 2

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Abstract 725 | 10:20-10:40

Guided Ultrasound as a Process-Intensification Strategy for Falling-Film Evaporation

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ABSTRACT

Evaporation is an energy-intensive operation widely used for the concentration of liquid foods. Guided ultrasound offers a potential approach for intensifying falling-film evaporation by transmitting acoustic energy along the evaporation surface, with the potential to alter liquid-film hydrodynamics and enhance heat and mass transfer. This study aimed to establish the computational and engineering basis for applying guided ultrasound to falling-film evaporation. Numerical simulations were conducted using a stainless-steel tubular geometry with an outer diameter of 10.7 mm and an inner diameter of 9 mm to characterize guided acoustic wave propagation. Longitudinal and flexural wave modes were evaluated from 50 to 100 kHz, including determination of phase and group velocities, to identify candidate modes and frequencies for experimental implementation. In parallel, a falling-film evaporation system was designed for controlled liquid-film formation and guided ultrasound application. Design calculations considered evaporation-surface geometry, liquid distribution, film thickness, flow rate, and residence time. A laboratory-scale configuration consisting of a stainless-steel evaporation plate enclosed within a transparent chamber was designed to permit visualization of film hydrodynamics and ultrasound-induced phenomena. Collectively, the guided-wave simulations and evaporator design provide the foundation for experimentally investigating guided ultrasound as a process-intensification strategy. Subsequent work will determine the effects of guided acoustic energy on film hydrodynamics, evaporation rate, heat-transfer performance, and energy consumption using model solutions and liquid food systems.

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Abstract 695 | 10:40-11:00

Supercritical Carbon Dioxide Drying for Creating Porous Red Lentil Proteins: Effects of pH and Solvent Exchange

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ABSTRACT

Drying plays a crucial role in protein processing as it directly influences the structural stability and functional properties of proteins. With a growing demand for sustainable and plant-based protein sources, red lentil protein (RLP) has gained much attention as a promising plant protein alternative. This study explores the effect of different drying techniques, namely freeze-drying (FD), air drying (AD), and supercritical carbon dioxide drying (SCD) at different pH ranges (acidic pH 4.5 (SCD-A) and neutral pH 7 (SCD-N)) on structural and functional characteristics of RLP. SCD RLP (119 m^2/g) exhibited a significantly higher surface area than the ones dried using AD (0.07 m^2/g) and FD (0.30 m^2/g) ($p < 0.05$), contributing to enhanced solubility and functionality. The SCD samples had superior foaming capacity (FC) (183%), creaming index (CI) (48%), and water absorption index (WAI) (3.21%) compared to the FD and AD samples. The FD samples had lower solubility and non-homogeneous particle size compared to SCD and AD samples, resulting in reduced functional properties. The differential scanning calorimeter (DSC) and X-ray diffraction (XRD) analyses confirmed the thermal stability and amorphous nature of SCD RLP, respectively, while scanning electron microscopy (SEM) images revealed a well-developed porous microstructure. Furthermore, the Fourier transform infrared spectroscopy (FTIR) results confirmed that the neutralization process reduced protein hydrophobicity, thereby enhancing its solubility and colloidal stability. Overall, SCD proved to be a promising alternative for RLP drying, offering enhanced functionality, improved structural integrity, and strong potential as a scalable, sustainable, and green technology for producing plant-based proteins suitable for advanced food and nutraceutical applications.

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Abstract 952 | 11:00-11:20

Camelina Seed Valorization into High-Value Ingredients Using Integrated Green Biorefinery Approach

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ABSTRACT

Camelina is a promising oilseed crop for biofuel production; however, conventional processing methods use only a small fraction of the seed for fuel, with the rest treated as waste. There is a pressing need for sustainable manufacturing approaches that enable the full utilization of camelina seeds and generate value-added co-products through a circular economy. The goal of this study was to develop an integrated green biorefinery platform based on supercritical carbon dioxide (SC-CO_2) technology to convert camelina processing residues into multiple high-value ingredients for food and nutraceutical applications.

A clean SC-CO_2 biorefinery was designed to fractionate camelina seed components. Mucilage was isolated and converted into bioaerogels. Demucilaged camelina seeds were dried using an alternative SC-CO_2-based method to improve protein functionality. Ethanol-modified SC-CO_2 lipid extraction yielded astaxanthin, a high-value antioxidant, which was purified using an innovative enzymatic interesterification process. Omega-3-rich oil and lecithin were extracted from the mucilage-free residue via SC-CO_2, and the remaining protein-rich fraction was evaluated for functionality and transformed into aerogels.

Novel food-grade mucilage-based bioaerogels with ultra-low density (0.05 g/cm^3) and high surface area (240 m^2/g) were produced from camelina. These bioaerogels exhibited rheological behavior comparable to that of commercial food thickeners, highlighting their potential as sustainable alternatives and stabilizers. Emulsions stabilized with camelina lecithin performed equivalently to those stabilized with soy lecithin. Incorporating mucilage and protein aerogels improved the printability and structural integrity of 3D-printed food inks, while the process also enhanced astaxanthin bioaccessibility.

This work presents a scalable, clean biorefinery model for the full utilization of camelina seeds and potentially other crops. It generates high-value food and nutraceutical ingredients, enhancing profitability and sustainability while supporting rural adoption, growth of the circular bioeconomy, and economic resilience in agricultural communities.

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Abstract 663 | 11:20-11:40

Where Green Chemistry Meets Food Processing: Developing the Next Generation of Plant Protein Ingredients

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ABSTRACT

Consumer demand for nutritious, sustainable, and clean-label plant protein ingredients continues to grow. To meet these needs and address global environmental challenges, it is essential to transform underutilized protein sources into high-quality, sustainable ingredients for human nutrition. In this research, biodegradable, non-toxic, and environmentally friendly natural deep eutectic solvents (NADES) were employed to develop a green strategy for producing clean-label plant protein ingredients from both oilseed (soybean) and non-oilseed (cowpea) legumes. We investigated the effects of key variables, including flour-to-NADES ratio, NADES composition and type, and time. Our findings revealed that the optimized NADES-assisted soy protein isolate (SPI) achieved 89% protein purity and a 52% extraction yield—comparable in purity and significantly higher in yield ($P < 0.05$) than conventional SPI (91% purity and 38% yield). Similarly, NADES-assisted extraction from cowpea demonstrated enhanced protein recovery (90% purity and 52% yield) compared to conventional alkaline solubilization followed by acid precipitation (85% purity and 54% yield). Also, NADES extraction improved gelation and emulsification properties of both protein ingredients. Further characterization of the nutritional and (off-)flavor properties confirmed that these clean-label plant protein ingredients hold strong potential for incorporation into diverse food products.

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Abstract 590 | 11:40-12:00

Pulsed Electric Fields (PEF) Processing for Improvement of Food-Grade Fungal Bioprocesses

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ABSTRACT

Biotechnological production methods, e.g. fermentation of substrates using different microorganisms, are gaining increasing attention in food processing, but are often lengthy and expensive. Therefore, PEF treatments were applied to fungi fermentations, to intensify upstream and downstream processing.

Different PEF treatments (up to: 20kV/cm, 650kJ/kg, 1000Hz; batch or continuous) were accomplished, using rectangular pluses of 5 µs. The influence of the treatments on growth behavior (upstream) or extraction of intracellular target substances (downstream) was subsequently analyzed.

For **yeasts**, the following results were identified: **Upstream** application of PEF was not able to significantly and reproducibly influence the growth of *Saccharomyces cerevisiae, Pichia pastoris* and *Kluyveromyces marxianus*. In **downstream** processing**,** recovery of cytoplasmatic protein, mannoprotein and beta-glucans from *Saccharomyces pastorianus* after continuous PEF treatment was comparable to chemically induced autolysis. For recombinant protein extraction from *Pichia pastoris*, PEF was effective, reducing microbial counts by 0.5-3.0 $\log_{10}$.

For **filamentous fungi**, PEF treatment during **upstream** processing increased germination of *Penicillium roqueforti*, *Rhizopus oligosporus* and *Aspergillus oryzae* conidiospores. In liquid cultures of *Lentinula edodes*, *Pleurotus eryngii,* and *Pleurotus ostreatus*, initial or periodic (every 48-72h) PEF treatments had negligible effects on biomass formation and growth. **Downstream** processing of *Pleurotus eryngii*, *Laetiporus sulphureus*, *Aspergillus oryzae*, and *Rhizopus oligosporus* mycelia by PEF led to liberation of up to 48.5% of total intracellular proteins. Pigment extraction (laetiporic acids) from *Laetiporus sulphureus* did not increase following PEF, possibly due to low water solubility.

Altogether, the obtained results seem promising to increase the productivity of filamentous fungi fermentations. The extraction of intracellular components, such as proteins, via sublethal PEF-treatment is possible but biomass yields of following fermentations are lowered concurrent with removed cell constituents. Further research into the recovery of specific intracellular target compounds after sublethal PEF treatment could facilitate the wider application of PEF in food and biotechnological fermentations.

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Oral Session 6: Processing for Enhanced Food Safety

Monday, November 9, 2026

Co-chairs: Deepti Salvi/Abani Pradhan. 1:20 pm-3:00 pm. Queen 4

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Abstract 930 | 1:20-1:40

UV-C Decontamination of Low-Moisture Foods: Role of Powder Redistribution and Wavelength

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ABSTRACT

Low-moisture powdered foods are challenging to decontaminate because UV-C is primarily a surface treatment and particle layering can shield microorganisms from light exposure. This study integrates two stages of research aimed at improving UV-C treatment of powdered foods: development of a batch-style powder redistribution system and evaluation of 254 and 222 nm UV-C wavelengths in wheat flour and powdered infant formula. *Enterococcus faecium* ATCC 8459, a conservative surrogate for *Salmonella* in low-moisture foods, was used to evaluate treatment efficacy. In the first stage, several redistribution approaches were compared during 254 nm treatment of wheat flour. Continuous vibration using a weighing-boat sample base improved particle exposure, and reducing the treated sample mass from 1.00 to 0.15 g increased the reduction at 2.48 J/cm² from 2.0 to 3.6 log CFU/g. The results demonstrated that powder movement and reduced layer thickness are critical determinants of UV-C efficacy. Building on this system, in the second stage of study, 254 and 222 nm UV-C were compared at 0.50, 1.24, and 2.48 J/cm². At 2.48 J/cm², 254 nm achieved 4.5 and 3.5 log reductions of *E. faecium* in wheat flour and infant formula, respectively, compared with 2.4 and 1.5 log reductions at 222 nm. Despite the greater microbial inactivation with 254 nm, electrical energy required per log reduction was comparable between wavelengths. No visibly discernible color changes were observed under the tested conditions. These findings demonstrate that effective UV-C processing of powders depends on both wavelength selection and engineered particle redistribution. The work provides food engineers with a pathway toward nonthermal, energy-efficient decontamination of low-moisture foods while highlighting powder handling and exposure uniformity as key considerations for scale-up.

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Abstract 815 | 1:40-2:00

Evaluation of *Salmonella* Stress Response Genes and Antimicrobial Resistance in Poultry Processing for Improved Food Safety

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ABSTRACT

Salmonella enterica is a leading cause of foodborne illness in the U.S. and worldwide. Several interventions have been undertaken by the food industry to reduce the incidence and load of *Salmonella* in the food chain. These interventions primarily involve thermal, acid, and desiccation stress, such as heat treatment, refrigeration or freezing, the addition of preservative acids, and reduction in water activity. However, *Salmonella*, like many other foodborne pathogens, has shown a unique ability to tolerate such stressors, which poses a new challenge to the food industry. Recently, whole genome sequencing (WGS) has seen widespread application in the fields of epidemiological investigations and surveillance of bacterial foodborne pathogens. The objectives of this study were to identify gene signatures associated with *Salmonella* stress response during poultry processing using WGS data and develop genome-based machine learning models to predict antimicrobial resistance (AMR) in *Salmonella* isolated from chicken meat. Several machine learning algorithms including random forest, neural network, logit boost, and support vector machine were trained on *Salmonella* WGS data. Furthermore, genomic information on *Salmonella* isolates from chicken samples was combined with the AMR phenotype data to different antibiotics such as amoxicillin-clavulanic acid, ampicillin, streptomycin, and tetracycline. The best-performing machine learning model for each antimicrobial was used to predict the AMR phenotypes, and the predictions were compared from ResFinder. All models achieved high performances based on the area under the receiver operating characteristic (AUROC) curve metric, with logit boost showing the best performance with an AUROC score of 0.904, sensitivity of 0.889, and specificity of 0.920. When the AMR phenotype predictions of the machine learning models were compared to predictions from ResFinder, the predictions were accurate (> 95%). These studies help improve food safety initiatives, particularly in food processing, engineering, and predictive microbiology.

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Abstract 914 | 2:00-2:20

Emerging Food Safety Technologies combined with Machine Learning can Strengthen the Future of the Food Industry

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ABSTRACT

Food processing is rapidly moving from reactive food-safety control toward intelligent systems capable of detecting hazards, predicting risk, and supporting interventions in real time. Emerging technologies such as multispectral and hyperspectral imaging, near-infrared spectroscopy, fluorescence imaging, cold atmospheric-pressure plasma, and connected digital compliance systems provide new opportunities to strengthen food safety while improving processing efficiency. Artificial intelligence (AI) and machine learning (ML) are central to converting the large volumes of data generated by these technologies into actionable decisions. In poultry processing, convolutional neural networks can classify carcasses exhibiting septicemia-toxemia, while spectral and fluorescence imaging can support detection of visible and non-visible fecal contamination. Hyperspectral and near-infrared measurements can also be combined with neural networks, support vector machines, and other supervised-learning approaches to classify stages of microbial spoilage and identify a smaller number of signature wavelengths for development of faster and lower-cost sensing systems. Beyond detection, AI/ML can integrate microbiological, environmental, process, supplier, and historical data to estimate risk, identify abnormal trends, prioritize corrective actions, and provide early-warning alerts before failures become food-safety events. These predictive systems can complement emerging intervention technologies such as cold plasma, which uses reactive oxygen and nitrogen species, charged particles, electric fields, and ultraviolet photons to inactivate foodborne and spoilage microorganisms without the high temperatures associated with conventional thermal processing. Future food-safety systems will increasingly connect sensing, prediction, intervention, verification, and documentation within a unified decision-support architecture. The greatest opportunity is not simply automation of existing inspection tasks, but development of adaptive food-processing systems that continuously learn from process data, recognize emerging hazards, recommend targeted interventions, and document outcomes. Such integration could reduce dependence on subjective inspection, improve consistency, enhance traceability, reduce food waste, and enable a shift from retrospective verification toward preventive, data-driven food-safety management across increasingly complex, high-throughput, and digitally connected food processing operations.

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Abstract 639 | 2:20-2:40

Preparation of Zinc-Modified Chitin Nanofibers and Their Effects on Pathogen-Contaminated Microgreen Growth via Antimicrobial Activity and Oxidative Enzyme Modulation

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ABSTRACT

Microgreens are highly susceptible to seed-borne foodborne pathogens, which threaten both product safety and crop productivity. Developing multifunctional seed treatment technologies that simultaneously improve microbial safety and plant performance is therefore an important challenge for the food industry. This study aimed to develop zinc-modified chitin nanofibers (Zn@ChNFs) as a sustainable nanomaterial for pathogen control and growth enhancement in microgreen production. Zn@ChNFs were synthesized through ammonium persulfate oxidation followed by zinc coordination, preserving the native nanofibrous structure while achieving a maximum Zn loading of 2.9%. Their antimicrobial activity and effects on contaminated radish seed germination, microgreen growth, physiological responses, and nutritional quality were systematically evaluated. Zn@ChNFs exhibited significantly enhanced antimicrobial activity against *Listeria monocytogenes*, achieving more than a 1.04 log CFU/g reduction on contaminated seeds and sustained pathogen suppression throughout microgreen cultivation. Compared with water and pure ChNFs, Zn@ChNFs significantly improved seed germination, shoot length, leaf area, and biomass under bacterial stress. They also promoted nitrogen assimilation and chlorophyll biosynthesis, resulting in enhanced photosynthetic performance. Furthermore, Zn@ChNFs increased protein, polyphenol, and flavonoid contents, enhanced DPPH and ABTS antioxidant capacities, and elevated catalase and peroxidase activities, indicating improved tolerance to pathogen-induced oxidative stress. These findings demonstrate that Zn@ChNFs provide an effective seed nanopriming strategy that integrates antimicrobial protection with crop quality enhancement. This approach offers a sustainable solution for improving the safety, nutritional value, and production efficiency of microgreens, highlighting its potential application in food engineering and commercial fresh produce production.

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Abstract 588 | 2:40-3:00

Importance of engineering logistics in process validation to achieve food safety

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ABSTRACT

Food processing is one of the most fundamental methods used to transform raw agricultural commodities into safe, stable, and convenient products for consumers. Modern technologies have significantly expanded the scope of food processing, enabling manufacturers to produce a wide variety of products ranging from minimally processed foods to fully cooked and ready-to-eat items. Achieving consistent and safe food products requires more than standardized formulations; it also requires a clear understanding of critical operational parameters associated with processing equipment. Equipment design, heat source type, heat penetration, airflow patterns, relative humidity, residence time, and process control systems all play important roles in determining processing effectiveness. Variations in these parameters can influence heat transfer, microbial inactivation, and product uniformity, making equipment performance a key factor in ensuring food safety. Under the Food Safety Modernization Act (FSMA), 21 CFR 117.160 mandates that food manufacturers validate that preventive controls effectively manage identified hazards. This requires scientific validation of in-plant food manufacturing processes to confirm that controls consistently produce safe foods. This presentation highlights the complexity of modern food processing systems and emphasizes the critical role of engineering logistics during in-plant validation. By integrating customized high-temperature data loggers, operational parameters, and real-time process monitoring, manufacturers can generate scientifically sound validation data, optimize processing conditions, and ensure their systems consistently produce safe products, protecting consumers from foodborne illness outbreaks.

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Oral Session 7: Microbial Survival and Inactivation

Monday, November 9, 2026

Co-chairs: Qiao Ding/Juzhong Tang . 1:20 pm-3:00 pm. Queen 5

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Abstract 834 | 1:20-1:40

Understanding Bacterial Survival Mechanisms to Develop Effective Food Processing Technologies

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ABSTRACT

Food processors are increasingly expected to achieve robust microbial control while preserving product quality, reducing the use of preservatives to meet consumer demands, and minimizing energy-related production costs. However, pathogens are becoming increasingly resistant by adapting to harsh processing conditions via stress response and self-repairing mechanisms. The presentation aims to highlight that understanding bacterial survival mechanisms can benefit the development of efficient food processing technologies for microbial inactivation.

Case studies of *Escherichia coli* O157:H7 on lettuce during cold storage and *Salmonella* Typhimurium in low-moisture foods will be used to demonstrate bacterial adaptation and resistance under different processing conditions. The development of hurdle technologies targeting different cellular components to achieve synergistic microbial inactivation at lower treatment intensities will be demonstrated through studies combining UV-A light or high-frequency ultrasound with natural phenolic compounds. Bacterial physiological changes were assessed by evaluating membrane integrity and fluidity, ROS levels, and metabolic and enzymatic activities. Microbial stress responses were also evaluated with RNA-seq/qPCR.

Results showed that *E. coli* during cold-storage activated oxidative, osmotic, acid, cold, antimicrobial-efflux, attachment, and biofilm-related responses that could increase resistance to subsequent interventions. Similarly, *Salmonella* adapted to low-a_w conditions developed more rigid membranes and activated multiple stress-resistance pathways. In contrast, simultaneous UV-A treatment with benzoic acid produced >5-log *E. coli* reductions within 30 min ($p<0.05$), whereas individual treatments achieved <1–1.5-log reductions. Phenolic acids also significantly enhanced inactivation by UV-A or high-frequency ultrasound ($p<0.05$). Across these treatments, synergy was associated with membrane damage, intracellular acidification, oxidative stress, enzyme inactivation, and suppression or overloading of cellular defense and repair mechanisms.

The findings demonstrate the benefit of designing synergistic processes based on pathogen physiology and food matrix characteristics rather than empirical approaches. Future development should integrate treatment optimization with continuous processing capability to enable scalable applications in food manufacturing.

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Abstract 848 | 1:40-2:00

Engineering Plasma Micro/Nanobubbles for Next-Generation Pre- and Postharvest Food Safety and Sanitation

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ABSTRACT

Plasma micro/nanobubble (PMNB) technology integrates atmospheric plasma chemistry with the enhanced gas–liquid mass transfer and interfacial properties of micro- and nanobubbles, providing a promising chemical-reduced approach for microbial management, water sanitation, and food safety. This presentation highlights our development of PMNB as a scalable platform spanning preharvest hydroponic production and postharvest fresh produce washing. In hydroponic systems, PMNB is investigated for mitigating foodborne pathogen hazards in recirculating nutrient solutions while modulating microbial communities in the nutrient solution and plant root zone. These studies explore the potential to move beyond indiscriminate microbial inactivation toward controlled microbiome management while maintaining plant health and production performance. For postharvest applications, continuous-flow PMNB systems have been developed and evaluated for inactivation of foodborne pathogens on fresh produce, prevention of wash-water-mediated cross-contamination, and maintenance of antimicrobial efficacy under increasing organic loads. Engineering efforts focus on plasma reactor configuration, operating conditions, micro/nanobubble generation, gas–liquid mass transfer, hydraulic circulation, and integration into continuous and recirculating washing systems to support scale-up and practical implementation. Mechanistic investigations characterize plasma-generated reactive oxygen and nitrogen species, their generation, transfer, persistence, and transformation in aqueous environments, as well as microbial cellular damage and interactions among reactive species, bubbles, organic matter, microorganisms, and biological surfaces. Collectively, these studies establish a process–chemistry–microbiology framework for understanding and engineering PMNB treatments across complex food and agricultural environments. By connecting preharvest microbial management with postharvest sanitation through a common water-treatment platform, PMNB technology offers a potential next-generation strategy for improving microbial safety, reducing cross-contamination, decreasing reliance on conventional chemical sanitizers, and advancing sustainable water use and reuse throughout the fresh produce supply chain.

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Abstract 886 | 2:00-2:20

Estimation of Inactivation Parameters Under Dynamic Conditions: Listeria monocytogenes in Salami During Fermentation and Drying

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ABSTRACT

Many commercial food processes occur under dynamic conditions, such as changing temperature, pH, moisture, etc. Some processes are technically challenging to simulate under constant conditions. An alternate approach is to estimate the inactivation parameters directly from the process under dynamic conditions. The objective of this research was to use a case study of Listeria inactivation in fermenting and drying salami to demonstrate a systematic method to estimate parameters under continuously changing pH and moisture.

To produce dry fermented sausages, ground pork was inoculated with L. monocytogenes (Lm) at 2 x 10^7 cfu/g. The sausages were fermented at 38.9C and 90% RH for about 12 hr. Product pH was measured automatically every 20 min. Following fermentation, sausages were dried at 13C under stepwise RH conditions of 88% for 48 h, 82% for 120 h, and 76% thereafter until a target aW of 0.85 was reached after 300 hr. L. monocytogenes concentration and aW were measured every 24 hr.

A log-linear primary model with a modified Bigelow secondary model were used describe Lm inactivation throughout the process. Inputs to the model were time, and measured pH and aW. Parameters to be estimated were Dref, zaW, zpH, and logN0. Nonlinear regression in MATLAB was used.

Product pH dropped from 5.5 to 4.8 during fermentation, and then gradually reduced to 4.5-4.75 during drying. Product aW dropped from 0.95 to 0.85 over 300 hr. Lm concentration reduced from 7.5 to about 4.8 log CFU/g. Best results (RMSE=0.358 logCFU/g) were found when estimating only Dref (29.6 hr, 26% error), zpH (0.89, 17% error), and logN0 (6.9-7.4) in the model. The term zaW was not significant.

The authors hope that the template presented will help researchers in estimation of parameters for both inactivation and growth during dynamic processes.

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Abstract 944 | 2:20-2:40

Staphylococcus aureus growth, toxin production, and toxin stability in dried sausage products

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ABSTRACT

Hazard analysis and critical control point (HACCP) guidance for meat products emphasizes the need for a CCP to control *S. aureus* growth and prevent staphylococcal enterotoxin formation in processes that have extended holding times within the growth range of *S. aureus* (50-122°F/10-50°C). Limited historical data on *S. aureus* growth in noncomparable products (i.e., steak and kidney pie) and nonrepresentative conditions inform these recommendations. These critical limits are difficult or impossible to meet at production scale, sometimes due to process design (i.e., long, low temperature drying processes) or manufacturing scale (i.e., product staging during transitions from continuous to batch processes). Processors often point to excessive numbers of finished product testing results indicating no detection of enterotoxin as a justification of the safety of their process. The objective of this study was to quantify the growth of *S. aureus*, enterotoxin production, and heat stability of enterotoxins in pork and chicken sausage in a dynamic convection heating system to inform product release, testing, and/or disposition of product inventory. Standard and slightly extended processing times produced modest increases in *S. aureus* populations (<3 log CFU/g) with no detectable enterotoxin production. Abusive "worst-case" conditions (sausage: 40-46°C, 15 h) resulted in *S. aureus* populations >5 log CFU/g with detectable enterotoxins; however, after the completion of the lethality phase (sausage drying: 63°C, 8 h) enterotoxins were no longer detectable (VIDAS SET2). Findings from this study prompted a review of the historical literature related to the heat stability and testing methods used for staphylococcal enterotoxins which identified significant gaps in knowledge that should be addressed to support hazard assessment and adequate and accurate control and detection strategies.

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Abstract 656 | 2:40-3:00

Design, Fabricate, and Test a Pilot Scale (115 L) Vacuum Steam Pasteurizer for the Treatment of Low-moisture Foods

Ewumbua Monono, North Dakota State University

ABSTRACT

Vacuum steam pasteurization (VSP) has been shown to be effective for microbial inactivation of low-moisture foods at the laboratory scale, yet its large-scale applicability remains poorly characterized. Scaling up this process requires a better understanding heat transfer and overall energy efficiency that is governed by grain mixing behavior. Therefore, this study integrates computational fluid dynamics and the discrete element method (CFD–DEM) to optimize the internal geometry and operating parameters of a pilot-scale VSP chamber. A spheropolyhedron representation of hard red spring wheat (HRSW) was adopted to capture its faceted yet rounded morphology. A 3^3 factorial DEM study evaluated the effects of baffle count (10, 15, 20), baffle angle (20°, 25°, 30°), and rotational speed (12, 18, 24 rpm) on particle distribution and unloading efficiency. The optimal configuration—10 baffles set at 20° and a rotational speed of 18 rpm—produced uniform particle dispersion and a 96.74% unloading efficiency. Subsequent CFD–DEM coupling predicted that 50 kg of wheat would reach 45 °C after 6.5 min of preheating with 100 °C air. A pilot chamber fabricated using the optimized geometry was experimentally validated, requiring 12 min to reach 45 °C and achieving a 94.98% unloading efficiency. HRSW kernel dimensions and solid density were unaffected ($p > 0.05$) after treatment in the fabricated VSP, but bulk density and fracture strength decreased at higher temperature (85 °C), suggesting increased porosity and endosperm softening. These quality losses were linked to protein denaturation, thiol–disulfide rearrangement, and starch pre-gelatinization caused by localized steam condensation. These findings highlight the value of DEM-guided design optimization for enhancing heat-transfer performance in VSP systems and provide a scalable framework for improving the pasteurization of low-moisture food grains.

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Oral Session 8: Surface Disinfection and Modification

Monday, November 9, 2026

Co-chairs: Ren Yang/Yifan Cheng. 1:20 pm-3:00 pm. Queen 6

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Abstract 619 | 1:20-1:40

Engineering UV Surface Disinfection of *Salmonella*: From Penetration-Limited Kinetics to a Tunable High-Intensity Laser

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ABSTRACT

Ultraviolet (UV) irradiation offers rapid, residue-free sanitation of food-contact surfaces, but its efficacy is undermined by nonlinear inactivation kinetics and the "tailing effect," whose mechanistic basis remains poorly understood. This presentation integrates two complementary studies that diagnose why conventional UV-C underperforms on contaminated surfaces and demonstrate a tunable high-intensity UV laser alternative.

The first study quantified how bacterial spatial distribution, cell density (0.001 to 10 nominal layers), and wavelength (254 vs. 222 nm) govern *Salmonella enterica* inactivation on dry glass. Transmittance measurements established UV-C penetration depths of 2.71 cell layers at 254 nm but only 0.55 layers at 222 nm. A dual-population kinetic model resolving directly exposed and optically shielded subpopulations described all survival curves ($R^2 > 0.948$); spread inoculation, which suppresses drying-induced clotting, produced far fewer shielded cells than spot inoculation.

The second study characterized a 5 W, 355 nm Q-switched UV-A laser, chosen because high-power UV-C lasers remain limited in availability, against desiccated *S.* Enteritidis PT-30. A 4×4 factorial varied defocusing distance (2 to 10 cm) and spacing-to-diameter (SD) ratio (0.71 to 0.044). Inactivation was log-linear (Decimal reduction dose: D_f = 21.9 to 91.7 J/cm²) with no tailing effect, possibly due to deeper penetration than UV-C, reaching ≥6-log reductions in under one minute once spot overlap was optimized; scanning geometry was the key operator-tunable parameter.

Collectively, heterogeneous UV exposure, not intrinsic cell resistance, drives the tailing effect, and contamination pattern and wavelength critically determine efficacy. The UV-A laser incurred a significantly higher energy cost per log reduction than UV-C, owing to weaker nucleic acid absorbance, but combined thermal and nonthermal effects that may extend its utility to non-smooth surfaces. Together these findings inform improved validation protocols and the design of next-generation UV disinfection systems for food-processing environments.

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Abstract 778 | 1:40-2:00

Defining Electrochemical Process-Structure Relationships for Passive Antibiofouling and Antimicrobial Stainless Steel

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ABSTRACT

Objective: Stainless steel is widely used in food-processing environments, yet bacterial attachment and biofilm formation remain persistent sanitation challenges. This work developed a practical electrochemical framework for producing mechano-bactericidal nanotextures directly on stainless steel and identifying condition-specific nanotexturing windows without extensive trial-and-error optimization.

Method: Using SS316L in nitric acid (HNO3) as a model system, anodic polarization curves were collected in a two-electrode power-supply setup and correlated with surface morphologies characterized by scanning electron microscopy and atomic force microscopy. For bacterial adhesion assays, samples were submerged in *Salmonella* (*S*. Newport) at different growth phases for 30 min, fluorescently stained, and imaged by confocal microscopy.

Results: The first local maximum in the current-density-voltage curve was identified as an operational nanotexturing marker, approximately 1.4 V for SS316L with 0.38 cm² exposed area in 48% w/w HNO3. Etching at this condition generated characteristic nanoscale protrusions within 60 s, whereas higher voltages produced smoother surfaces. This marker shifted systematically with processing variables, decreasing with increasing HNO3 concentration (25-50% w/w) and increasing with exposed area (0.38-4.0 cm²). However, etching at the corresponding condition-specific nanotexturing voltage produced broadly similar nanotopographies. Comparable nanotextures were also obtained across tested changes in temperature, electrolyte volume, agitation, coupon geometry, and alloy grade (316L vs. 304), supporting polarization curves as setup-specific process maps for scale-up. Biological testing showed that nanotextured stainless steel reduced *S.* Newport attachment by approximately 80-90% across early-log, mid-log, and early-stationary phases. Multiplex confocal staining further showed increased intracellular reactive oxygen species (ROS) and membrane damage, with mid-log cells showing the strongest response. ROS intensity strongly correlated with membrane damage, suggesting a ROS-associated membrane disruption mechanism.

Significance: These findings establish electrochemical process mapping as a scalable strategy for fabricating always-on stainless-steel food-contact surfaces with passive antibiofouling and antimicrobial functionality.

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Abstract 730 | 2:00-2:20

Comparative Evaluation of 222, 254, and 405 nm Light Processing for Safety and Shelf-Life Quality of Dried Fruits

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ABSTRACT

Objective: Light-based technologies offer a nonthermal approach for controlling post-processing contamination of dried foods, but efficacy and product-quality impacts depend on wavelength, treatment conditions, microorganism, and food surface characteristics. This study compares 222 nm far-UV-C, 254 nm UV-C, and 405 nm visible blue light to support product-specific selection of surface treatments that balance microbial safety and quality.

Methods: In the first phase, dried apple, peach, mango, strawberry, and pineapple were inoculated with *Salmonella* Typhimurium, *Listeria monocytogenes*, *Staphylococcus aureus*, and *Escherichia coli* O157:H7 and subjected to light treatments over different exposure conditions. For 222, 254 nm, and 405 nm treatments, microbial survivals were evaluated up to 450 mJ/cm², 450 mJ/cm², and 4500 mJ/cm² cumulative fluences respectively, and inactivation kinetics were fitted by the Weibull models. In the second phase, the shelf-life microbial stability and quality of light-treated dried fruits are evaluated and compared to untreated controls after 3 months of ambient storage. The yeast and mold, total microflora, as well as physicochemical attributes, including a_w, moisture, pH, color, are assessed.

Results: Microbial inactivation was strongly dependent on wavelength and fruit matrix. Overall, 254 nm UV-C provided the greatest and most consistent inactivation, with reductions >4 log CFU for most pathogen–fruit combinations. 222 nm far-UV-C also achieved substantial reductions but was generally 15–30% less effective than 254 nm at comparable fluence, while 405 nm light produced slower and lower inactivation. Quality screening indicated minimal changes in a_w and pH, with small dose-dependent color changes at the highest exposures. Shelf-life testing showed significant differences in quality deterioration between treated and untreated controls ($p<0.05$).

These findings demonstrate that light-based surface processing should integrate microbial efficacy, wavelength, product matrix, and quality effects. Combining inactivation kinetics with shelf-life performance provides a practical framework for selecting practical treatment that improve safety while maintaining product quality.

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Abstract 615 | 2:20-2:40

Establishing a processing window for high-irradiance 405-nm light treatment in paprika powder using *Enterococcus faecium* as a *Salmonella* surrogate

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ABSTRACT

Low-moisture spices can harbor *Salmonella* for prolonged periods, underscoring the need for validated dry interventions. This study quantified the inactivation of *Salmonella* spp. and *Enterococcus faecium* (NRRL B-2354) in paprika powder ($a_w \approx 0.55$) during ultra-high irradiance (UHI) monochromatic blue light treatment (405 nm) and developed validation-oriented kinetic models. Paprika (3 g) was treated as a thin layer at 5 cm using three irradiances (548, 697, and 842 mW·cm^{-2}) for 60–300 s (≈32.9–252.5 J·cm^{-2}). Both organisms exhibited dose-dependent reductions, with lethality increasing with irradiance. At 697 mW·cm^{-2}, maximum exposure (300 s) achieved 7.78 ± 0.17 log reduction of *Salmonella* and 6.76 ± 0.42 log reduction of *E. faecium*; at 548 mW·cm^{-2}, reductions were lower (maximum 3.27 ± 0.27 log for *Salmonella*). Survivor curves were non-log-linear; among evaluated models, a Geeraerd-type model best described the data and supported the calculation of validation-oriented D-values. At irradiances where ≥5-log reductions were observed, *E. faecium* required a dose equal to or greater than that of *Salmonella* to achieve a 5-log reduction, supporting its use as a conservative surrogate at the 5-log target. UHI exposure produced rapid heating, reaching up to 132°C at the highest irradiance, indicating a strong photothermal contribution relevant for process design. These results establish an experimentally supported processing window and modeling framework to support future process validation of high-irradiance 405-nm treatments for paprika powder under pilot-scale or commercial-representative conditions.

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Abstract 659 | 2:40-3:00

Catalytic Nonthermal Technologies for Disinfection of Low- and Intermediate-Moisture Foods

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ABSTRACT

Low- and intermediate-moisture foods pose persistent microbiological safety challenges. Although low water activity inhibits microbial growth, bacterial pathogens can survive for extended periods and may exhibit increased resistance to conventional interventions. Effective decontamination must therefore provide substantial microbial inactivation while preserving flavor, color, functionality, milling performance, and seed viability. This presentation examines two promising nonthermal or low-temperature technologies: catalytic intense pulsed light (cIPL) and silicon carbide-assisted microwave processing (cMW).

cIPL is well suited to powdered and particulate foods, including milk powders, flours, egg white powder, and seasonings. It combines high-peak-power, short-duration broadband light pulses with TiO2 photocatalysis and controlled particle transport. Photochemical and localized photothermal effects are strengthened by catalyst-mediated oxidation, while vibration, mixing, and thin-layer exposure continually renew particle surfaces and reduce optical shadowing. In nonfat dry milk and wheat flour, 60-second cIPL treatments achieved 2.52-5.42 log CFU/g reductions of Cronobacter sakazakii, Enterococcus faecium, and Bacillus cereus, with photocatalysis contributing approximately one additional log reduction. Performance depends on pulse energy, optical properties, water activity, mixing intensity, and residence time.

cMW combines microwave energy, rapidly heated silicon carbide susceptors, and fluidized particle contact to concentrate energy at contaminated grain and seed surfaces while limiting unnecessary internal heating. In wheat kernels, a 15-second treatment produced an approximately 4.0-log reduction of inoculated Escherichia coli with a 0.89% moisture reduction. Extending treatment to 30 seconds yielded at least a 5.2-log reduction with a 1.95% moisture reduction, without significant changes in the measured nutrient profile.

By preferentially targeting surface contamination rather than heating the entire food mass, cIPL and cMW provide rapid, resource-efficient, and quality-preserving approaches for dry-food processing. Successful scale-up will require uniform energy delivery, effective particle transport, hygienic equipment design, continuous process control, and product-specific validation.

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Oral Session 9: Innovations to Advance Processing

Monday, November 9, 2026

Co-chairs: Balu Nayak/V.M. Balasubramaniam. 1:20 pm-3:00 pm. King 1

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Abstract 777 | 1:20-1:40

Ingredient Group Benchmarking: A New Framework for Predictive Engineering of Multi-Ingredient Food Systems

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ABSTRACT

Food process innovation in the digital era requires an integrated domain knowledge of ingredients and formulation in a processing system. However, the classical mechanistic models and validations on process and product attributes are constrained with simple assumptions i.e. focus on individual ingredients rather than group or community of ingredients. Although digitization through machine learning and digital twins simplify process dependent product attributes, the application is constrained with limited and fragmented data. However, mechanistic and data-driven approaches are each constrained by assumptions, data quality requirements, and validation costs, creating significant barriers to accurately predict and efficiently scale-up when used independently. This case study illustrates new ways of understanding the multi-ingredient properties with the integration of physical validation through mechanistic models and hybrid data through digitization, including a new concept of ingredient group (i.e. grains) benchmark. This presentation will highlight examples from thermal processing using ingredient moisture influence on finished product quality. The focus will be on mechanistic approaches of the process performance challenges to ingredient variability in a multi-ingredient and multi-component formulation on the thermal conductivity, diffusivity, rheology, transformation kinetics, and final product quality. These new ways will reduce development time and provide predictive engineering to accelerate innovation in food industry.

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Abstract 762 | 1:40-2:00

Translating Food Engineering Research into Practice: Opportunities for Academic–Industry Collaboration

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ABSTRACT

Academic–industry collaboration is critical to accelerating innovation in the consumer-driven food industry by bridging scientific discovery and commercial application. This presentation will highlight the opportunities and challenges associated with academic–industry partnerships from an academic perspective. Long-term mutually beneficial collaborations enable sustained technology development, validation, and translation of laboratory discoveries into scalable, market-relevant solutions. For industry, partnerships with academic institutions can reduce investment risk by enabling emerging technologies to be evaluated under controlled conditions before large-scale commercialization. Academic institutions, in turn, provide multidisciplinary research expertise, specialized facilities, and opportunities for workforce development, while students gain industry mentorship, practical experience, and exposure to real-world challenges. Over the past three decades, diverse partnership models—including dual-use science and technology consortia, NSF-style university–industry centers, and university-based food industry centers—have demonstrated varying degrees of success.

Establishing sustainable partnerships requires careful management of key challenges, including sponsored-project costs, intellectual property ownership and licensing, publication rights, and confidentiality. Industry often requires rapid, market-responsive outcomes, whereas academic research typically requires more time for experimentation, validation, peer review, and knowledge generation. Clearly defined expectations, milestones, deliverables, timelines, and intellectual property agreements are therefore essential for successful collaboration.

Future partnerships should emphasize the co-development and validation of food-processing technologies that respond to evolving consumer expectations while improving food safety, nutritional quality, shelf life, and product quality, with reduced reliance on chemical preservatives. Strong, sustained academic–industry partnerships can foster an innovation ecosystem that integrates scientific expertise, industrial knowledge, technology validation, and workforce development. Such collaboration is essential for translating research into safer, healthier, more sustainable, and consumer-responsive food products while enhancing the competitiveness and long-term resilience of the food-processing industry.

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Abstract 640 | 2:00-2:20

Extrudates and Shortbreads from Millet Blends and Their Fortification with Flavonoids

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ABSTRACT

Millets are gluten-free grains with rich nutrient profiles, known for their high fiber and moderate protein content. Being climate-resilient crops, millets can be sustainable alternatives to conventional cereal crops. The United Nations declared 2023 as the International Year of Millets to highlight their potential, as they remain underutilized in human diets. To attract a wider consumer base, millet-based puffs and shortbreads were developed using different millet blends.

Extrusion (a thermomechanical process) and baking (primarily a thermal process) were employed to isolate the effect of mechanical processing from thermal processing. Two millet blends, pearl-barnyard (3:2) and proso-barnyard (1:1), were selected for their balanced nutritional profiles and ease of processing. Puffs were made using a lab-scale single screw extruder by adopting a Box-Behnken Design to vary temperature, screw speed, and feed moisture content. Shortbreads were baked in a rotary oven, and a Central Composite Design was used to obtain experimental conditions for baking time and temperature. The physicochemical properties of the experimental puffs and shortbreads were compared with commercial products to identify the most desirable samples and the corresponding processing conditions.

To enhance the nutraceutical value of the millet-based products, they were fortified with flavonoids epigallocatechin gallate (EGCG) and quercetin, which are known for their antioxidant and anti-inflammatory properties. Due to their susceptibility to thermal degradation and poor stability, different stabilization strategies were employed, including non-covalent complexation of EGCG with whey protein isolate and encapsulation of quercetin using modified starch. Free and complexed/encapsulated flavonoids were incorporated into the millet blends and processed under optimal conditions determined earlier. Their retention was quantified using HPLC, revealing that the stabilization strategies minimized flavonoid loss during baking but not during extrusion. Overall, this study provides insights into enhancing the nutraceutical value of processed foods while promoting the use of environmentally sustainable underutilized grains.

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Abstract 961 | 2:20-2:40

Structure-Texture Relationship in Ultrasonic Compression Nutrition Bars

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ABSTRACT

Ultrasonic compression is an innovative technique for manufacturing nutrition bars. This process combines mechanical compression with ultrasonic vibrations, generating heat within the material and enhancing particle bonding through surface melting and the formation of solid bridges between flour particles. By adjusting ultrasonic energy and amplitude, manufacturers can produce compacted food bars with a wide range of textural properties.

The objective of the study was to investigate the application of ultrasonic welding in producing nutrition bars with different firmness levels by modifying processing conditions and material properties. The study also examined how the resulting internal structure influences the texture and mechanical properties of the bars.

An ultrasonic welder was used to compress cornmeal fractions with four different average particle sizes. Each sample was placed inside a mold fitted with an ultrasonic horn. Once a mechanical force of 222 N was achieved, ultrasonic vibrations were activated, and compression continued until the predetermined welding energy and amplitude settings were reached.

The bars exhibited a wide range of fracture stress values from 100 to 400 kPa. The average fracture stress decreased as particle size increased. Micro-computed tomography analysis revealed that ultrasonic compression reduced the internal porosity of the bars depending on both ultrasonic energy and particle size. Overall, ultrasonic compression significantly transformed the initial microstructure of the materials by promoting particle fusion and bonding. The results demonstrated that fracture stress increased as particle size decreased. Furthermore, at a constant particle size, increasing welding energy reduced porosity and increased bar firmness.

These findings demonstrate that ultrasonic welding can be used to manufacture nutrition bars with a broad range of textural characteristics by controlling processing parameters and selecting appropriate food powder particle sizes. This technology offers promising opportunities for food manufacturers to develop healthier snacks with improved structural integrity and product quality while reducing water requirements, processing time, and material waste.

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Abstract 711 | 2:40-3:00

Food Engineering Innovations in the Year 2050

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ABSTRACT

Trends in science and technology continue evolving at a breathtaking pace, thus any projections to 2050 are fraught with uncertainty. The nature and variety of foods will evolve, given many fusion choices from various cuisine traditions. At the opposite economic end will remain the questions of food security, supply, economy and affordability. Clean labels will be expected to increase, while some junk foods will remain by popular demand. The impact of GLP-1 drugs has resulted in modified taste perceptions, and this is likely to remain a challenge for some time, as the food industry seeks tastier, healthier options. The integration of cost with new technologies will remain in the foreseeable future. Minimization of food supply chain losses will remain an important global issue. Demonization of processing using the "ultraprocessing" misnomer is a challenge to be overcome.

Food safety considerations dictate that the cautious, risk-averse nature of the food industry may not change markedly. Advances in AI will provide powerful tools for monitoring and analyzing data, greatly strengthening risk-assessment. Nevertheless, the further possibility of microorganism evolution in response to changing climate and environmental conditions will ensure that this remains an ongoing problem. Questions of liability for errors from use of AI need to be addressed.

Preservation technologies will have advanced. Nevertheless, the heat-averse paradigm of the early 21st century needs to be reassessed given findings that sub-optimal nonthermal processes can actually increase pathogen virulence. The current paradigm in food processing involves a single kill step followed by hurdles, which represents an open-loop control method. The advent of in-package real-time sensor technologies together with the Internet of Things (IOT) promises the capability of ubiquitous sensing and corrective action even at late stages of the food supply chain. Costs permitting, this could help eliminate widespread recalls, if products can be processed as needed instead of recalling them.

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Oral Session 10: Food Digestion and Health I

Monday, November 9, 2026

Co-chairs: Gail Bornhorst/Gulustan Ozturk. 1:20 pm-3:00 pm. King 2

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Abstract 819 | 1:20-1:40

Classifying Digestion Behavior: Modeling and Links to Food Structure

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ABSTRACT

Understanding the fate of food during digestion can help design foods with targeted digestion behavior to improve health. Food breakdown has been linked to gastric emptying and nutrient absorption. Based on patterns in gastric breakdown behavior (rate of softening) and initial texture (Young's modulus), foods can be classified into six classes through the Food Breakdown Classification System (FBCS). This study aimed to develop a machine learning model to predict FBCS class with initial food properties, and to develop links between FBCS class and behavior during dynamic gastric digestion. For machine learning model development, initial texture, microstructure (micro-computed tomography), and in vitro gastric softening half time were determined on 51 foods. Texture- and shape-based features were extracted from micro-computed tomography images and used to train four machine learning models (decision trees, k-nearest neighbor, random forest and support vector machine). Models were tested using 5-fold and leave-one-out cross validation. Accuracy, precision, recall and F1-score were determined. Dynamic gastric digestion was conducted using the Human Gastric Simulator (HGS) on chickpeas and haloumi cheese with different types of processing for up to 180 minutes, and the gastric emptying and digesta properties were measured. Stratified sampling with 5-fold cross validation resulted in high F1-scores (0.99–1.00). Leave-out sampling and leave-one-out cross validation resulted in lower performance (validation: 0.35–0.49; test: 0.47–0.79). Misclassified foods shared properties with foods in other classes, suggesting a larger dataset is needed. Dynamic digestion results showed that for chickpeas and cheese, the particle size after mastication and rate of water uptake in early stages of digestion were critical to breakdown and gastric emptying. This study has demonstrated the possibility of using initial properties and machine learning to classify a food within the FBCS, which can be used to streamline product development of foods with targeted digestion behavior.

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Abstract 863 | 1:40-2:00

From Dairy Coproduct to Functional Foods: Unlocking the Potential of Whey Protein Phospholipid Concentrate

Gulustan Ozturk [1,2], Sonali Mohapatra[2], Jee-Hwan Oh[1], Xuejun Pan[2], Jan-Peter van Pijkeren[1,3], Mitchell T. Armstrong[1], Karen Antunes[1], Nathaniel B. Willis[1], Mark B. Meyer[1], Joseph F. Pierre[1]

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ABSTRACT

Whey protein phospholipid concentrate (WPPC) is an underutilized dairy coproduct generated during whey protein isolate manufacturing that is naturally enriched in milk fat globule membrane lipids, glycoproteins, and bioactive proteins. In this presentation, I will highlight our recent studies demonstrating the biological functionality of WPPC and its protein- and lipid-enriched fractions.

WPPC was fractionated using membrane filtration and physicochemical separation techniques to obtain protein- and lipid-enriched fractions for functional evaluation. A protein-enriched ultrafiltration retentate that retained milk fat globule membrane-associated glycoproteins promoted the growth of *Limosilactobacillus reuteri* ATCC PTA 6475, improved probiotic survival during simulated gastrointestinal transit, and enhanced bacterial persistence following intestinal transit in a murine model. These findings support the potential of WPPC-derived glycoproteins as a dairy-based matrix to improve probiotic survival and gastrointestinal persistence. I will also present findings from dietary intervention studies evaluating whole WPPC and its lipid- and protein-enriched fractions in weanling mice. Whole WPPC and its protein-enriched fraction significantly increased femur length, whereas the lipid-enriched fraction enhanced bone mineral density. In addition, WPPC supplementation upregulated intestinal calcium transporter genes and differentially modulated the gut microbiota, demonstrating that distinct WPPC bioactive fractions contribute to complementary physiological functions related to skeletal development and gastrointestinal health.

Together, these findings demonstrate how underutilized dairy coproducts can be transformed into multifunctional ingredients with applications in probiotic delivery, bone health, and functional food development. By linking dairy processing with biological functionality, this work highlights the potential of WPPC as a platform for developing next-generation functional dairy foods.

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Abstract 820 | 2:00-2:20

Ohmic-assisted thermal sterilization of a solid–liquid ready-to-eat food: Process performance, product quality, and *in vitro* digestion

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ABSTRACT

Conventional thermal sterilization can adversely affect food quality due to slow heat transfer and prolonged thermal exposure. Ohmic-assisted thermal sterilization (OATS) may provide an alternative to conventional overpressure retorting for foods in flexible packages. This study investigated the effects of OATS on processing performance, food quality, nutritional properties, and *in vitro* digestion of ready-to-eat (RTE) spicy herb-based sea bass soup, consisting of sea bass fillet as the main solid component and soup as the liquid phase. Sterilization was conducted at 122°C with a target F_0 of 6.5 min. OATS provided faster heating and reduced total processing time by approximately 46% compared with conventional water-spray retorting (CT). Energy consumption and carbon dioxide emissions were also reduced by approximately 36%. OATS-treated samples exhibited lower sea bass fillet hardness and less color darkening than CT-treated samples. The whole product also showed significantly lower thiobarbituric acid-reactive substances (TBARS) values following OATS ($p < 0.05$), indicating reduced lipid oxidation. During *in vitro* digestion, no significant difference in free amino group release was observed between OATS- and CT-treated samples. However, OATS-treated samples exhibited higher antioxidant activities throughout the oral, gastric, and intestinal phases. Sensory evaluation revealed significantly higher scores for flavor, taste, and overall liking for OATS-treated samples than for CT-treated samples ($p < 0.05$). Overall, OATS represents a promising sterilization technology for solid–liquid RTE food matrices, offering shorter processing times, lower energy consumption and environmental impact, and better preservation of product quality.

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Abstract 662 | 2:20-2:40

Understanding the impact of hydrocolloid-protein interactions on nutrient supplementation of dysphagic beverages

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ABSTRACT

Dysphagic beverages are mostly formulated with hydrocolloids to achieve the desired consistency that promotes bolus control and prevent liquid aspiration into the lungs. These beverages do not fulfil the nutrient requirements of dysphagics. Hence, the development of stable ready-to-drink protein-fortified thickened beverages is expected to improve liquid and nutrient intake of dysphagia patients. However, the primary challenge to creating such beverages is the issue of phase separation and sedimentation, which are due to macromolecular interactions, additives (salt, sucrose), pH and temperature. Further, these also impact the viscosity and viscoelasticity of beverages.

We present the behavior of different hydrocolloid-protein systems that have potential application in dysphagic beverage. The investigation focused on mixtures of hydrocolloids (methylcellulose and xanthan gum) with proteins (whey protein and pea protein isolates). Mixtures with partially soluble native pea protein isolate showed sedimentation behavior. Sedimentation rate decreased with increasing total macromolecular and NaCl concentrations. Conversely, phase separation was observed in mixtures with the other high solubility proteins. The concentration threshold for phase separation was determined by constructing phase diagrams, which showed that protein concentration threshold PC_t was mixture dependent. For instance, with xanthan-whey mixtures, the PC_t was <5% for the protein with a degree of hydrolysis (DH) of 10%. However, the PC_t was ~7% for the whey protein with DH=15%. Also, addition of sucrose (20%) produced ~20% increase in the PC_t of the xanthan-whey mixture. This behavior was observed to different extents with other mixtures. Additionally, the mixtures showed distinct flow properties and viscoelastic behaviors.

The results demonstrate the limited compatibility of hydrocolloid-protein mixtures and the effects of biopolymer type and additives on the stability and functional properties of these mixtures. Notwithstanding, some of the mixtures formulated here had adequate protein content and the appropriate flow and shear viscoelastic properties for dysphagia beverage.

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Abstract 804 | 2:40-3:00

Oligosaccharides-protein conjugates for selective targeting of proteins to probiotic bacteria in the colon

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ABSTRACT

Background: The gut microbiome supports host metabolism, immunity, and intestinal barrier integrity. Most existing prebiotics are carbohydrate-based and do not address the limited availability of protein in the colon, as approximately 90% of dietary protein is absorbed in the upper gastrointestinal tract.

Objectives: This study aimed to develop protein-containing prebiotics that selectively deliver both prebiotic carbohydrates and peptides to beneficial bacteria in the gut, enhancing their growth and beneficial metabolic activity compared with conventional carbohydrate-only prebiotics.

Methods: Maillard conjugates combining the human milk oligosaccharide 2′-fucosyllactose (2′-FL) with peptic-then-tryptic protein hydrolysates were prepared. The conjugates self-assemble into micelles comprising a protein core and an oligosaccharide shell, designed to retard upper gastrointestinal protein absorption and enable targeted delivery to health-promoting bacteria in the gut. Lactoferrin and potato protein hydrolysates were evaluated *in vivo*. The platform was further expanded by incorporating resveratrol and applying genipin-mediated crosslinking.

Results: Lactoferrin-based conjugates increased the abundance of desired short-chain fatty acid (SCFA)-producing bacterial taxa, elevated colonic SCFA concentrations, and reduced plasma inflammatory lipopolysaccharide levels in mice, outperforming the unconjugated components and saline controls. Potato protein-based conjugates similarly promoted health-associated gut bacteria *in vivo*, increased microbial SCFA production, and improved markers of gut barrier integrity and metabolic health compared with conventional prebiotic and saline controls. The conjugates did not increase harmful proteolytic fermentation products. Potato protein hydrolysates provided a cost-effective, non-allergenic, and sustainable alternative to lactoferrin. Genipin crosslinking reduced proteolytic susceptibility and premature resveratrol release.

Conclusions: Protein-containing prebiotics represent a novel and versatile platform for selectively co-delivering prebiotic oligosaccharides, peptides, and polyphenols to desired bacteria in the colon. This strategy may enable next-generation functional foods and dietary interventions that modulate the gut microbiome more selectively and effectively, thereby enabling tailored promotion of intestinal and metabolic health.

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Oral Session 11: Food Quality and Postharvest Monitoring

Monday, November 9, 2026

Co-chairs: Sundaram Gunasekaran/Colm O’Donnell. 4:20 pm-6:00 pm. Queen 4

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Abstract 864 | 4:20-4:40

Biosensors for Detecting Food Contaminants

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ABSTRACT

Food products, whether natural or manufactured, can be contaminated with a wide range of substances that pose serious health risks, in some cases even leading to death. Consequently, ensuring food safety across the global food chain remains a critical priority. While conventional analytical methods offer high precision and accurate quantification, they are frequently constrained by high costs, specialized equipment requirements, and lengthy processing times. These limitations have driven extensive research into simple, rapid, and cost-effective approaches for contaminant detection. Biosensors, which utilize biological recognition elements such as antibodies, aptamers, and enzymes, have emerged as promising alternatives, often in combination with organic and inorganic nanomaterials. Recent breakthroughs in nanomaterial synthesis have yielded structures capable of mimicking the catalytic functions of natural enzymes. These enzyme-mimicking nanomaterials, known as nanozymes, have opened new opportunities for sensing applications and are now evolving toward more sophisticated materials, including single-atom catalysts. This talk highlights recent advancements in nanomaterial-based sensors for the rapid and sensitive detection of biochemical contaminants in food, with a specific focus on the emerging applications of nanozymes and single-atom catalysts.

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Abstract 916 | 4:40-5:00

Application of advanced process analytical tools in milk powder processing

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ABSTRACT

Process analytical technology (PAT) is a framework that facilitates real-time monitoring and control of critical quality attributes in manufacturing processes. Despite the many reported benefits from the adoption of PAT tools in dairy processing including more consistent and improved final product quality and functionality, the adoption of PAT tools by dairy processors to date has been limited.

In this study selected PAT tools (spectral, hyperspectral imaging and torsional process viscometry) were investigated for their potential to improve process efficiency as part of the EU funded DiTECT project. Trials were carried out at both pilot and full-scale on three process monitoring applications including ultrafiltration, evaporation and powder classification.

Fluorescence was demonstrated to be suitable for monitoring of membrane integrity in whey ultrafiltration applications with true protein concentrations in whey permeate measured over a concentration range of 0.005 to 0.5 %w/w.

An on-line torsional-mode vibrating viscometer was demonstrated to be suitable to monitor milk concentrate viscosity after the evaporator and before the balance tank. Strong correlations were observed with reference rheometry over a wide range of milk composition and heat treatment specifications.

Principal component analysis (PCA) and support vector machine discriminant analysis (SVMDA) models were developed for milk powder scorched particle levels with total correct identification ratios of greater than 91% for discrimination of milk powders with AA and A quality levels from other quality levels.

The PAT tools validated in this study were demonstrated to be suitable and sufficiently robust for use as PAT tools in dairy processing.

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Abstract 710 | 5:00-5:20

Sounds Cheesy - Dairy and Plant-Based cheese texture analysis with Non-Contact Ultrasound and AI

Thomas A. Hazlehurst[1,2], Wenjing Feng[1] & Nik Watson[1,2]; [1]School of Food Science and Nutrition, University of Leeds, UK; [2]National Alternative Protein Innovation Centre, UK

ABSTRACT

The development of plant-based cheese alternatives is increasing in response to environmental and ethical concerns; however, replicating the texture of conventional dairy cheese remains a major challenge. Product development currently relies on extensive formulation trials and sensory testing, creating a need for rapid, non-destructive texture assessment methods. This study investigates the potential of non-contact (NC) ultrasound combined with machine learning for rapid characterisation of cheese texture.

NC ultrasound measurements were collected from cheese samples and analysed using a machine learning framework designed to extract meaningful information from the acoustic signals. Models were developed to predict key texture attributes, including firmness and hardness, as well as complete texture profile curves. Unsupervised learning approaches were also used to cluster samples according to their textural characteristics.

Initial results demonstrate that ultrasound-derived features capture textural variations between cheese samples and can be used to distinguish products with different texture profiles. Machine learning models show promising capability for predicting instrumental texture measurements and grouping samples according to texture-related properties.

The proposed NC ultrasound and machine learning framework provides a rapid, non-destructive approach for texture assessment. This technology has the potential to accelerate the development and optimisation of plant-based cheese formulations with textures more closely resembling conventional dairy cheese.

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Abstract 597 | 5:20-5:40

Post-Harvest Processing Under Extreme Constraints: Requirements and Conceptual Design for Cereal-Based Food Production in Lunar Habitats

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ABSTRACT

Future long-duration space missions will require food systems capable of reducing dependence on terrestrial resupply while operating within highly constrained environments. While plant cultivation is widely investigated for bioregenerative life support, crop production alone does not ensure food autonomy. The objective of this work is to define post-harvest processing requirements for cereal and grain crops in closed, resource-limited food systems, using lunar habitats as an extreme case study. A structured review of terrestrial cereal post-harvest chains was combined with a functional analysis of processing requirements under habitat constraints, including reduced gravity, limited volume, energy demand, dust containment, microbial contamination, crew time, maintainability, and multi-crop adaptability. The analysis identified key functional needs, including stabilization, cleaning, separation of edible fractions and residues, controlled transfer, dehulling, milling, storage, particulate containment, and reduction of manual handling. Based on these requirements, a preliminary integrated processing concept is proposed, combining functional modules for material separation, thermal treatment, controlled transfer, route selection, and mechanical reduction within a contained system architecture. The resulting concept aims to support the conversion of harvested granular plant materials into food-relevant fractions while limiting particulate release and improving compatibility with controlled habitat environments. By translating conventional post-harvest operations into requirements for compact and enclosed processing systems, this work contributes to the design of resilient food engineering solutions for future extraterrestrial habitats and other closed, resource-constrained food production scenarios.

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Abstract 770 | 5:40-6:00

Protecting Postharvest Food: AI-Powered Computer Vision Models for Stored-Product Insect Pest Monitoring

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ABSTRACT

Insect-pest infestation during grain storage causes approximately 40% of postharvest losses, yet conventional monitoring relies on manual inspection and expert identification — methods that are labor-intensive and difficult to scale. This study investigates AI-enabled computer vision for automated detection and counting of stored-product pests.

Multiple pest image datasets covering Coleoptera (beetles and weevils) and Lepidoptera (primarily moths) were collected using sticky traps, dome traps, and grain-sample inspection environments representing common monitoring conditions. One dataset — the Khapra dataset — contains species-specific and mixed-species images captured under varying infestation levels, free and concentrated pest distributions, and contrasting backgrounds. It includes three economically important species: *Tribolium castaneum*, *Rhyzopertha dominica*, and *Trogoderma granarium*.

YOLOv11-based object detection models were developed to identify and localize small pest instances against grain backgrounds. Beyond the baseline YOLOv11s, several architectural variants were explored, incorporating lightweight convolution, dynamic upsampling, improved bounding-box regression, and attention-based feature refinement. A density-stratified evaluation strategy was introduced to prevent inflated performance metrics arising from visually similar sequential images that spanned the training and validation sets. Preliminary results showed detection accuracies of 95% and 80% on free and concentrated test distributions, respectively, with performance strongly influenced by scene density, species composition, and spatial clustering. Dynamic upsampling improved detection in free-density scenes, while lightweight convolution and attention-based refinement were more effective under concentrated conditions.

These findings demonstrate the potential of AI-based pest monitoring for scalable, automated stored-product surveillance and underscore the importance of robust dataset design and realistic evaluation protocols for practical deployment

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Oral Session 12: Encapsulation and Delivery Systems

Monday, November 9, 2026

Co-chairs: Fanbin Kong/Youngsoo Lee. 4:20 pm-6:00 pm. Queen 5

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Abstract 772 | 4:20-4:40

Comparative Evaluation of Emulsification-Based Microencapsulation Techniques with Soy Protein Isolate for Enhanced Shelf-Life and Delivery of *Lactobacillus Rhamnosus* GG

Toshifumi udo, Hwa Eun Lee, Rakash Singh, Jinru Chen, Alexander Stelzleni, Fanbin Kong
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ABSTRACT

Probiotics are beneficial microorganisms that confer health benefits to the host; however, their efficacy is often limited by poor survival during gastrointestinal (GI) transit and loss of viability during storage. Emulsification-based microencapsulation is a promising strategy to improve the protection, delivery, and storage stability of probiotic bacteria. Nevertheless, the effects of different microcapsule structures on probiotic survival and storage stability remain insufficiently understood. This study investigated several emulsification-based microencapsulation strategies using soy protein isolate (SPI) to enhance the storage stability and gastrointestinal delivery of Lactobacillus rhamnosus GG (LRGG).

Five microencapsulation systems were prepared using 3% (w/w) SPI: a water-in-oil-in-water (W/O/W) double emulsion (MD), external gelation with sodium alginate (ME), a water-in-oil (W/O) emulsion containing pectin (MP), a W/O/W double emulsion containing pectin (MDP), and a W/O/W double emulsion combined with external gelation (MDE). The microcapsules were evaluated for LRGG survival during cold storage and simulated gastrointestinal digestion. In addition, a pig feeding study was conducted to assess the effects of different probiotic delivery formats on the swine gut microbiome. Fecal samples collected during pre-treatment, treatment, and post-treatment phases were analyzed to determine changes in selected bacterial populations and groups.

Compared with free LRGG, the MD, ME, MDP, and MDE systems improved LRGG viability during cold storage. In vitro digestion results further demonstrated that W/O/W double-emulsion and external-gelation systems enhanced probiotic survival and gastrointestinal delivery. The pig feeding study showed that probiotic delivery format significantly altered fecal bacterial populations, with microbial modulation persisting after probiotic administration ceased. Collectively, these findings demonstrate that the structural design of emulsification-based microcapsules plays an important role in probiotic protection, storage stability, and gastrointestinal delivery. Moreover, microencapsulation may influence interactions between administered probiotics and the resident intestinal microbiota, highlighting its potential as a strategy for improving the functional efficacy of probiotic delivery systems.

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Abstract 866 | 4:40-5:00

Application of a three-fluid nozzle in spray drying for encapsulation

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ABSTRACT

A three-fluid nozzle can be applied in spray drying, an advanced atomization technology that enables the simultaneous processing of immiscible or reactive liquid streams to produce structured microcapsules. Through a series of integrated studies, the impacts of nozzle-mediated contact time, interfacial interactions, feed composition, and biopolymer assembly on encapsulation efficiency, microstructure, and oxidative stability in model food systems have been investigated.

Orange oil encapsulation studies demonstrated that controlling liquid contact time before atomization and incorporating Quillaja extract improved emulsification, enhanced oil retention, and increased resistance to oxidative degradation through interfacial stabilization. Further investigation of emulsion composition revealed nonlinear relationships between gum acacia concentration, oil loading, and encapsulation efficiency, highlighting the importance of balancing emulsion stability and drying performance. To expand the functionality of the three-fluid nozzle during spray drying, a pH-driven electrostatic layering approach was developed for flaxseed oil encapsulation. Controlled interactions between oppositely charged biopolymers generated core-shell microcapsules with enhanced oxidative stability, demonstrating the ability of the three-fluid nozzle processing to create structured delivery systems through in situ interfacial assembly. The technique was subsequently applied to the co-encapsulation of flaxseed oil and iron bisglycinate, a combination prone to oxidation and nutrient degradation when mixed directly. By spatially separating reactive components within the particle architecture, the process maintained both iron solubility and lipid stability, illustrating the potential of spray drying using a three-fluid nozzle for multifunctional nutrient delivery.

Collectively, these findings establish spray drying with a three-fluid nozzle as a versatile and scalable platform for the processing of functional, stable, and nutritionally fortified powders. These studies advance understanding of the relationships among interfacial dynamics, biopolymer chemistry, feed formulation, and process conditions that govern capsule formation and performance. In addition, they provide a foundation for the development of next-generation encapsulation systems for functional foods and nutrient delivery.

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Abstract 913 | 5:00-5:20

Influence of starch source and incorporation of microencapsulated astaxanthin on the extrusion of crawfish enriched extrudates

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Incorporating aquatic proteins and bioactive compounds into extruded foods remains challenging, as high protein content often reduces expansion and texture, and elevated processing temperatures can compromise bioactive stability. This study evaluated the effects of starch source, microencapsulated astaxanthin (MA), and extrusion screw speed on the physicochemical properties of extrudates to improve product quality and stability.

ABSTRACT

Extrudate formulations were prepared using crawfish powder and chickpea protein isolate, each incorporated at 15.0%, along with corn flour, tapioca starch, or wheat flour at three concentrations (50.0, 55.0, and 60.0%). Two levels of MA were evaluated (5.0 and 10.0%). All formulations were processed using a single-screw extruder operated at two screw speeds (60 and 120 rpm), with formulation moisture standardized at 10.0%. The resulting extrudates were analyzed for expansion ratio, bulk density, moisture content, carotenoid content, protein content, fatty acid composition, and FTIR spectroscopy. All experiments were conducted in triplicate and analyzed using three-way ANOVA ($\alpha = 0.05$).

Increasing screw speed from 60 to 120 rpm significantly increased expansion ratio and reduced bulk density, with tapioca formulations showing the highest expansion ratio (1.87±0.07), lowest bulk density (0.84 g/cm³±0.04), and highest moisture content (15.43±0.81%) ($p < 0.05$). Starch source was the factor with the highest impact on physicochemical properties, while MA significantly enhanced color attributes and carotenoid content. Total carotenoids reached 54.58±0.18 μg/g, and protein content ranged from 7.85±0.68% to 32.08±3.39 % in wheat extrudates at 120 rpm. Saturated fatty acids increased with MA inclusion, reaching a maximum of 80.61 mg/g in tapioca-based extrudates at 10% MA and 60 rpm. FTIR analysis confirmed effective incorporation of astaxanthin and matrix-dependent molecular interactions.

This study demonstrated that appropriate starch selection could enable the production of extrudates containing protein and astaxanthin while maintaining an acceptable expansion ratio, texture, and color attributes under high-shear extrusion.

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Abstract 618 | 5:20-5:40

Harnessing Naturally Occurring Biopolymers to Encapsulate Curcumin for Improved Solubility and Stability

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ABSTRACT

Curcumin, the major bioactive compound in turmeric, has attracted increasing attention as a natural yellow pigment and functional food ingredient due to its potential antioxidant, anti-inflammatory, and health-promoting properties. However, its broader application in foods and nutrition is limited by poor water solubility, low stability, and low oral bioavailability. Encapsulation has been widely used to improve curcumin solubility, protect it from degradation, and enhance its bioaccessibility. However, conventional encapsulation approaches often rely on a two-step strategy, in which curcumin is first extracted and purified from turmeric and then encapsulated using additional delivery systems. This process can require high solvent use, energy input, and processing cost, limiting its sustainability and scalability. This talk introduces a one-step "plant-to-nano" strategy for directly converting raw turmeric into curcumin-loaded nanoparticles using endogenous turmeric proteins and polysaccharides. Dried turmeric powder was dispersed in water, adjusted to pH 13 to solubilize curcumin and biopolymers, filtered, and neutralized to pH 7 to induce nanoparticle formation. The redispersed nanoparticles showed a Z-average diameter of 125.6 ± 13.7 nm and a zeta potential of −28.6 ± 3.4 mV. Compositional, zeta potential, monosaccharide, SEC-MALS, and papain digestion analyses indicated that turmeric-derived acidic polysaccharides and proteins stabilized the nanoparticles. Compared with crystalline curcumin, the nanoparticles improved water dispersibility and food-system compatibility. Sustainability analysis further showed that, for turmeric-soymilk versus curcumin-soymilk powders containing approximately 10 kg curcumin, this approach reduced embodied energy by about 10-fold and embodied carbon emissions by about 22-fold, supporting a scalable and greener pathway for functional food ingredients.

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Abstract 653 | 5:40-6:00

Engineering Protein–Polyphenol Nanoparticles as a Potential Encapsulation and Delivery System for Functional Foods

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ABSTRACT

Protein–polyphenol nanocomplexes have emerged as promising encapsulation materials for improving the stability, functionality, and delivery performance of bioactive compounds in food systems. This study investigated tannic acid (TA)-mediated covalent conjugation with binary protein systems, together with ultrasound-assisted modification, to develop stable and functional protein-based nanocarriers. Zein was combined with either casein or plant proteins (pea protein isolate, PPI; soy protein isolate, SPI), and ternary protein–polyphenol nanoparticles were fabricated using a pH-driven approach. SDS-PAGE confirmed successful covalent grafting of TA onto all protein systems, while ultrasound further promoted protein–polyphenol interactions in the plant protein formulations. The resulting nanoparticles exhibited nanoscale particle sizes (approximately 74–80 nm), narrow size distributions (PDI < 0.30), and excellent colloidal stability (zeta potential up to −48 mV). Structural characterization revealed that TA conjugation induced significant rearrangements of protein secondary and tertiary structures, with ultrasound further enhancing conformational modifications, particularly in zein/PPI systems. These structural changes translated into substantially improved functional properties, including antioxidant activities of up to 57% and 79% DPPH· and $ABTS^{+\cdot}$ radical scavenging, protein solubility approaching 95%, and enhanced emulsifying activity indices from 25.25 to 35.05 m^2/g for zein/PPI and from 39.03 to 47.53 m^2/g for zein/SPI. Collectively, the results demonstrate that TA-mediated covalent conjugation, combined with ultrasound-assisted modification, provides an effective strategy for engineering multifunctional protein nanoparticles with improved physicochemical stability and bioactive functionality. These protein–polyphenol nanocomplexes represent promising encapsulation and delivery platforms for functional food applications

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Oral Session 13: Advances in 3D Food Printing

Monday, November 9, 2026

Co-chairs: Ali Ubeyitogullari/Viridiana Tejada-Ortigoza. 4:20 pm-6:00 pm. Queen 6

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Abstract 666 | 4:20-4:40

3D Food Printing for the Delivery of Functional Food Ingredients: A Step Toward Personalized Nutrition

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ABSTRACT

Bioactive food compounds, such as lutein and anthocyanins, have numerous health-promoting activities. Similarly, probiotics, live microorganisms, exhibit health benefits to the host by improving its intestinal microbial balance. However, they have poor stability/viability and bioavailability, limiting their efficacy. Thus, in this study, 3D food printing solutions were developed for the delivery of both hydrophilic and hydrophobic bioactive compounds as well as probiotics. First, lutein and anthocyanins were encapsulated into food-grade biopolymers (i.e., starch and zein) using a novel 3D food printing approach. Next, a 3D food printing approach was developed via a starch and alginate-pectin-based core-shell structure for pH-sensitive release of probiotics. Briefly, lutein-loaded zein gel was employed as the core layer, while anthocyanin-loaded starch gel was used as the outer layer in a coaxial extrusion 3D printing. The effects of layer height (0.4-1 mm), nozzle size (0.33-0.08 mm), printing temperature (55-95 °C), and ink concentrations (10-15%) were investigated and optimized. Encapsulated lutein showed only a 29-55% degradation rate after 21 days at 25 °C, while 97% of crude lutein was degraded under the same conditions. The bioaccessibilities of encapsulated lutein (9.8%) and anthocyanins (37.5%) were significantly higher compared to their crude counterparts (1.5% and 20.3%, respectively). In addition, the pH-sensitive alginate-pectin shell effectively protected probiotics in simulated gastric fluid, with 83.1% survival after 2 h, compared to the complete elimination of unencapsulated bacteria. Under simulated digestion, the retention of encapsulated probiotics was 97.2% in the oral phase, 83.3% under gastric conditions, and 82.7% in the intestinal phase. Conversely, unencapsulated probiotics showed 93.6%, 10.9%, and 6.3% retention, respectively. Overall, the developed dual-layered biopolymer-based encapsulation approach can serve as a platform technology to enhance the stability and bioavailability of functional food ingredients and provide high precision and flexibility in the development of personalized foods.

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Abstract 709 | 4:40-5:00

Innovative strategies for 3D food printing: Novel materials and AI

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ABSTRACT

Recently, 3D printing has been a technology extensively used in food. The possibility of using novel ingredients to develop complex formulations must be explored because, while plenty of work has been done regarding ingredient characterization for printing, commonly these materials cannot be considered a "complete" food. However, when dealing with a "complete" food where macromolecules such as protein, fat, carbohydrates and dietary fiber interact, and the printing process might get complicated. Several works have been published about food printing, however, few of them have printed high nutritional quality formulations because of the complexity and the challenges that come with it. Also, the creation of structures that result in differentiated and targeted textures is an interesting approach when printing. The mechanical characterization of such printed structures when post-processed, besides a TPA analysis is presented.

Materials such as chickpea flours that have been modified through thermal extrusion have been evaluated for printing. Insect flours have been also used as novel materials for high protein and high dietary fiber formulations. Mechanical characterization of tailored printed structures that have been post-processed is also presented. Finally, and artificial intelligence approach for improving printability during the process has also been evaluated.

The use of novel and sustainable materials and the use of tools such as artificial intelligence are crucial to keep on strengthening the numerous possibilities that 3D food printing still have to explore.

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Abstract 919 | 5:00-5:20

A Unified Dimensional Framework for Structural Design and Stability Analysis in 3D Food Printing

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ABSTRACT

Current research in 3D food printing is largely focused on determining *what can be printed*, with printability commonly assessed empirically through rheological properties, extrusion behavior, and reproduction of selected geometries. However, a unified engineering framework that connects material properties and printing conditions to the mechanics and stability of printed structures remains limited. This work introduces a dimensional approach in which complex printed morphologies are represented through structural elements of increasing dimensionality. Dimensional analysis integrates material properties, processing conditions, geometric variables, and structural mechanics into dimensionless criteria governing deposition and structural stability.

The resulting dimensionless groups describe the relative contributions of flow, interfacial effects, gravity, material strength, deformation, and geometric constraints. Their combinations are used to establish regime boundaries separating stable deposition and structure formation from spreading, deformation, flow instability, and structural failure. The proposed regime maps identify critical material, process, and geometric parameters controlling transitions between these behaviors. Selected stability criteria and regime boundaries are experimentally validated using food-based model materials.

The framework provides a unified engineering basis for moving 3D food printing beyond empirical printability toward predictive design of printable and mechanically stable food structures.

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Abstract 689 | 5:20-5:40

Decoding 3D Food Printability: Separating Extrudability from Shape Fidelity in Soybean Meal–Xanthan Inks

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ABSTRACT

Extrusion-based 3D food printing requires inks that flow continuously through a nozzle while retaining sufficient structure after deposition. However, printability is often treated as a single property, making it difficult to distinguish inadequate extrusion from poor structural fidelity. This study developed a quantitative framework that separates printability into extrudability and post-deposition fidelity and then integrates both dimensions into an overall printability index. Soybean meal–xanthan gum inks were used as a model system. Extrudability was quantified through computer-vision analysis of segmented, snake-shaped printing paths, while surface fidelity was evaluated from mesh surface areas of 3D-scanned cubes. Nine candidate equations for the extrudability index were screened using inks containing 5–45% (w/v) soybean meal. The selected equation exhibited a monotonic response to solids concentration, excellent model fit ($R^2 = 0.9992$), and high repeatability (coefficient of variation = 3.47%). Extrudability was negatively associated with storage modulus, loss modulus, and viscosity, but positively associated with tan δ, supporting the physical relevance of the index. A 3 × 3 factorial experiment evaluating soybean meal concentrations of 25–35% and xanthan gum concentrations of 0.2–0.8% showed that increasing either component generally reduced extrudability. Surface fidelity was influenced most strongly by soybean meal concentration and its interaction with xanthan gum. The integrated printability index identified 25% soybean meal with 0.5% xanthan gum as the best-performing formulation. These findings demonstrate that favorable extrusion alone does not ensure accurate printing; effective formulation requires balancing flow resistance with post-deposition stability. The proposed framework provides a practical approach for formulation screening and optimization, although validation across additional food-ink systems is needed to establish broader applicability.

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Abstract 957 | 5:40-6:00

From print to plate: Freeze-drying enables rapid reconstitution of multicomponent 3D-printed foods for dysphagia

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ABSTRACT

Three-dimensional (3D) food printing offers a promising approach for creating visually appealing, nutritionally customisable, texture-modified foods for individuals with dysphagia. However, limited storability and the need for suitable post-processing strategies remain key barriers to its practical application. This study investigated freeze-drying and rapid reconstitution as a preservation approach for multicomponent 3D-printed foods formulated with carbohydrate, plant-protein and oleogel components at protein-to-carbohydrate ratios of 1:9, 6:4 and 9:1. Printed structures were frozen, freeze-dried for 48 h and subsequently rehydrated in water at room temperature for up to 120 s. Structural fidelity, rehydration behaviour, moisture content, microstructure, textural properties and compliance with the International Dysphagia Diet Standardisation Initiative (IDDSI) were evaluated.

Freeze-drying effectively preserved the geometry of the printed structures with minimal deformation while generating porous networks that facilitated rapid water uptake. Following rehydration, all formulations recovered approximately 100% of their pre-freeze-dried weight, with optimal moisture recovery and structural integrity observed within approximately 60-90 s, depending on formulation. Freeze-drying substantially increased hardness due to moisture removal however, rapid rehydration restored softness to levels comparable with the original printed foods. Cohesiveness was also largely recovered, while adhesiveness remained low, an important attribute for safe swallowing. Microstructural analysis revealed interconnected porous networks within the carbohydrate and protein layers that promoted rapid water transport and reconstitution. Carbohydrate-rich structures exhibited greater shape retention during rehydration, whereas protein-rich structures were more susceptible to deformation with prolonged hydration. Importantly, all rehydrated formulations satisfied IDDSI Level 5 (minced and moist) criteria.

These findings demonstrate that combining 3D food printing with freeze-drying enables the rapid reconstitution of nutritionally customisable dysphagia foods while recovering key structural and swallowing-relevant textural properties. The ability to reconstitute the printed structures within 60-90 s while maintaining IDDSI Level 5 compliance highlights the potential of this approach for developing convenient, personalised food solutions for clinical and aged-care applications.

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Oral Session 14: Food Digestion and Health II

Monday, November 9, 2026

Co-chairs: Michael Ngadi/Jiakai Lu. 4:20 pm-6:00 pm. King 1

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Abstract 769 | 4:20-4:40

Assessing Mechanical Properties of Air-Fried Chicken Nuggets Using Structured-Illumination Reflectance Imaging

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ABSTRACT

Mechanical texture is an important quality attribute of air-fried chicken nuggets. Conventional puncture tests are destructive and unsuitable for rapid or in-line monitoring of texture. This study evaluated direct structured-illumination reflectance imaging (SIRI) of chicken nuggets and compared the predictive values of resulting ratios of direct-component (DC) and amplitude-component (AC) images. Fifty commercial nuggets subjected to varied air-frying conditions were imaged at 550 nm with three phase shifts at six spatial frequencies. The phase images were demodulated into DC and AC images, from which pixelwise AC/DC ratio images were calculated. Mean responses were extracted from a central region of interest. Maximum load, load-displacement slope, and energy to break point were obtained by puncture tests. Models were assessed using 500 repetitions of treatment-balanced five-fold cross-validation. The AC/DC ratio gave the strongest predictions of maximum load and energy to break point. At 0.15 mm^{-1}, its mean response achieved predictive R^2 values of 0.78 and 0.74, for maximum load and energy to break point, respectively. By comparison, the best single-frequency DC models achieved 0.48 and 0.34, while the five-frequency AC models achieved 0.66 and 0.62, respectively. Ratio-image performance changed slightly from 0.15 to 0.25 mm^{-1}, and combining all five nonzero ratio frequencies did not improve prediction. Load-displacement slope remained weakly predicted, with a predictive R^2 of 0.24. These internally validated findings indicate that a single AC/DC ratio feature tracked broad changes in nugget firmness and fracture work more effectively than DC or AC features.

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Abstract 732 | 4:40-5:00

Dietary Fibre based Fat Mimetic Systems for Large-scale Fat Reduction and Synergistic Modulation of Starch Digestion

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ABSTRACT

Growing demand for healthier foods has driven the development of dietary-fiber-based ingredients that provide fat-replacement functionality and physiological benefits. Chia mucilage (CM) and konjac glucomannan (KGM) have high water-binding capacity, but their distinct structural and rheological characteristics can limit their individual performance. This study investigated synergistic interactions between CM and KGM, including physicochemical and rheological properties, viscosity during in vitro digestion, and effects on starch digestibility and glucose bioaccessibility.

Freeze-dried CM/KGM mixtures at different ratios were analyzed by Fourier-transform infrared spectroscopy. Aqueous dispersions and oil-in-water emulsions containing 0.5% or 1% (w/w) mixtures were characterized for particle or droplet size, emulsion stability, flow behavior, viscoelasticity, and apparent viscosity during simulated gastrointestinal digestion at 50 s^{-1}. Effects on corn-starch pasting, in vitro digestibility, and glucose bioaccessibility were evaluated using digestion coupled with dialysis.

CM/KGM mixtures produced synergistic improvements in emulsion stability and rheology, particularly at CM:KGM ratios of 1:3, followed by 1:1. Compared with CM alone, the 1:3 mixture significantly increased the apparent viscosity of intestinal digesta from 1% aqueous dispersions. The rapidly digested starch fraction was strongly and negatively related to digesta viscosity at the beginning of the intestinal phase. Adding KGM to CM further reduced starch digestibility through increased viscosity, whereas CM showed greater glucose-adsorption capacity than KGM. The mixtures also decreased glucose bioaccessibility during intestinal starch digestion.

These findings establish the mechanistic foundation for 0Fat™, a CM/KGM dietary-fiber system designed to combine food-structuring and fat-mimetic functionality with modulation of starch digestion and glucose bioaccessibility.

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Abstract 842 | 5:00-5:20

Improving taste and antihypertensive activity of microalgal protein using atmospheric cold plasma coupled with enzymatic hydrolysis

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ABSTRACT

Microalgae are a promising source of alternative proteins for meeting the demand of the increasing world population due to their substantially high production rate (4−15 tons/ha/year) and high protein content (40−70%). Microalgal protein includes all the essential amino acids, but their potential bioactivities have not been fully explored. Furthermore, strong bitter notes of microalgae have prevented their applications in food product formulations. In this study, protein isolate from *Chlorella vulgaris* was treated by pin-to-plate atmospheric cold plasma (ACP) at an input voltage of 140 V for 20 min (the optimal treatment providing the best protein digestibility and functional properties in our previous study) followed by Alcalase hydrolysis (AH) at enzyme-to-substrate ratios (E:S) of 1%, 2%, and 3% to improve its taste and boost its antihypertensive activity. ACP treatment and AH at 1% E:S significantly decreased the bitterness of protein isolate by ~159% and 228%, respectively, but increasing the E:S showed a lesser debittering effect. AH at 1−3% significantly increased the umami taste by ~83−93%, although ACP treatment resulted in a ~43% reduction. Combining ACP as pretreatment with AH at 3% led to a ~103% lower bitterness and a ~124% higher umami taste. ACP treatment decreased the IC_{50} of the angiotensin-I converting enzyme (ACE-I) inhibitory activity of protein isolate from 1.67 to 1.55 mg/mL. AH also reduced the IC_{50} by ~21−50% and higher E:S had a more significant effect. ACP−AH combination resulted in ~36−69% lower IC_{50}. The results of this study revealed that the combination of ACP and AH treatments can effectively improve consumer acceptance of microalgal protein and enhance its nutritional value, ultimately helping the food industry develop new product formulations.

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Abstract 616 | 5:20-5:40

A Dysphagia Number for Physics-Based Design of Texture-Modified Fluids (Oral Presentation)

Jiakai Lu, Lucia Corvalan, Carlos Corvalan

Jiakai Lu (Department of Food Science, UMass Amherst); Lucia Corvalan (Department of Speech, Language, and Hearing Sciences, Indiana University Bloomington); Carlos Corvalan (Department of Food Science, Purdue University)

ABSTRACT

Texture-modified fluids are widely used for individuals with oropharyngeal dysphagia and are clinically classified using the International Dysphagia Diet Standardisation Initiative (IDDSI). Although IDDSI provides a practical framework for consistency classification, the underlying physical mechanisms governing these empirical levels remain poorly understood. In particular, shear viscosity alone cannot fully describe the complex interplay of flow resistance, extensional deformation, filament breakup, and capillary effects that occurs during swallowing. In this study, rheological data from xanthan gum, guar gum, and gellan gum formulations spanning IDDSI Levels 1–4 were analyzed using dimensionless scaling and data-driven sparse identification. Dimensionless groups were constructed to represent viscous-capillary effects, extensional resistance, filament relaxation, and viscoelastic memory. Principal component analysis first revealed that the multidimensional rheological behavior could be largely represented by a reduced physical space. Sparse identification further isolated viscous-capillary resistance and dynamic filament cohesion as the dominant mechanisms governing the clinical classification. These two competing effects were combined into a single dimensionless parameter, termed the Dysphagia Number, which describes the balance between resistance to flow and resistance to extensional fragmentation. Despite the fundamentally different molecular structures and thickening mechanisms of the three hydrocolloids, their formulations collapsed onto a common scaling framework. The resulting framework suggests that IDDSI consistency reflects a coupled multiphysics balance rather than any single rheological property. Representing this balance through a rheological phase diagram provides a pathway toward physics-based formulation and inverse design of texture-modified foods with targeted swallowing characteristics.

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Abstract 831 | 5:40-6:00

Impact of Gastric Acid Suppression on Protein Digestion in Dairy and Plant-Based Beverages

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ABSTRACT

Protein digestion is influenced by gastric acidification, protein coagulation, and enzymatic hydrolysis. However, limited information is available on how reduced gastric acidity affects the digestion of proteins. This study evaluated the impact of gastric acid suppression on protein digestion in whole milk, low-fat milk, kefir, and pea- and soy-based milk alternatives using a dynamic in vitro gastric digestion model.

The Human Gastric Simulator was used to simulate 3 h of gastric digestion followed by 3 h of small intestinal digestion. Healthy adult conditions were simulated using gastric fluid at pH 0.8 and a secretion rate of 4.1 mL/min, whereas acid suppression was simulated using pH 2.5 and a secretion rate of 2.05 mL/min. Particle size were monitored during gastric digestion by image analysis, protein hydrolysis was quantified based on free amino group release, and protein molecular weight profiles were evaluated by SDS-PAGE.

Gastric acid suppression altered protein coagulation and hydrolysis in a matrix-dependent manner. Whole and low-fat milk formed solids (>0.6 mm) under both conditions, but solid formation was delayed by 30 min under acid suppression. For whole and low-fat milk under healthy conditions, protein hydrolysis was 15-20% after gastric digestion and reached 95–100% after 360 min of gastric and small intestinal digestion. However, under acid suppression, milk samples reached only 55–61% protein hydrolysis after 360 min gastric and small intestinal digestion. In contrast, kefir, pea, and soy milk did not form curds (no solids > 0.6 mm at any time) and maintained high protein hydrolysis (90–100% after total digestion) for both conditions.

These findings demonstrate that the effects of gastric acid suppression on protein digestion depend on protein source and food matrix. Understanding these interactions may support the development of protein-rich foods tailored to populations with reduced gastric acidity.

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Oral Session 15: Rapid Pathogen Detection

Monday, November 9, 2026

Co-chairs: Soojin Jun/Hyeon Woo Park. 4:20 pm-6:00 pm. King 2

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Abstract 791 | 4:20-4:40

Rapid and sensitive detection of foodborne pathogens using bio-nanocomposites functionalized electrochemical immunosensor with dielectrophoretic attraction

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ABSTRACT

Rapid detection and identification of potentially harmful microorganisms in food are essential to prevent foodborne outbreaks and ensure our safety. Due to the faster response time and relatively high sensitivity and selectivity of biosensor-based detection methods comparable to conventional methods, biosensing has attracted growing attention as an alternative approach for early detection of foodborne pathogens in a variety of food products. The functionalized electrochemical immunosensor coupled with flow-based dielectrophoretic biosensing was designed and fabricated for detection of bacteriophage MS2 as a norovirus surrogate. The cyclic voltammogram showed the current for PEI-SWCNTs electrode was increased compared to the value of the PEI film surface, followed by a decrease in the current after antibody immobilization and MS2 attachment. Antibody immobilization on the detector and electric field applied to the fluidic channel at 10 V_{pp} and 1 MHz provided higher current changes by antibody-MS2 complexes than the assay without antibody and DEP. The change in current signals showed dependence on the concentrations of MS2 in the sample solution. The total assay was achieved within 15 min. The developed microwire-based electrochemical immunosensor with DEP-assisted cell trapping has potential for fast, simple, and selective detection of low levels of target bacteria in the presence of mixed bacterial communities and food matrix. The proposed sensing technology and the device can have a beneficial influence on food industries by offering rapid detection of multiple pathogens in foods.

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Abstract 692 | 4:40-5:00

The potential of deep learning and big data for detecting microbial risks in food

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ABSTRACT

Ensuring microbial safety in food systems demands rapid, accurate, and practical detection methods. This work introduces a deep learning-based approach for detecting and classifying both spoilage yeasts and foodborne bacteria within a few hours. The method relies only on conventional cultivation and simple optical microscopy, without requiring specialized equipment or labeling. In the yeast detection study, seven species were successfully classified based on microcolony morphology within 6 hours. The model achieved a mean precision of 96.0% and a mean recall of 96.3%, even in the presence of food debris such as tomato and juice matrices. Synthetic training images generated using a generative adversarial network (GAN) improved performance for challenging species. Precision for *Wickerhamomyces anomalus* increased by 7.7%, and recall for *Debaryomyces hansenii* improved by 5.6%. In a separate study, a bacterial detection model was trained using both bacterial and food debris images, including samples from chicken, spinach, and cheese. This approach eliminated false positives and enabled accurate detection of *Escherichia coli*, *Listeria monocytogenes*, and *Bacillus subtilis* within 3 hours. The model showed a mean precision of 100% and a mean recall of 94.4%. Validation with GFP-producing *B. subtilis* further confirmed its robustness in real food matrices, where it reached 94.6% precision and 92.5% recall. These results demonstrate that deep learning, when combined with standard laboratory methods, provides a rapid and low-cost solution for microbial monitoring in the food industry. The proposed approach shows strong potential for real-world applications.

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Abstract 645 | 5:00-5:20

Portable SERS and Impedance Sensing Systems for Rapid Detection of Salmonella in Poultry Products

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ABSTRACT

Salmonella incidence in the United States has remained largely unchanged for nearly three decades, underscoring the need for rapid detection and real-time decision support as regulations increasingly focus on poultry processing facilities. This study presents two portable platforms for rapid *Salmonella* detection in poultry rinsate: a fiber-optic surface-enhanced Raman spectroscopy (SERS) system and a microfluidic impedance biosensing system. Both platforms are integrated with web technology- based GUI interface for secure operation using Django web framework and housed in compact aluminum enclosures. The SERS platform combines a laser source, Raman spectrometer, optical path components, SERS and environmental sensors, GPS, 10.1" touchscreen interface, Intel NUC compute for control, acquisition, automated spectral processing, PDF reporting, threshold-based diagnostic, and local edge storage. The web interface displays sensor testing status (+/-) along with weather (BME280) and GPS data. The SERS sensor integrates highly uniform and repeatable nanoantenna arrays fabricated onto a side-polished multimode optical fiber core using microsphere photolithography, Cr/Au deposition, and lift-off techniques. The impedance platform integrates six microfluidic biosensors, a custom high-impedance acquisition circuit, automated fluid handling, syringe pumps, probe fixture, tubing, custom 3D-printed components, Raspberry Pi4 and Raspberry Pi5 for hardware and display control, environmental sensing, touchscreen operation, database management, and automated reporting. Each microfluidic biosensor incorporates Cr/Au electrodes, electroplated Au sidewalls, antibody-functionalized detection electrodes, focusing and trapping electrodes, an SU-8 microchannel, and PDMS sealing, enabling simultaneous testing of three biosensors per run. Both platforms were evaluated using turkey rinsate spiked with varying *Salmonella* concentrations and unspiked controls. The SERS and impedance systems produced concentration-dependent responses and detected *Salmonella* at concentrations as low as 10 CFU/mL within 10 min and 70 min. By combining advanced sensor fabrication, automated sample analysis, secure and traceable data management, and real-time decision support, these portable platforms provide practical tools for rapid pathogen detection for poultry processing.

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Abstract 859 | 5:20-5:40

Filter-assisted screening technologies as an engineering approach to detect low-level quantities of target bacteria from large sample volumes

Rachel Cheng, Diego Fredes-Garcia, Hyun Choi, Monica Ponder, and Yifan Cheng, Department of Food Science and Technology, Virginia Tech, Blacksburg, VA, 24060 USA

ABSTRACT

Reliable recovery of microbial contaminants from foods prior to rapid detection is essential for developing testing frameworks that reduce time-to-result while minimizing the risk of false-negative results. Membrane-based filtration offers a promising concentration strategy, but filters must maintain flow through particulate-containing food matrices while enabling efficient bacterial recovery for downstream detection.

The objective of this study was to evaluate the performance of unmodified as-is cellulose filters, plasma-treated filters (PF), and zwitterionically modified filters (ZF) for filtration performance and recovery of ampicillin-resistant *Escherichia coli* from two media: modified Buffered Peptone Water (mBPW) and simulated broth, consisting of mBPW with coffee creamer.

Broths were inoculated with *E. coli* at approximately 150 CFU/mL and filtered using a stirred cell operated at 25 psi and 100 rpm, with approximately 40 mL processed per filtration. Filtrates were plated on TSA supplemented with ampicillin for selective enumeration, while filters were enriched in TSB supplemented with ampicillin to select for inoculated bacteria. Filtration time, filter mass change, processed volume, flow rate, liquid recovery, particle size distribution, and post-filtration carryover were recorded.

Before bacterial recovery was evaluated, filtration performance in simulated broth showed that ZF increased the amount of simulated broth filtered by approximately 3-fold compared with as-is filters, while PF increased the amount filtered by approximately 10-fold. For all filter treatments, filtrate particle size distributions were reduced below the nominal membrane pore size, indicating effective removal of larger particulates from the simulated food matrix.

In mBPW, ZF achieved the highest bacterial recovery, 59.7 ± 10.6%, compared with 47.0 ± 7.3% for as-is filters and 43.0 ± 7.0% for PF. ZF recovery was significantly greater than as-is (adjusted $P = 0.035$) and PF (adjusted $P = 0.010$), while carryover remained low, ranging from 0 to 2 MPN. In simulated broth, ZF again produced the highest bacterial recovery, 61.8 ± 19.7%, compared with 44.8 ± 4.5% for as-is filters and 42.4 ± 7.7% for PF. Confocal laser scanning microscopy confirmed that zwitterionic chemistry reduced *E. coli* adsorption to cellulose fibers, corroborating the recovery data. These findings are relevant to food engineering and the food industry because they demonstrate that membrane surface modification can improve sample throughput, particulate reduction, and bacterial recovery for rapid food safety testing workflows.

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Abstract 936 | 5:40-6:00

Toward the Self-Monitoring Food Plant: Integrating Rapid Molecular Sensing and Genomics into Food Process Control

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ABSTRACT

Modern food-processing systems continuously monitor physical and chemical parameters such as temperature, pressure, flow, and pH, yet microbiological information used to assess raw-material quality, process hygiene, and product safety is often generated days after processing decisions must be made. Rapid, decentralized molecular sensing could enable microbial information to become an additional input for process monitoring and control.

To demonstrate the feasibility of this approach, we developed NOMAD (Nanopore-based On-site Microbiome Analysis of Diversity), a field-deployable workflow for rapid characterization of microbial communities in raw bovine milk using full-length 16S rRNA gene sequencing. Eight sample-processing and DNA-extraction protocols were evaluated to optimize microbial recovery from raw milk. Sequencing was performed using the Oxford Nanopore MinION platform, and sequencing duration was systematically evaluated against a 72-h reference dataset. Real-time basecalling was performed using MinKNOW with the Dorado basecaller, followed by quality filtering and taxonomic classification using Kraken2 and refinement of species-level relative abundances using Bracken. This streamlined pipeline enabled sequence data to be converted rapidly into interpretable microbial community profiles.

A four-hour sequencing run recovered 93% of total species richness, with microbial diversity and dominant community composition remaining stable thereafter. The complete workflow—from DNA extraction through library preparation, sequencing, and bioinformatic analysis—was completed in approximately 10.5 h, enabling same-day microbial characterization. The workflow also provided enhanced taxonomic resolution of dairy-relevant organisms, including spoilage-associated *Pseudomonas* spp.

These results demonstrate the feasibility of moving high-resolution microbial measurements from centralized laboratories closer to food production and processing operations. Integration of rapid genomic information with conventional process data could enable earlier identification of microbial shifts associated with incoming raw materials, hygiene failures, spoilage risk, and other process deviations. Such microbial sensing platforms represent an important step toward self-monitoring food plants in which integrated biological, physical, and chemical information collectively support responsive, data-driven process control.

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Plenary Session 2. Artificial Intelligence/Machine Learning Monarchy Ballroom

Tuesday, November 10, 2026

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8:35-9:05

From Chemometric Sensing to Decisions: AI/ML-Driven Analytics for Real-Time Food Quality Control

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ABSTRACT

FT-NIR and FTIR spectroscopy and other Chemometric Sensing methods are becoming well-established tools for rapid, non-destructive quality assessment and control across the food industry, offering a faster, cheaper alternative to traditional wet-chemical analysis for monitoring composition, authenticity, and safety. This talk uses chemometric sensing as a working example, though the same principles extend to other sensor and process data streams, to examine how artificial intelligence and machine learning move beyond raw measurement toward interpretation and decision making, turning spectra and signals into actionable calls on quality, safety, and process control. Alongside these opportunities, the talk will address practical barriers to industrial adoption: sensor calibration, instrument drift, the challenge of transferring models across devices, and issues with training data. Finally, I will provide, from an academic perspective, suggestions for food companies considering AI/ML-enabled sensing: what to prioritize, what pitfalls to avoid, and how to build a foundation for reliable, scalable, decision-ready deployment. The goal is a grounded, academic/industry-relevant view of how chemometric sensing and AI/ML together are reshaping food quality decision making, and what it will take to get there.

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9:05-9:35

Lessons learned in deploying enterprise AI that delivers Return on Investment (ROI).

Manmit Shrimali, Turing Labs

ABSTRACT

A mayonnaise development cycle compressed from 1.8 years to four months at 10 percent lower cost. 52 master sausage recipes consolidated to four. A $20M innovation pipeline enabled, with $5M delivered. These came out of six years of deploying AI at scale in food and beverage, with customers including Kraft Heinz, Unilever, Tesco, Herdez, and Kalsec.

What separated the deployments that reached those numbers quickly from the ones that took far longer was not the technology. It was decisions about ownership and ways of working, not about the science. Food and beverage innovation is still largely traditional, running on spreadsheets and trial and error, so putting AI into that environment means changing how teams work. That work starts before the first experiment.

Our hardest lesson was organizational. The programs that moved fastest had an owner with real decision-making authority and a clear internal approval path. Where that was missing, conversations ran for a long time before anything was tested, regardless of how enthusiastic the team was about the technology. Company cultures differ, and the pace followed the clarity of ownership more closely than the appetite for AI.

We will also address the myths that stall these programs: that AI in innovation is an IT initiative, that you need perfect data before you start, and that scientists will not adopt it. Each one changes what a realistic timeline looks like.

Finally, we will show the trajectory of AI's evolution from searching to acting, and what that means for the future role of your people in the innovation process.

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Oral Session 16: Valorization of Food and Agricultural Byproducts

Tuesday, November 10, 2026

Co-chairs: Qingyang Wang/Kumar Mallikarjunan. 10:20 am-12:00 pm. Queen 4

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Abstract 941 | 10:20-10:40

Valorization of Wine Grape Pomace into Bio-Based Antifungal Extracts for *Botrytis cinerea* Control

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ABSTRACT

Wine production generates substantial quantities of grape pomace, consisting primarily of skins, seeds, and stems remaining after fermentation. Although commonly treated as a low-value byproduct, fermented wine grape pomace retains substantial amounts of phenolic compounds and represents a promising resource for development of value-added bioactive ingredients. This study investigated the potential to valorize wine grape pomace as a source of natural antifungal compounds for controlling *Botrytis cinerea*, an important fungal pathogen associated with pre- and postharvest losses of fruits. Wine grape pomace extracts were prepared using either 70% ethanol or water, and their effects on *B. cinerea* mycelial growth were evaluated on potato dextrose agar (PDA). Because selected plant-derived phenolic compounds may exhibit photoactive antimicrobial properties, extract treatments were also evaluated with 30 min of UV-A exposure. Colony diameter was monitored during incubation (25˚C), and treatment effects were evaluated using linear mixed-effects models with biological replicate (n=5) as a random effect, followed by pairwise comparisons of least-squares means. In the ethanol-extraction experiment, pomace extract significantly inhibited fungal growth ($p<0.05$), with a day-6 least-squares mean colony diameter of 12.3 mm compared with 26.5 mm for the ethanol solvent control, corresponding to a 53.6% reduction in colony diameter. UV-A exposure further reduced colony diameter to 8.7 mm, or 67.2% relative to ethanol control, although this additional inhibition was not statistically significant. In the aqueous-extraction experiment, pomace extract significantly reduced day-4 colony diameter by 87.4% relative to the water control ($p<0.05$), with least-squares means of 11.5 and 91.6 mm, respectively. UV-A exposure did not further enhance inhibition under the conditions tested. These preliminary findings demonstrate that fermented wine grape pomace contains extractable compounds capable of suppressing in vitro *B. cinerea* growth. Ongoing work is evaluating extraction conditions, antifungal efficacy, and strategies to translate this underutilized processing byproduct into a practical bio-based antifungal ingredient.

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Abstract 721 | 10:40-11:00

Recent Advances for Valorization of Dairy Permeates

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ABSTRACT

US Dairy industry processes milk to various products such as fluid milk, cheese, yogurt, and dry dairy ingredients resulting in dairy permeate as the by product. The dairy permeate is currently underutilized and most of the permeate ends up as animal feed. The dairy industry is looking into ways to increase the value of this by product. This presentation will provide recent advances that are being developed and considered for valorization of dairy permeates. The value-added products include health and wellness products, enhanced food formulations and novel products like bioplastics, surfactants and fuels. The technologies that are being studied include enzymatic biocatalysis, microbial fermentation, metabolic engineering, chemical conversion, and membrane filtration.

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Abstract 668 | 11:00-11:20

Machine Learning-Guided Resource Recovery from Acid Whey via Chitosan Coagulation and Electrodialysis

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ABSTRACT

Acid whey is a major byproduct of dairy processing and poses significant environmental challenges due to its high organic load, acidity, and nutrient content. However, it is also rich in recoverable resources, including proteins, fats, lactose, lactic acid, minerals and water, making it a promising feedstock for circular food and bioprocessing systems. This study developed an integrated framework combining bio-based chitosan-gel coagulation, electrodialysis, and machine learning (ML)-guided optimization for acid whey valorization. Chitosan gel was initially applied to recover suspended proteins, fats, and minerals from acid whey, producing a nutrient-rich material with potential applications such as animal feed or fertilizer while reducing turbidity and minimizing membrane fouling during downstream electrodialysis. Using 400 experimental data points, three machine-learning models were developed, with Random Forest demonstrating the highest predictive accuracy (R^2 = 0.78). Simulated-annealing optimization achieved 91% turbidity removal, while an adaptive deep neural network–reinforcement learning strategy further increased removal to approximately 95% within 60 min through real-time process adjustments. The clarified acid whey was subsequently treated by electrodialysis, achieving approximately 90% lactic acid recovery in the concentrate chamber. Future work will extend ML-based optimization to the electrodialysis process by evaluating operating variables such as voltage, current density, flow rate, treatment time, and feed characteristics to improve separation efficiency, maximize lactic acid recovery, and minimize energy consumption. Overall, this data-driven approach supports circular dairy processing and offers a transferable strategy for sustainable resource recovery from food-processing byproducts.

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Abstract 915 | 11:20-11:40

Valorizing by-products from grain processing through the development of cross-linked arabinoxylans with tunable rheological properties

Clay Swackhamer [a*], Da Chen [b], Bruce R. Hamaker [b]

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ABSTRACT

The sustainability of the food system could be improved through more effective utilization of grain-processing by-products such as bran. Meanwhile, the food industry could benefit from novel thickeners and stabilizers capable of imparting desired rheological properties in food products. Approximately 115 billion kg of corn bran are produced annually, along with 171 billion kg of bran from the combination of rice, wheat, barley, and sorghum, highlighting substantial opportunities for valorization. Bran from these crops is rich in arabinoxylan, a hemicellulose composed of a xylose backbone and arabinose substituents, some of which contain ferulic acid residues capable of forming cross-links. In this study, corn-bran arabinoxylans were subjected to chemical and enzymatic treatments designed to investigate how ferulic acid content, debranching, and cross-linking affect viscosity. We hypothesized that cross-linking would generally increase viscosity, debranching would decrease viscosity, and cross-linked arabinoxylans with higher ferulic acid content would produce greater viscosity than those with lower ferulic acid content. Modified and unmodified arabinoxylans were dispersed in water (pH=7) at 5% (w/w) and were analyzed using shear-rate sweeps from 0.1 to 100 s^{-1} with a cone-plate geometry on a TA DHR-3 rheometer. Cross-linking significantly increased apparent viscosity at 10 s^{-1} relative to unmodified arabinoxylans (0.097 versus 0.040 Pa·s; $p < 0.05$). Cross-linked, high-ferulic-acid arabinoxylans also exhibited significantly greater viscosity than cross-linked, low-ferulic-acid arabinoxylans (0.147 versus 0.048 Pa·s; $p < 0.01$), supporting our hypothesis. Debranching substantially reduced viscosity regardless of ferulic acid content. These results demonstrate the potential for novel cross-linking and debranching processes to rationally modulate rheology of arabinoxylan suspensions. These materials could become a new class of functional hydrocolloids usable by product developers to control rheology of food products, while simultaneously valorizing brans to increase sustainability of the overall food industry.

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Abstract 907 | 11:40-12:00

Processing-Assisted Valorization of Pumpkin Seed Flour and Its Fractions for Food Applications

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ABSTRACT

Pumpkin seed flour (PSF), a protein-rich byproduct of pumpkin processing containing approximately 50-60% protein, is an underutilized resource with considerable potential for food applications. However, its broader utilization has been limited by inadequate functional properties. This work investigated three complementary strategies for valorizing different fractions of PSF: (1) utilization of the whole flour, (2) recovery of its protein fraction, and (3) conversion of the residual fiber-rich fraction into a fermented food ingredient. First, partially defatted PSF dispersions (10%, w/v) were subjected to single-pass microfluidization at 100, 150, or 200 MPa. Microfluidization substantially enhanced the functional properties of PSF, increasing solubility by up to 710%, water-holding capacity by 246%, and oil-holding capacity by 400%, while also improving foaming properties. These improvements were primarily associated with particle size reduction and protein unfolding induced by microfluidization. The functionally modified PSF was subsequently incorporated into cupcakes as an egg replacer and produced textural properties comparable to those of conventional cupcakes. In a second approach, isolated pumpkin seed proteins exhibited strong gel-forming properties and were evaluated as wall materials for the encapsulation of oxidation-prone oils. Ultrasound-assisted encapsulation achieved encapsulation efficiencies of up to 80%, demonstrating the potential of pumpkin seed protein as a functional encapsulant. Finally, the pumpkin seed residue (PSR) remaining after protein extraction, consisting primarily of carbohydrates and residual protein, was evaluated as a substrate for kombucha fermentation. A kombucha analog produced from PSR supported acetic acid bacteria and yeast populations comparable to those observed in green tea kombucha. Consumer evaluation (n = 100) further demonstrated acceptable overall product acceptance, with the highest desirability observed after 7 days of fermentation. Collectively, these findings demonstrate that processing-assisted fractionation and functionalization can enable the comprehensive valorization of PSF into food ingredients and products, providing a sustainable approach for converting pumpkin-processing byproducts into value-added food applications.

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Oral Session 17: Upcycling into High-Value Ingredients

Tuesday, November 10, 2026

Co-chairs: Kiruba Krishnaswamy/Prasanth PIllai. 10:20 am-12:00 pm. Queen 5

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Abstract 951 | 10:20-10:40

Upcycling Indigenous Elderberries: Circular Food Processing and Development of High-Value Colorant Powders

Karishma Shri Ravichandran[2] and Krishnaswamy, Kiruba[1,2]
Department of Chemical and Biomedical Engineering[1]; Division of Food, Nutrition and Exercise Sciences[2].
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ABSTRACT

North American elderberry (*Sambucus nigra subsp. canadensis*) fruits differ from European elderberry due to the presences of acylated anthocyanins and are rich sources of Vitamin A, Vitamin C and high antioxidant properties. However, their high moisture content and susceptibility to pigment degradation limit commercial utilization. This study investigates the application of spray drying, vacuum drying, freeze drying to transform elderberry fruits into shelf-stable natural colorant powders while preserving anthocyanin content and color quality.

Whole elderberry pulp and pomace were processed into free-flowing powders. Process parameters were evaluated through drying yield, moisture content, water activity, and powder morphology. Color characteristics were quantified using L*, a*, b* measurements, total color difference (ΔE), chroma, and hue angle, while anthocyanin retention and antioxidant capacity were used as indicators of bioactive stability. The influence of carrier materials and inlet air temperature on pigment protection during spray drying was also assessed.

These results highlight the tradeoffs between product quality and processing efficiency across drying technologies and establish engineering guidelines for the manufacture of elderberry-based natural color ingredients. The work advances the valorization of fruit-processing byproducts by integrating drying process optimization with color preservation, supporting the development of sustainable, clean-label food systems and circular bioeconomy initiatives.

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Abstract 697 | 10:40-11:00

From Dairy Byproducts to Alternative Proteins: A Circular Fermentation Approach

Pin-Cheng Chen and Prasanth K. S. Pillai , Department of Food Science and Nutrition, University of Minnesota, St. Paul, Minnesota, 55414, United States

ABSTRACT

The growing demand for sustainable alternative proteins has increased interest in fermentation-based platforms for producing nutritionally rich and functional food ingredients. *Euglena gracilis* is a metabolically versatile microalga with significant potential for alternative protein production; however, the cost of conventional fermentation media remains a major barrier to economical scale-up. This study investigated the valorization of dairy coproducts as alternative nutrient sources for producing protein-rich *E. gracilis* biomass while reducing dependence on conventional fermentation media. Lactose-rich whey permeate (WP) was evaluated as an alternative carbon source following food-grade enzymatic processing. Lactase-treated WP effectively replaced conventional glucose and supported biomass production of approximately 10 g/L, reaching ~80% of that obtained with commercial medium. In parallel, a protein- and phospholipid-rich dairy fraction was physically and enzymatically modified and evaluated as an alternative to conventional nitrogen sources, including yeast extract and tryptone. Optimization of heterotrophic cultivation resulted in *E. gracilis* biomass containing approximately 30–40% protein. Protein characterization demonstrated high nutritional quality, including a complete essential amino acid profile, an amino acid score of ~97%, and a PDCAAS of 0.96. The resulting protein ingredients also exhibited desirable techno-functional properties, including solubility, emulsification, foaming, gelation, and water- and oil-holding capacities, supporting their versatility in applications such as meat analogues, protein beverages, egg replacements, bakery products, and snacks. Overall, this work demonstrates a circular fermentation platform that integrates dairy coproduct valorization with the production of nutritionally high-quality and multifunctional alternative proteins, providing a promising pathway to reduce fermentation input costs while creating high-value food ingredients.

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Abstract 688 | 11:00-11:20

Rethinking Seafood Waste: Engineering High-Value Products Through Upcycling of Underutilized Marine Resources.

Kevin E. Mis Solval, Associate Professor, University of Georgia – Department of Food Science and Technology, Griffin campus, Griffin, GA 30223.

ABSTRACT

The global seafood industry generates millions of tons of processing by-products each year, including skins, bones, shells, scales, and underutilized species that are frequently discarded or used in low-value applications. These materials represent an abundant source of collagen, gelatin, chitin, minerals, and other bioactive compounds with significant potential for value-added applications. This presentation highlights recent advances in food engineering approaches that transform marine processing by-products into high-value ingredients and biomaterials, supporting the transition toward a circular blue bioeconomy.

The objective of this presentation is to demonstrate how innovative processing technologies can convert underutilized marine resources into sustainable and high-value products with applications in foods, and food packaging. Research conducted at the University of Georgia focuses on the valorization of cannonball jellyfish, fish processing by-products, and shellfish residues using environmentally responsible extraction, hydrolysis, purification, and biopolymer engineering techniques. The resulting materials are characterized for their physicochemical, functional, mechanical, and biological properties to determine their suitability for diverse commercial applications.

The presentation will showcase representative case studies, including the production of food-grade marine collagen, gelatin, and collagen peptides with enhanced functional properties, and potential uses in biodegradable bioplastic films for sustainable food packaging. Results demonstrate that marine-derived biopolymers exhibit excellent film-forming ability, desirable mechanical performance, and promising bioactive properties while contributing to waste reduction and increased resource efficiency. In addition, preliminary assessments indicate that upcycling seafood by-products can create new revenue streams for processors while reducing environmental impacts associated with waste disposal.

Recent findings demonstrate that food engineering innovations can transform seafood processing residues into valuable products that advance sustainability, strengthen coastal economies, and support the development of resilient, circular food systems. The presentation will also discuss opportunities and remaining challenges for scaling these technologies from laboratory research to industrial commercialization.

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Abstract 962 | 11:20-11:40

Fermintelligence, an AI platform for Sustainable Protein from Agri-food Side Streams

Ryan O'Shea[1] and Nicholas Watson[1]
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ABSTRACT

Nearly 29% of the world's population faces food insecurity, while millions of tonnes of nutrient-rich agri-food waste are generated daily. These waste streams can be upcycled into microbial protein through fermentation, but designing economically viable processes remains complex, costly, and inaccessible for many organisations, particularly small and medium enterprises.

We present the current development status of an open-access AI platform designed to accelerate the conversion of agri-food waste into microbial protein. Users enter their waste composition, material flows, and location and receive tailored, actionable outputs spanning process design and financial performance. By integrating techno-economic assessment from the outset, the platform identifies which process designs have plausible commercial viability before costly experimental work begins. It also provides an R&D roadmap that prioritises the most valuable trials, potentially reducing experimentation needs by up to 90%, and recommends partners where users lack expertise, facilities, or market access.

Illustrative case studies covering UK crop residues and Indonesian okara, whey, and rice bran will demonstrate how the platform is being designed to support local waste valorisation opportunities. By making the economics of waste-to-protein transparent and accessible, the platform aims to redefine who can innovate and where sustainable protein can profitably be produced.

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Abstract 672 | 11:40-12:00

Cold Plasma-Modified Apple Pomace Fiber: Physicochemical Properties and Gut Microbiota Modulation Effect

Tianming Yao, Department of Food Science, Rutgers University, New Brunswick, NJ, 08901, USA

ABSTRACT

Apple pomace, a major by-product of the apple juice and cider industries, contains abundant bioactive fiber with well-documented health benefits. Apple pectin is among the most structurally complex dietary fibers, consisting of homogalacturonan (HG) and highly branched rhamnogalacturonan (RG) domains that differ substantially in structure and biological function. We hypothesized that modifying the HG/RG ratio would alter pectin functionality and selectively modulate the gut microbiota. Cold plasma (CP) is an emerging non-thermal, sustainable food processing technology; however, its application for enhancing dietary fiber functionality remains largely unexplored. This study investigated the effects of CP treatment on the structural modification and gut microbiota modulation of apple pomace pectin. Apple pomace powder was treated using a mesh plasma reactor under varying voltage (150, 200, and 250 V), frequency (500, 1000, and 1500 Hz), and treatment time (10, 15, and 20 min). Structural changes, including molecular weight, degree of esterification, monosaccharide composition, extraction yield, and HG/RG ratio, were characterized using HPLC and complementary analytical methods. Total phenolic content and antioxidant capacity were determined by colorimetric assays. Response surface methodology (RSM) was applied to optimize processing conditions. Functional properties were evaluated using a 7-day consecutive *in vitro* fecal fermentation model, with microbial community shifts analyzed by 16S sequencing and short-chain fatty acids quantified by GC. CP treatment significantly altered pectin structure in a processing-dependent manner. The highest HG/RG ratio was achieved at 200 V, 1000 Hz, and 15 min, whereas the greatest antioxidant activity was observed at 200 V, 500 Hz, and 15 min. Fermentation studies demonstrated that high-HG/RG pectin preferentially enriched *Bifidobacterium* members, whereas RG-enriched pectin promoted various species. These findings demonstrate that CP technology provides a rapid food engineering approach to tailor dietary fiber functionality, enabling the development of novel prebiotic ingredients for targeted gut microbiome modulation and precision nutrition applications.

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Oral Session 18: Sustainable and Resilient Food Supply Chains

Tuesday, November 10, 2026

Co-chairs: Jen-yi Huang/Minliang Yang. 10:20 am-12:00 pm. Queen 6

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Abstract 708 | 10:20-10:40

Closing the Loop in Inland Aquaculture: A Progressive Life Cycle Assessment of Microalgae-Integrated Recirculating Systems

Thomas Tsui[1] and Jen-Yi Huang[1,2]

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[2]Department of Food, Agricultural and Biological Engineering, The Ohio State University, Columbus, OH 43210, USA

ABSTRACT

Recirculating aquaculture systems (RAS) reduce water reliance compared to conventional aquaculture, yet they face ongoing resource challenges in terms of nutrient discharge, energy demand, and sludge accumulation. Integrating microalgal photobioreactors and waste fermentation offers a promising circular solution, though temporal dynamics and operational uncertainties complicate the assessments of net environmental trade-offs. To evaluate these dynamics, this study presents a life cycle assessment (LCA) framework structured around a progressive scenario analysis across five sequential closed-loop configurations: baseline RAS (S1), microalgae wastewater treatment (S2), predictive water reuse (S3), microalgae feed substitution (S4), and solar energy integration (S5). A daily dynamic model (90 days) coupled with 3,000 Monte Carlo simulations was implemented for seven commercial fish species using species-specific Gamma-distributed feed conversion ratios (FCR). Photobioreactor nutrient removal was predicted using machine learning algorithms combined with the Monod kinetics, while predictive control dynamically regulated water exchange. Daily operational flows were coupled with a cradle-to-gate LCA (ReCiPe 2016 Midpoint H) based on 1 kg of fish produced. Progressive integration markedly reduced freshwater consumption from ~20 L/kg fish (S1 and S2) to 4.1 L (S3) and 3.8 L (S4), while total nitrogen and phosphorus discharges dropped from 133 mg and 16 mg in S1 to 3.5 mg and 1.3 mg in S4, respectively. Tilapia exhibited the greatest FCR improvement (16%−30%). However, photobioreactor operation introduced an energy penalty, increasing the median global warming potential (GWP) from 14.51 kg CO_2 eq in S1 to ~16.53 kg CO_2 eq in S2 and S3. Feed substitution (S4) reduced the land use impacts by 9.7%, and solar integration (S5) lowered the GWP back to 14.74 kg CO_2 eq, offsetting the energy penalty. The findings support a phased implementation strategy: prioritizing microalgae feed substitution for immediate resource and land savings, followed by regional solar infrastructure deployment for long-term decarbonization.

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Abstract 877 | 10:40-11:00

LCA applications for sustainable food system: from product packaging to nutrition-integrated analysis

Minliang Yang
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ABSTRACT

LCA is a system-level tool to identify where the environmental burdens of food arise and how they can be reduced. This talk will illustrate the breadths of LCA applications across the food system, from processing, packaging to the integration of nutrition and environmental evaluation of sustainable proteins.

First study focuses on sustainable packaging in dairy products, using a cradle-to-grave model that jointly accounts for packaging production and downstream food waste management, which often overlooked in previous analysis. Comparing conventional cartons with novel packaging formats shows how packaging design could reduce downstream food waste and meaningfully lower the overall system footprint.

Turning to sustainable proteins, coupled LCA and TEA of pulse protein production examines trade-offs among protein purity, climate impact, and production costs. Comparing protein concentrate and isolate produced via dry and wet fractionation routes reveal how higher purity is achieved at the expense of greater energy demand, cost and environmental burdens.

Lastly, building upon LCA approach, nutrition metrics have been introduced to evaluate the dual-impacts via nutritional-LCA (nLCA) approach. Rather than relying on mass alone, this approach integrates nutritional quality of food/diet with their environmental impacts. Applied first to compare commercial plant proteins with animal proteins, and then at the dietary level, nLCA identified products and dietary patterns that optimize the balance between environmental and nutritional sustainability.

For food industry, these applications demonstrate how a systematic evaluation like LCA can guide packaging innovation, protein processing, and product development, moving sustainability assessment beyond single-metric footprints toward holistic decisions that are environmentally responsible, economically viable, and nutritionally sound.

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Abstract 698 | 11:00-11:20

A Digital Atlas of Food and Agricultural Byproducts in California

Edward Spang, Department of Food Science & Technology
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University of California - Davis, Davis, CA, 95616, U.S.A.

ABSTRACT

Approximately one third of food produced worldwide is not eaten, leading to more than $2.5 trillion in economic, environmental, and social costs. Food processing byproducts represent a particularly promising stream for food loss and waste (FLW) valorization that is currently underutilized or wasted. According to ReFED, the leading non-profit tackling FLW in the US, the food manufacturing sector produced 13.2 million tons (Mt) of surplus food and byproducts in 2023, equivalent to $34.8 billion in commercial potential. Yet we currently lack comprehensive data on the quantity, composition, and current applications of these byproducts. As such, we are hindered in our efforts to develop effective solutions that could reduce FLW and promote circular food systems. In response to this challenge, we created a comprehensive database of major food processing byproduct flows in California, including almonds, pistachios, pomegranates, and tomatoes. We quantified and mapped biomass and byproducts from crop to processing facility, while also consolidating data on the biochemical composition of each byproduct flow. The composition data is essential for identifying scalable valorization strategies that can maximize the value of byproducts, particularly related to upcycling these material streams for use in the ingredient, nutraceutical, pharmaceutical, and cosmetic industries. The result of this effort is the Byproduct Database (byproductdatabase.com), a user-friendly, web-based resource to access and review comprehensive data on food and agricultural byproducts. While the current version is focused on four crops in California, we are actively working to extend the database to other crops, and ultimately, to expand the model globally to other regions.

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Abstract 638 | 11:20-11:40

A Sensor-Enabled Decision-Support System for Safe, Efficient, and Sustainable Food Supply for All

Haitao Li[1], Kate Trout[2], Amit Morey[3], Vijay Anand[4], Mahmoud Almasri[2], Hoa Hoang[2], Paula Penagos[1], Kalyan Gudigandla[1], Prakash Dadi[1]
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[2]University of Missouri, Columbia, Missouri
[3]Auburn University, Auburn, Alabama
[4]Kennesaw State University, Kennesaw, Georgia

ABSTRACT

Salmonella remains a critical public health and economic burden in the United States, responsible for approximately 1.35 million infections and $3.7 billion in annual economic losses, with infection rates showing no significant decline over recent decades. A key contributing factor is the absence of integrated, data-driven, end-to-end supply chain solutions capable of addressing pathogen risks across the full agri-food system. To bridge this gap, this work presents SENS-D (Sensor-Enabled Decision-Support System), a cloud-based platform developed under NSF's Convergence Accelerator Program through an interdisciplinary collaboration grounded in human-centered design and One Health principles.

SENS-D integrates three tiers of analytics—descriptive, predictive, and prescriptive—built upon a multi-type, multi-sectoral One Health data environment spanning animal health, human health, and environmental domains. The descriptive analytics module employs geographic information systems to aggregate food safety records, biosensor outputs, meteorological data, and population vulnerability indices for real-time *Salmonella* risk monitoring. The predictive analytics module quantifies bacterial growth dynamics as a function of time–temperature profiles through controlled laboratory experiments, generating shelf-life models to support risk-informed decision-making. The prescriptive analytics module formulates and solves two mixed-integer nonlinear programming models: Strategic Sensor Placement Optimization (SSPO), which determines cost-effective sensor configurations across the supply chain by explicitly trading off sensor accuracy, sensitivity, and cost; and Sensor-Enabled Intelligent Distribution of Perishable Foods (SEIDPF), which integrates real-time pathogen testing results and predicted shelf life to optimize processing, distribution, and product diversion decisions across safety, efficiency, and sustainability objectives simultaneously.

Validation through stakeholder engagement and experimental studies demonstrates that SENS-D significantly improves testing efficiency and reduces operating costs relative to current industry practices. By providing a holistic, data-driven decision-support platform, SENS-D offers a transformational approach to pathogen control in poultry supply chains, with broad applicability across food sectors and direct relevance to food engineering practice and food industry operations.

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Abstract 884 | 11:40-12:00

Food Safety Outbreaks, Market Responses, and Commodity Risk Profiles in U.S. Produce Markets

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ABSTRACT

Fresh fruits and vegetables remain significant vehicles of foodborne disease in the United States. Interagency Food Safety Analytics Collaboration (IFSAC) reports estimate that 85% of *E. coli* O157-related illnesses are collectively attributed to just vegetable row crops and beef (IFSAC). Beyond their public health consequences, food safety recalls can also disrupt produce markets through two competing economic channels (Hussain and Dawson, 2013). Product withdrawal reduces available supply and can raise prices, while consumer avoidance reduces demand and can lower both prices and sales (Arnade et al., 2009). Therefore, this study examines how produce recalls affect wholesale prices and retail quantities, with the objective of identifying whether market disruptions following recalls are more consistent with supply or demand contraction and using these responses to develop commodity specific food safety risk profiles. We combine CDC NORS outbreak reports, openFDA enforcement records, USDA AMS terminal market and shipping point prices, and weekly SPINS retail scanner data for nine FSMA 204 produce commodity groups. Using surveillance measures, we construct monthly Food Safety Risk Labels through principal component analysis, with the first component explaining 51% of the variation, and separate risk into persistent risk and short-term acute shocks using EWMA smoothing. We then conduct an event study of n= 474 Class I and II recalls contamination free baselines and use joint movements in wholesale prices and retail quantities to classify recalls as supply contraction, demand contraction, or an ambiguous market response. Retail quantity data are available for 330 events. The resulting labels provide commodity specific risk profiles that characterize how food safety events are associated with pricing and sales disruptions. These labels are descriptive risk indicators rather than causal estimates and can be used to profile commodity exposure to potential price, sales, and revenue disruptions associated with food safety events.

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Oral Session 19: Modeling and AI for Food Safety and Quality I

Tuesday, November 10, 2026

Co-chairs: Luyao Ma/Fabrizio Sarghini. 10:20 am-12:00 pm. King 1

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Abstract 670 | 10:20-10:40

Rethinking AI for Food Quality: Moving Beyond Accuracy toward Explainable, Robust, and Data-Efficient Models

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ABSTRACT

Rapid, non-destructive food quality assessment is essential for reducing food waste and improving postharvest quality management. However, the deployment of artificial intelligence (AI)-enabled imaging and spectroscopic techniques in the food industry remains limited by insufficient model interpretability, naturally imbalanced data distributions, and unclear data and computational requirements. This presentation will discuss three complementary strategies for addressing these deployment limitations, using Hass avocado ripeness assessment as a representative application.

Smartphone imaging and handheld Raman spectroscopy were used to capture visual and chemical changes during avocado ripening. The sensing data were annotated with firmness and internal quality measurements to train convolutional neural networks, vision transformers, and traditional machine learning models. Three methodological questions were investigated: i) whether model predictions could be explained using visually meaningful features; ii) how different algorithms and resampling strategies could address imbalanced ripeness classes; and iii) and how training-set size and image resolution influenced predictive performance and computational demand.

Smartphone-based regression predicted avocado firmness with an R^2 of 0.919, while explainable AI identified image regions contributing to internal quality classifications. Using 1,274 Raman spectra, a shallow one-dimensional convolutional neural network achieved a receiver operating characteristic area under the curve of 0.831 for classifying avocados as unripe, ripe, or overripe. Resampling improved the performance of traditional machine learning models, whereas the convolutional neural network performed best on the original imbalanced dataset. Statistical comparisons further showed that, depending on the algorithm, 500-700 training images achieved performance statistically indistinguishable from that obtained using larger evaluated datasets. Lower image resolution also reduced computation demand without significantly compromising prediction accuracy.

Together, these studies provide a framework for developing AI-enabled food quality assessment methods that are explainable, robust to real-world data limitations, and statistically informed in its data and computational requirements.

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Abstract 657 | 11:00-11:20

Physics-informed neural networks for thermal lethality estimation in packaged foods: a simulation-first route to validation

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ABSTRACT

Thermal lethality in food processing depends on the temperature history experienced by the product, decisively determined at the slowest-heating location. Determining the temperature distribution with sufficient accuracy is a prerequisite for process design and safety, a task carried out experimentally, through analytical methods based on time-temperature data, or through numerical-computational studies based on validated mechanistic models. The latter is preferred but may require long computation times; physics-informed neural networks (PINNs) can expedite these calculations. The objective of this study was to develop and test a staged validation strategy for using PINNs to compute thermal lethality indices in packaged foods.

A finite-volume solver generated the complete 3-dimensional reference temperature field for a multi-region package comprising product, headspace and wall domains. Sparse synthetic virtual sensors were sampled from the numerical solution, and a parametric PINN was trained by combining these observations with the heat-transfer governing equation, initial and boundary conditions, and a temperature-coupled lethality residual. Safety was assessed via an equivalent-exposure index evaluated at 72 °C. In the base geometry, final centre and cold-spot temperature errors were below 0.1 °C, and the cold-spot lethality error from integrating the PINN-predicted temperature trajectory was about 1.2%. For the independent test geometry, temperature errors remained below 0.5 °C, but the exponential temperature dependence of lethality amplified these into an underestimation of about 10% in the equivalent-exposure index. The direct lethality head was less robust than post-processing the PINN field through the standard lethality integral. Results support PINNs as complementary, data-efficient tools for thermal-process analysis, while showing that safety-relevant validation must rely directly on lethality and cold-spot histories, not only on global temperature error. This is among the first studies combining a multi-region, differentiable PINN architecture with a simulation-first comparison of direct and temperature-integral lethality prediction across held-out geometries, offering a reusable validation protocol.

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Abstract 649 | 11:20-11:40

Fusing Hyperspectral Imaging and Acoustic Sensing Data for Nondestructive AI-based Apple Pest Infestation Detection and Quality Evaluation

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ABSTRACT

The US exports approximately one-third of its apples globally. Destinations in Asia and South America, where the U.S. ships its apples, have zero tolerance for organisms of quarantine concern, such as the codling moth (CM), the most devastating pest of apples. This pest is a major concern for the apple industry in the US because a couple of incidents in recent times have led to apples being sent for low-value applications or discarded outrightly. This is an even bigger problem for organic apple production.

The current method of CM detection is ineffective, random, and manual. It does not test every apple harvested for the supply chain. This is a destructive method where apples are randomly selected and cut open to check for any signs of CM larvae (the most devastating phase of CM infestation).

We proposed a sensor data fusion nondestructive detection approach that harnesses the power of acoustic sensing (acoustic impulse and vibro-acoustic) and hyperspectral imaging methods, coupled with machine learning, to detect the presence of CM at any phase of its activities in apples. This research was conducted with three..."varieties of apples that cut across the common pigmentation synonymous with apples, namely, Gala, Fuji, and Granny Smith.

The results obtained indicate that the fusion of acoustic and HSI data improves the accuracy of apple infestation prediction for sorting purposes. The accuracy of detection increased from 91.6% to 94%. In addition, the study determined that AI-sensor-based evaluation of apple qualities is achievable with prediction statistics for TSS, texture, pH, and moisture content with R^2 values of 0.92, 0.95, 0.97, and 0. 91, respectively. This study demonstrated that CM infestation across different varieties of apples can be detected nondestructively using AI-powered systems, and that combining two sensor data can improve detection accuracy. This has potential applications in the apple industry, especially for organic apples.

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Abstract 939 | 12:00-12:20

Improving the Quality of Fried Foods Using Hybrid Mixture Theory-Based Modeling of Transport and Electromagnetic Equations During Microwave Frying

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ABSTRACT

Hybrid mixture theory (HMT) based unsaturated fluid transport model was coupled with poroviscoelastic and electromagnetic equations to study the conventional and microwave frying of foods. During frying, the porous structure, transport properties, and mechanical properties change continuously. As frying progresses, smaller pores merge to form larger pores, cell wall thickness changes, and the material changes from viscous or elastic to viscoelastic. The material expands or shrinks depending on its nature and phenomena such as glass transition and pore pressure. Eulerian-Lagrangian transformation was used to transform the equations from moving to stationary coordinates and *vice versa*. The poroviscoelastic constitutive equations coupled with the momentum balance equations were used to describe the volume changes caused by positive pore pressure and shrinkage caused by elastic recovery in the material. Model validation was performed by conducting experiments using a prototype with 2.45 and 5.8 GHz wave generators built in Tang Lab at the Washington State University. The validated model was used to study oil uptake and textural changes in potatoes during frying. The solution of the model provided insights into this highly dynamic process. Simulations indicated that microwave frying combined with conventional heating allows greater control over pore pressure and crispy layer formation in French fries than conventional frying. Pore pressure control led to reducing oil uptake in French fries without adversely affecting the mechanical texture. Microwave frying allowed to reduce the frying times by 33-76% and oil content by 3-33% than conventional frying. Our proof-of-concept study shows that the microwave frying combined with conventional frying in a single unit operation can be a promising method for the food industry to develop fried foods with reduced oil content and desirable texture.

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Abstract 703 | 11:40-12:00

Math and models to help people make better food safety decisions

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ABSTRACT

I'll discuss two problems where food safety models are needed because traditional experiments and observational studies won't answer the critical food safety questions needed for broader change. The first problem will be school share tables, where we ask: Can schools safely allow students to share food from the provided meal? This work combines experimental data on spoilage organism growth in milk, with heat transfer models, to build a Quantitative Microbial Risk Assessment for milk spoilage and pathogen growth if schools allow milk on share tables in the school lunch program. The second problem will be managing *Salmonella* in raw poultry, where we ask: How might we adapt Statistical Process Control and Machine Learning to identify ways to continually improve on *Salmonella* reductions? This work uses industry data measuring Salmonella and generic microbial loads throughout poultry processing, and connects to process control data for key processes, to identify which features in the data may be more important to outcomes in final products. These examples will show how Quantitative Microbial Risk Assessment can be applied to questions beyond their classical application in public health, and how engineering approaches to product quality can be applied to food safety.

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Oral Session 20: Cellular Agriculture and Fermentation

Tuesday, November 10, 2026

Co-chairs: Reza Ovissipour/Nitin Nitin. 10:20 am-12:00 pm. King 2

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Abstract 825 | 10:20-10:40

Sequential enzymatic pretreatment and *Saccharomyces boulardii* fermentation of cactus cladode biomass for producing bioactive food ingredients and serum alternatives for cellular agriculture

Wasitha P.D.W. Thilakarathna[1], Setareh Shiroodi[1], Deepak K. Jha[2], Vikas Dadwal[2], Bhimanagouda Patil[2], and Reza Ovissipour[1*] of the [1]Department of Food Science and Technology, Texas A&M University, College Station, TX 77843, United States, and [2]Vegetable and Fruit Improvement Center, Department of Horticultural Sciences, Texas A&M University, College Station, TX 77845, United States

ABSTRACT

Cactus (*Opuntia ficus-indica*) is a highly resilient biomass resource, providing a valuable opportunity for sustainable production of ingredients for food industry. This study aimed to convert cactus cladode biomass (CCB) into bioactive ingredients and serum substitutes for cellular agriculture applications through a sequential enzymatic delignification and saccharification pretreatment (DL+SC), followed by fermentation with *Saccharomyces boulardii* (SB). The optimal conditions for CCB delignification using *Aspergillus* laccases were established using a central composite design of response surface methodology. A maximum lignin removal of 59.39% was achieved under the optimized conditions of 35.95 °C, pH 5.55, a laccase concentration of 37.68 *Myceliophthora* units/g dry CCB, and a reaction time of 6.93 hours. Delignified CCB was saccharified using cellulase from Trichoderma reesei (10 filter paper units/g dry CCB) at 50 °C for 48 h. DL+SC-pretreated CCB was fermented with SB for 2–4 days. Bioactivities of the resulting metabolite mixture were evaluated in a benzo(a)pyrene-induced cancer model of Caco-2 cells. DL+SC pretreatment and subsequent fermentation with SB significantly enhanced the anticancer potential of CCB in vitro, with its phenolic-rich extracts (50–100 µg/mL) reducing oxidative stress and DNA damage in benzo(a)pyrene-exposed Caco-2 cells. These enhanced bioactivities can be associated with improved phenolic profile, particularly elevated gallic acid concentrations. Fermentation periods exceeding two days did not further enhance the bioactivities. To evaluate as a serum alternative for cellular agriculture, protein was isolated from DL+SC-pretreated and SB-fermented CCB using an alkaline precipitation method. When used to replace fetal bovine serum (FBS) in the culture medium, the isolated protein sustained the proliferation of immortalized lamb muscle cells at 54.65% compared to the medium containing 10% FBS. These findings highlight the potential to use CCB as a sustainable source of bioactive food ingredients and serum substitutes for cellular agriculture through the proposed DL+SC pretreatment and SB fermentation processes.

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Abstract 906 | 10:40-11:00

Hybrid Alt-Protein Products with Fungal Biomaterials

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ABSTRACT

Background: Fungal mycelium offers a renewable, food-compatible platform for developing structured hybrid cellular agriculture products that can provide structural support for cells while incorporating lipid phases that reproduce the architecture and sensory properties of animal tissues.

Methods: *A. oryzae* biofilms were engineered through three complementary approaches: yeast infusion, enzymatic modification, and protein-based surface coating. Oleaginous *Yarrowia lipolytica* and non-oleaginous *Saccharomyces cerevisiae* were incorporated into fungal networks to modify scaffold architecture and functionality. Glucanase and chitinase treatments were used to selectively modify fungal cell-wall polysaccharides, while zein and wheat gluten were applied as protein coatings through heat crosslinking. Scaffold morphology, biochemical composition, and structural properties were characterized using scanning electron microscopy (SEM), Fourier-transform infrared spectroscopy (FTIR), and mechanical testing. Biocompatibility was evaluated using 3T3 fibroblasts and C2C12 myoblasts. In a complementary approach, *A. oryzae* biofilms were integrated with ethyl cellulose–stearic acid oleogels using zein or wheat gluten as interfacial adhesives. Wettability, SEM, SDS-PAGE, oil retention, thermal stability, and texture profile analysis were used to evaluate the resulting composites.

Results: Yeast incorporation remodeled fungal scaffold architecture, generating increased porosity and enriched surface features while altering biochemical composition and structural properties. Yeast–fungal hybrids supported improved mammalian cell adhesion, proliferation, and early differentiation compared with native *A. oryzae* scaffolds. SEM confirmed successful yeast integration within the fungal network. In fungal–oleogel composites, zein exhibited superior interfacial adhesion compared with wheat gluten, likely due to its amphiphilic properties and compatibility with the fungal matrix. The hybrid composites effectively immobilized oil, reducing oil leakage and thermal weight loss during cooking. Cooked composites exhibited hardness values of approximately 3–13 N, comparable to the textural range of selected processed meat products. **Conclusions:** These studies highlight fungal biomass as a platform for developing sustainable fungal-based scaffolds and structured lipid matrices for next-generation hybrid cell-Ag products.

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Abstract 586 | 11:00-11:20

Chemical Hydrolysis of Brewers' Spent Grain for Mycoprotein Production: Deconstructing Pre-Concepts

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ABSTRACT

Brewers' spent grain (BSG), the brewery sector's largest by-product, offers a high-volume feedstock for circular-bioeconomy valorization. We demonstrate a mild acid–enzymatic hydrolysis pathway that enabled uninhibited mycoprotein fermentation in which early growth consumed compounds often deemed inhibitory (e.g., furfural, HMF, organic acids), highlighting a value-added route to alternative proteins while upcycling BSG.

Pre-tests compared mild acid versus alkaline pretreatments of BSG, followed by cellulase/xylanase treatment, to identify conditions for fungal fermentation. Mild acid hydrolysis (2% w/v H_2SO_4, 121 °C, 25 min) gave the highest reducing-sugar conversion. We evaluated BSG load (60-100 g/L) and enzymatic hydrolysis time (1–24 h), 8 hours being optimum. A Box–Behnken optimization identified the best condition as 20 U/g for both cellulase and xylanase, 100 g/L solids, 40 °C. Fermentations (6 d, 30 °C, 160 RPM) were carried out with *Neurospora crassa* (10^5spores/100 mL) in Vogel salts containing the chemical/enzymatic hydrolysate standardized to 30 g/L reducing sugars and supplemented with 10 g/L yeast extract. Biomass (DCW), protein (Kjeldahl), reducing sugars (DNS), and glucose, xylose, arabinose, HMF, and furfural (refractive-index chromatography) were measured every 24 h.

HMF was not detected after chemical/enzymatic treatment; furfural was 0.16 g/L prior to inoculation. Biomass peaked on day 2 (18.4 g/L) and slightly decreased on day 3 (17.8 g/L), while protein content increased from 32% (day 2) to 42% (day 3), corroborating that biomass alone is not a direct proxy for fermentation yield. A clear glucose effect emerged: xylose and arabinose consumption accelerated once glucose fell below ~3 g/L. Notably, all furfural was consumed within the first 24 h, suggesting that, under mild acid conditions, inhibitor formation was insufficient to impede growth and that residual furans were likely co-opted as early carbon sources.

Overall, these results support BSG mild acid–enzymatic processing as a promising, value-added strategy for mycoprotein production and advance the circular use of lignocellulosic by-products.

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Abstract 953 | 11:20-11:40

Impact and Challenges with Cellular Agriculture

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ABSTRACT

Future foods include cellular agriculture-based methods, with a focus on innovative and sustainable food practices to address global environmental sustainability, the increased demand for protein-rich foods, as well as growing public health concerns, animal welfare issues, and food security. A key emerging technology to help address these challenges includes cellular agriculture (or cell-based foods, cultivated meat). This biotechnology and tissue-engineering approach to future foods provides novel strategies to generate protein-enriched foods with positive outcomes towards the environmental, human, and animal health. However, many challenges remain to achieve impact that will be addressed within the context of the remarkable progress in the field over the past few years.

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Abstract 611 | 11:40-12:00

Microbial Production of Value-Added Products in Biofilm Bioreactors

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ABSTRACT

Fermentation deals with the use of microorganisms to produce molecules that are utilized in the food, chemical, pharmaceutical, and bioenergy industries. It is the biological process by which different microorganisms, including bacteria, yeast, and mold, transform substrates into substances that are beneficial to wellbeing of humans and environment at a low production cost. To enhance the fermentation process, strain development, optimization of media, optimization of growth parameters, bioreactor designs, and simulation fermentation/separation are constantly being studied. Another approach to enhance the fermentation performance is to increase biomass concentration in the bioreactor. Biofilm reactors have been gaining attention of researchers to achieve this goal. Our lab has been working on the design and application of biofilm reactors to enhance the production of numerous microbial products. Biofilms represent a natural form of cell immobilization, and an increased concentration of microorganisms in the bioreactor. The structure of the biofilm matrix provides resistance to extreme conditions of pH and temperature, contaminations, hydraulic shocks, antibiotics, and toxic substances. The biofilm bioreactor design generates microbial concentrations that are not possible in a conventional suspended-culture bioreactor. Biofilm reactors have been used to produce many value-added products, such as organic acids, alcohol, enzymes, antibiotics, bacteriocins, and more. This paper will summarize the applications of biofilm reactors in our laboratory for the productions of value-added products including nisin, lysozyme, and vitamin K. In all these studies, the performance of fermentations has been significantly improved. This approach can certainly open a door to enhance the production of microbial products in the biotech and food industries.

Requested Session: Precision Fermentation and Cellular Agriculture

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Oral Session 21: Innovations in Protein Processing

Tuesday, November 10, 2026

Co-chairs: Mahfuzur Rahman/Belal Hasan. 1:20 pm-3:00 pm. Queen 4

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Abstract 651 | 1:20-1:40

Transforming Plant Proteins with Cold Plasma: Ingredient functionality to Film Performance

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ABSTRACT

Plasma technology has emerged as a non-thermal, chemical-residue-free approach for enhancing plant-protein applications. This study highlights the opportunities and problems of cold plasma treatment of plant proteins with examples of protein ingredient quality and film performance.

In the first study, dielectric barrier discharge plasma (pin-to-plate, PP30) and plasma-activated water (PAW30) were applied to defatted soy flour to reduce lipid oxidation caused by lipoxygenase (LOX) and lipase (LP). PP30 achieved greater enzyme inactivation, reducing LOX and LP activities by 54%and 57%, respectively, whereas PAW30 produced lower reductions of 19% for LOX and 35% for LP. PP30-treated soy proteins exhibited lower concentrations of aldehydic compounds associated with beany flavor. Plasma treatment also promoted protein aggregation and exposure of reactive functional groups, which improved foaming capacity (by 2- 5%), emulsion stability, and gelation properties by 12-15%.

The second study evaluated 30-min dielectric barrier discharge plasma treatment of pea protein, rice bran protein, and wheat gluten. Protein solubility increased, particularly for pea protein by 6.6%, while rice bran protein and wheat gluten showed smaller improvements of 1.2 and 1.3%, respectively. However, emulsifying activity, emulsion stability, foaming capacity, and foam stability generally declined, indicating that plasma-induced structural changes may weaken interfacial functionality. Digestibility improved for pea protein (by 3%) and wheat gluten (by 2%), whereas rice bran protein showed only temporary improvement during digestion and lower final digestibility (by 0.8%) after prolonged intestinal exposure.

In the third study, argon plasma-treated rice bran protein films showed strong antimicrobial activity against *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*. Treated films reduced bacterial populations to 0.9log CFU/mL after 8h and to undetectable levels after 24h. FTIR and XPS confirmed increased oxygen-containing surface groups, while hydrogen peroxide concentrations reached 93.2mg/L in rice bran protein films.

Collectively, these findings demonstrate the versatility of cold plasma as a scalable technology to advance plant-based food systems by simultaneously improving protein-ingredient functionality and enabling antimicrobial, biodegradable packaging solutions.

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Abstract 920 | 1:40-2:00

Optimization of Hydrolysis Conditions for Lactose in Milk Permeate using Multi-Response Surface Methodology

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ABSTRACT

The U.S. has expanded its production of high-protein dairy ingredients, resulting in a large amount of by-product, specifically milk permeate. In 2025, the U.S. generated over 59,000 metric tons of milk permeate. Upcycling of this by-product can produce clean-label, food-grade ingredients for functional dairy applications. Enzymatic hydrolysis of the lactose in milk permeate converts it into glucose and galactose, resulting in a sweeter product that can serve as an effective alternative sweetener. This study aimed to assess the impact of four critical variables- enzyme load, temperature, pH, and reaction time on the rate of lactose hydrolysis. Pasteurized and partially concentrated milk permeate was sourced from an industry supplier and analyzed for its proximate composition. The enzyme β-galactosidase derived from *Aspergillus niger* was used to convert lactose into monosaccharides. The individual and combined effects of the hydrolysis parameters were optimized using Response Surface Methodology with a Box-Behnken Design. The milk permeates consist of 10.2% lactose, 0.25% protein, 1.28% as, and practically no fat. Variance analysis and surface plot evaluations identified the optimal conditions as pH 6.11, 43.08°C, 53.5 minutes, and an enzyme load of 0.427% to achieve the maximum degree of hydrolysis (DH). To validate the optimum conditions, we performed a lactose hydrolysis experiment with the specified conditions. Under these conditions, lactose hydrolysis was 98.36%, closely aligning with the predicted value of DH ~100%. This study will provide the dairy industry with a scalable, cost-effective methodology for valorizing milk permeate, converting a challenging by-product into a viable ingredient stream.

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Abstract 622 | 2:00-2:20

Machine Learning and Molecular Modeling for Protein Solubility Prediction and Structure–Function Discovery

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ABSTRACT

Protein solubility is a key property that influences protein functionality, processing performance, and end-use applications in food systems. This presentation will describe our recent work using machine learning and molecular modeling to improve protein solubility prediction and to better understand the molecular basis of protein structure–function relationships. A stacking machine learning model integrating sequence-derived, structural, and graph-based features was developed to predict protein solubility, achieving improved performance over existing approaches and demonstrating transferability to food proteins. To investigate the molecular basis of protein solubility, machine learning was combined with AlphaFold-predicted protein structures and molecular dynamics simulations to examine the physicochemical and structural characteristics of Osborne protein classes. The analyses identified key sequence and structural features associated with protein solubility and provided new insights into the molecular determinants underlying protein classification. Together, these complementary approaches demonstrate how integrating predictive modeling with molecular simulations can advance our understanding of protein structure–function relationships and support the development and selection of proteins for food and agricultural applications.

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Abstract 583 | 2:20-2:40

Extrusion Processing Strategies for High-Cheese Hybrid Snack Formulations

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ABSTRACT

Fresh cheddar cheese demonstrates strong potential as a nutrient-rich ingredient for next-generation extruded snacks. In this study, fresh cheese was successfully incorporated at levels ranging from 25–35% (w/w) into extruded snack formulations through targeted optimization of extrusion conditions. Color, physical, and compositional properties of extruded snacks were evaluated using standard methods, including CIE L*a*b* color measurement, expansion ratio, bulk density, porosity, and texture analysis, with measurements performed in triplicate. Proximate composition including protein, fat, moisture, ash, carbohydrates, and minerals was determined using AOAC-approved methods by an external laboratory. Optimal processing was achieved at 18% feed moisture, 125 °C barrel temperature, and 400 rpm screw speed, allowing stable extrusion while preserving product structure. Increasing cheese content significantly enhances nutritional value. However, it also introduced processing and textural challenges. Snacks containing 35% cheese had low force (83.99 N), less expanded structures, while formulations with 25% cheese produced firmer textures (273 N). These results highlight the need to balance cheese concentration with mechanical energy input to achieve desirable eating quality. A critical factor in successful processing was the screw profile selection. Initial trials using a texturized vegetable protein (TVP) screw profile were unsuccessful, leading to excessive shear and structural breakdown. Improved performance was achieved by selecting the screw configuration with reduced kneading blocks and predominantly conveying elements to minimizing mechanical stress but keeping adequate mixing. Temperature control was very critical as frictional heating at the feeder screw caused matrix to clump. The low temperatures were maintained in the early barrel zones to prevent premature melting. These findings demonstrate that extruding fresh cheese snacks require fundamentally different processing strategies than conventional starch- or protein-based extrudates. Future work will focus on optimizing post-extrusion drying to improve shelf life and consumer acceptability.

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Abstract 756 | 2:40-3:00

Harnessing aggregates of plant protein hydrolysate as fat replacer: the role of degree of hydrolysis

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ABSTRACT

Plant protein hydrolysate aggregates are increasingly explored as fat replacers because of their low-calorie nature, and ability to modify texture and oral lubrication. However, the effects of degree of hydrolysis on the aggregate characteristics and their subsequent fat-mimicking performance remain poorly understood. In this study, pea protein hydrolysate aggregates (PPHA) were prepared at three degrees of hydrolysis (DH 3.0, 4.5, and 7.0%) and incorporated at an equal concentration into skim-milk-based cream cheese. Relationships among DH, aggregate characteristics, cheese microstructure, mechanical behavior, lubrication, and sensory perception were investigated using rheological and tribological analyses, microscopy, ultra-small- and small-angle X-ray scattering, and sensory evaluation.

Aggregate properties varied considerably with DH, with PPHA-4.5 exhibiting the highest apparent viscosity and most effective lubrication. Incorporation of PPHA substantially decreased the storage modulus and shortened the characteristic relaxation time of cream cheese, indicating the formation of a softer and more readily deformable matrix. These changes were more pronounced for PPHA produced at moderate and higher DH. PPHA incorporation also markedly reduced friction within the mixed lubrication regime, with PPHA-4.5 and PPHA-7.0 providing greater lubrication than PPHA-3.0. Confocal and Cryo-SEM showed that PPHA-3.0 maintained a relatively compact protein network, whereas increasing DH resulted in more open and heterogeneous structures. X-ray scattering further demonstrated substantial changes in mesoscale organization following PPHA incorporation, including enlargement of the characteristic structural domains. These rheological, tribological, and structural modifications were accompanied by enhanced sensory softness and creaminess, particularly for PPHA-4.5. The results demonstrate that DH plays a critical role in determining the fat-mimicking functionality of PPHA, with moderate hydrolysis (DH 4.5%) providing the most favorable balance among matrix softening, lubrication, structural modification, and sensory performance.

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Oral Session 22: Innovative and Sustainable Food Packaging

Tuesday, November 10, 2026

Co-chairs: Kang Huang/Jooyeoun Jung. 1:20 pm-3:00 pm. Queen 5

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Abstract 715 | 1:20-1:40

Substrate-independent coatings for multifunctional food packaging applications

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ABSTRACT

The chemical diversity of food-packaging materials presents a major challenge for introducing surface functionality, as conventional modification approaches often require substrate-specific pretreatments. This study aimed to develop substrate-independent phenolic-amine coatings (PACs) as versatile interfacial platforms for engineering multifunctional food-packaging surfaces. PACs were formed through one-step aqueous deposition using combinations of phenolic compounds and amine-containing molecules under mild and organic solvent-free conditions. The effects of precursor composition and processing parameters, including phenolic-to-amine ratio, pH, concentration, and deposition time, on coating formation were investigated. Coating coverage, surface chemistry, morphology, wettability, adhesion, and stability were characterized using complementary spectroscopic, microscopic, and surface-analysis techniques. The versatility of the coating approach was evaluated on chemically distinct packaging substrates, including plastics, metals, and cellulose-based materials. In this study, we tested 35 combinations of phenolics and amines. The resulting PACs formed adherent interfacial layers across substrates with substantially different surface chemistries, demonstrating their potential as a substrate-independent modification strategy. The abundant phenolic and amine functionalities within the coatings further enabled secondary surface engineering, including immobilization of functional particles and antimicrobial agents and formation of hydrophilic surface layers. These modifications provided opportunities to introduce antimicrobial, controlled-release, and antifouling functionalities without altering the bulk properties of the packaging material. Phenolic-rich extracts derived from food-processing byproducts were also investigated as alternative coating precursors, demonstrating the potential to integrate agricultural waste valorization with functional packaging development. Overall, this work establishes phenolic–amine deposition as a modular surface-engineering approach for converting conventional packaging materials into multifunctional interfaces and provides a flexible platform for developing active and sustainable food-packaging systems.

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Abstract 641 | 1:40-2:00

Agri-Food Biowaste as a Resource for Sustainable Packaging: Bridging Extraction, Fiber Engineering, and Application

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ABSTRACT

The environmental burden of plastic packaging and the generation of more than 5.5 billion tonnes of agri-food residues annually highlight the need for sustainable material solutions. This study developed an integrated food engineering framework that links waste valorization, fiber engineering, and packaging performance to create high-value packaging materials from agri-food biowaste. The objective was to combine (i) cascading biorefinery extraction, (ii) lignocellulosic fiber processing, and (iii) packaging system validation to advance sustainable materials for food applications.

A two-stage approach was employed. First, spent coffee grounds were subjected to cascading biorefinery processing using supercritical CO_2 extraction (2400 psi, 54.4°C) followed by mechanochemical pulping and wet milling to recover lipids, phenolics, and cellulose-rich fibers. Second, twelve agri-food biowaste streams were characterized, delignified using peracetic acid, and evaluated for fiber composition, morphology, drainage properties, and mechanical performance. Engineered lignoholocellulose fibers were subsequently fabricated into lightweight biofoams and tested as biodegradable packaging pads.

The biorefinery process enabled complete biomass utilization by recovering functional compounds while preserving fiber quality for structural applications. Characterized feedstocks contained 10-65% cellulose, 10-66% lignin, and up to 2132 mg GAE/100 g phenolics. Fibrous materials such as hemp hurd and rhubarb pomace exhibited superior drainage and tensile strength (up to 7.32 MPa), while biofoams achieved densities of 11-18 mg/cm³ and compression strengths up to 135 N. Packaging validation demonstrated that hemp hurd-based biopads reduced mechanical damage, weight loss, and spoilage of strawberries under simulated supply-chain conditions.

These findings demonstrate a scalable pathway for converting agri-food residues into biodegradable, performance-tailored packaging materials, supporting circular bioeconomy strategies and reducing reliance on petroleum-based packaging in the food industry.

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Abstract 845 | 2:00-2:20

Catechol-Functionalized Biopolyesters as Sustainable and Innovative Anticorrosive Coatings for Aluminum Food Contact Materials

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ABSTRACT

Justification:

Aluminum cans represent a sustainable packaging alternative to single-use plastics, yet historical reliance on bisphenol A (BPA)-based epoxy liners poses significant health and environmental concerns. The industry's transition to BPA-non-intent (BPA-NI) coatings often faces performance gaps in "hard-to-hold" beverage matrices—characterized by low pH, high ethanol, high electrolyte composition and presence of other corrosive components—where coating failure leads to metal corrosion.

Objective:

This research addresses these limitations by developing a novel, biomass-derived anticorrosive coating system utilizing phenolic-functionalized biopolyesters.

Methods:

An unsaturated copolyester (UPE) was synthesized via melt-polymerization using biomass-derived monomers. To enhance protective properties, the UPE backbone was post-functionalized with catechol moieties through a base-catalyzed thia-Michael addition.

The resulting polymers were formulated with a melamine-based crosslinker and spin-coated onto aluminum alloy 3000 series coupons to thicknesses of approximately 1.5 μm. The performance of these sustainable liners was evaluated through accelerated immersion studies in 3.5% NaCl at 40°C using electrochemical impedance spectroscopy.

Results:

Results demonstrated that catechol-functionalized coatings provided exceptional corrosion protection, maintaining a pore resistance above 108 Ω/cm2 throughout the 14-day study. In contrast, coatings containing non-phenolic styrene moieties exhibited visible failure and a drop in pore resistance to 106 Ω/cm2 after only one day of immersion.

Conclusions:

The superior performance of the catechol-functionalized system is attributed to the strong interfacial adhesion of the anticorrosive catechol groups toward the aluminum substrate.

This study provides a scalable, innovative strategy for development of high-performance, bio-based food contact polymers, offering a viable alternative to BPA-based epoxy resins while advancing the sustainability and safety of canned beverages.

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Significance:

Such anticorrosive biopolyester linings offer a promising solution to key challenges facing the aluminum can beverage packaging industry, including the phase-out of BPA-based epoxy liners, the growing demand for packaging increasingly corrosive ("hard-to-hold") beverages in aluminum cans, and mounting regulatory and consumer pressure to reduce reliance on petroleum-derived single-use plastics.

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Abstract 731 | 11:20-11:40

Cold Oxygen Plasma and Nanocellulose Reinforcement of Chitosan-Zein Composite Films for Sustainable Food Packaging

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ABSTRACT

Biodegradable chitosan films are promising alternatives to persistent petroleum-based food packaging because of their film-forming and antimicrobial properties, but inadequate barrier performance and mechanical weakness constrain wider use. This study aimed to improve chitosan-based packaging films by combining nanocellulose reinforcement, cold oxygen plasma treatment, and a zein-based hydrophobic coating.

Preformed chitosan films and chitosan film-forming solutions were exposed to cold oxygen plasma, a non-thermal ionized gas that modifies surfaces through reactive oxygen species without solvents or high temperatures. Nanocellulose was incorporated as a biobased reinforcement, and a secondary zein layer was applied to produce multilayer composite films.

Plasma treatment increased film surface roughness and surface free energy and decreased the water contact angle from 78° to approximately 36°, indicating substantially improved wettability and potential coating adhesion. Plasma treatment of the film-forming solution reduced viscosity by nearly 40%, producing films with greater flexibility and higher elongation at break. However, the zein coating unexpectedly exhibited a water contact angle of approximately 20°, demonstrating that improved interlayer adhesion can coincide with poor exterior water repellency.

These findings identify surface chemistry, rather than coating identity alone, as a critical design variable for multilayer biobased packaging. Ongoing fatty-acid modification of zein will address this limitation, followed by evaluation of barrier, mechanical, and biodegradation performance. The work advances scalable, solvent-minimized engineering strategies for high-performance compostable food-packaging systems.

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Abstract 673 | 2:40-3:00

Development of Thermoformed Molded Fiber Tray for Cheese Packaging

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ABSTRACT

Cheese packaging requires effective moisture, oxygen, and grease barriers because of the product's high moisture content, sensitivity to oxidation, and relatively long refrigerated shelf life. Conventional cheese packaging is primarily plastic-based. This study aimed to develop a recyclable multilayer molded fiber tray as a sustainable alternative for cheese preservation. The tray consisted of a hardwood pulp substrate, sodium alginate primer, microfibrillated cellulose (MFC) film, and styrene-butadiene (SB) latex topcoat, combined with a transparent regenerated cellulose lidding film. A full factorial design evaluated three MFC and SB latex coating levels, with all of them retained over 85% fiber content, supporting compatibility with conventional paper recycling systems. Water vapor transmission rate, oxygen transmission rate, grease resistance, and surface morphology were evaluated. As to the results, the uncoated tray exhibited a water vapor transmission rate of 545.3 g/m²·day. Coating significantly improved moisture barrier performance, with the 45 g/m² MFC and 10% SB (C45-P10) formulation achieving 82.5 g/m²·day, corresponding to an approximately 85% reduction. Oxygen transmission rates of trays containing 35 or 45 g/m² MFC ranged from 12 to 16 cm³/m²·day and were statistically comparable to the commercial control. All coated trays achieved the maximum Kit 12 grease-resistance rating. Scanning electron microscopy confirmed that the MFC layer covered the porous fiber network, while the SB latex formed a smoother and more continuous surface. The C45-P10 formulation was selected as the optimum balance among barrier performance, cost, and recyclability. A techno-economic analysis at a production capacity of 40 million trays per year estimated a minimum selling price of $0.24 per tray. Shelf-life studies using mozzarella and feta cheeses are ongoing, with weight loss, texture, pH, water activity, color, and microbial quality being monitored. Overall, the multilayer molded fiber tray shows promise as a renewable, high-barrier alternative to conventional plastic cheese packaging.

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Oral Session 23: Transforming Food Engineering Education

Tuesday, November 10, 2026

Co-chairs: Sam Saguy/Jorge Welti-Chanes. 1:20 pm-3:00 pm. Queen 6

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Abstract 648 | 1:20-1:35

Transforming Food Engineering Education: AI, Sustainability and Innovation

Professor Emeritus I. Sam Saguy, The Robert H. Smith Faculty of Agriculture, Food & Environment, The Hebrew University of Jerusalem, Israel

ABSTRACT

The future of Food Engineering (FE) education is entering a transformative era shaped by population growth, exponential scientific and innovation unabated progress, sustainability imperatives, evolving consumer expectations, and increasing emphasis on nutrition, health and wellness, and enginomics. Recent publications highlight the urgent need to modernize traditional curricula equipping graduates also with competencies in digital technologies, sustainability science, interdisciplinary collaboration, and essential soft skills. Sustainable food systems encompassing circular economy principles, waste valorization, climate-responsive production, and resource efficiency are emerging as core learning outcomes, reflecting global warming, environmental degradation, food insecurity, and demographic pressures.

FE education integration of AI and advanced digital tools is essential for preparing food engineers to lead next-generation food systems. Academic programs must cultivate data literacy, digital ethics, systems thinking, and innovation capacity, enabling graduates to harness AI in the design of resilient, sustainable, and consumer-centered processes. By embracing these scholarly insights and emerging technologies, advanced FE education should integrate machine learning, IoT, twin models and digital analytics into core coursework for producing professionals equipped to navigate and drive the next frontier of food engineering innovation.

Strong, proactive partnerships between academia and industry are equally critical. Structured collaborations, including internships, cooperative education placements, joint research initiatives, and industry driven capstone projects bridge the gap between theory and practice, align curricula with real-world challenges, and enhance employability. Such ecosystems foster experiential learning, innovation, and professional skill development while exposing students to contemporary technological and sustainability-driven challenges.

Beyond technical proficiency, FE education must emphasize entrepreneurship, interdisciplinary problem-solving, adaptive learning models (including hybrid and project-based approaches), and lifelong learning frameworks responsive to rapidly evolving technologies and sustainability benchmarks. Embedding these dimensions across curricula supports a paradigm shift from traditional lecture-based instruction toward learner-centered, innovation-oriented education capable of producing agile, resilient professionals prepared to address complex technological, environmental, and societal challenges.

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Abstract 650 | 1:35-1:50

Competency Development and Challenge-Based Learning: Present and Future Educational Models for Food Engineering Programs

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ABSTRACT

The structure of current and future academic programs in Food Engineering must be based on a model that develops disciplinary and transversal competencies, promoting the practical application of knowledge through challenge-based learning. These challenges address real-world problems within organizations or communities, enabling students to apply existing knowledge and generate new insights. The model encompasses four core disciplinary competencies focused on: (1) solving engineering problems by applying the fundamentals of chemistry, physics, and biology; (2) generating consumer-centric solutions for the food industry; (3) designing sustainable food production and processing methods; and (4) establishing quality and food safety plans aligned with international regulations. Additionally, curricula must foster transversal skills such as ethics, communication, critical thinking, future vision, and innovation. Challenges serve as vehicles for learning and community transformation. They demand complex actions that prompt students to mobilize cognitive and external resources to deliver innovative, entrepreneurial, creative, and relevant solutions. By integrating these challenges into academic courses, institutions bridge the gap between theoretical content and real-world scenarios designed by professors and industry partners. This approach encourages active student engagement with social and professional environments, facilitates the integration and transfer of knowledge, and enables the mobilization of necessary resources to solve problems in specific scenarios. Finally, this study presents the outcomes of implementing this model across several global institutions and compares them with traditional academic program structures.

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Abstract 592 | 1:50-2:05

AI Can Coach—Experiments Still Teach:

Take-Home Lab Kits for Resilient Food Engineering Education

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ABSTRACT

Food Engineering education is being reshaped by AI and digital tools, sustainability imperatives, and widening variability in student access to laboratory infrastructure. While AI can accelerate learning through tutoring and feedback, the development of engineering judgment still depends on physical experimentation, from measurement and involving uncertainty and interpretation under real constraints. Within a USDA Higher Education Challenge (HEC) granted project with multiple institutional collaboration, we operationalized this principle through portable, low-cost take-home lab kits for packaging mechanics (paper and plastic puncture resistance), supported by short videos and scaffolded activities that allow students to generate and analyze real data outside traditional labs .

Our contribution to this Education Panel session's "future education" discussion is an implementation-ready, evidence-oriented approach that complements competency- and challenge-based curricula: (1) experiment-anchored modules that can be embedded into existing courses to preserve hands-on practice in hybrid settings; (2) a coded assessment architecture (consent, demographics, self-reported learning experience, and learning-gain metrics) that enables cross-section and cross-site evaluation while protecting privacy; and (3) a continuous-improving loop where learning evidence informs iterative refinement of instructions and prompts. Pilot deployments indicate high accessibility and measurable pre/post knowledge gains, reinforcing that AI is most effective when positioned as coaching and feedback "at scale", not as a replacement for experimentation. We close by outlining how portable labs can serve as a practical layer within broader FE program redesign, supporting resilient, sustainability-relevant education while aligning with industry expectations for AI-literate, evidence-driven, and experimentally grounded engineering graduates..

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Abstract 701 | 2:05-2:20

The seemingly unwieldy breadth of the science base supporting food engineering education

Professor Keshavan Niranjan, Food and Nutritional Sciences, University of Reading (UK)

ABSTRACT

Classical Engineering Education has always relied on a strong science base, but the extent of this science base was restricted to Physics, Maths and Chemistry. Since its inception, Food Engineering Education required its science base to include microbiology and biochemistry, in addition to physics, chemistry and mathematics, so that concepts such as food safety, food quality and hygienic design became embedded in the very methodology of engineering design. Thus, Food Engineering Education, inherently embraced a broader science base than other classical engineering disciplines like mechanical or civil engineering. With the advent of biochemical, biomedical and biosystems engineering in the 1970s, accompanied by an explosive growth in quantitative life sciences, and the recognition of their application to foods, the science base of food engineering grew further to include all aspects of life sciences like molecular biology and what is now known as omic sciences! If food engineering is assumed not to be restricted to process design alone, but also include food product formulation engineering, then its science base expands further to include all aspects of food and nutritional sciences, including sensory and consumer sciences. Given that *health* and *environment* are the main drivers of all scientific endeavors for the foreseeable future, the science base of food engineering must include aspects of health and environmental sciences.

With its reliance on such a broad and multidisciplinary science base, this presentation will consider: 1) How does Food Engineering Education deal with a science base that is seemingly unwieldy? 2) Is the science base, along with all its quantitative features, a pre-requisite for learning food engineering design? Or, can the science base, or parts of it, be acquired “on the go” while learning design skills? 3) What role can AI play in accessing the science base necessary for the engineering design of processes and products?

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Abstract 911 | 2:20-2:35

Rethinking Food Engineering Education for Complex Materials and Societal Impact

Prof. Osvaldo H. Campanella, Department of Food Science and Technology,
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ABSTRACT

Food Engineering education has historically shared a strong foundation with Chemical Engineering, particularly through unit operations and classical transport phenomena. However, food materials are inherently more complex, exhibiting multiphase structures, nonlinear and time-dependent rheology, and molecular transitions that strongly influence processability, quality, and consumer perception. Preparing the next generation of food engineers requires an educational framework that explicitly addresses this complexity.

This presentation will discuss the role food material science as a core component of modern Food Engineering curricula. Topics will include glass transition phenomena, macromolecular interactions, and structural transformations during processing, and how these concepts explain texture development, product stability, sensory attributes and nutritional functionality.

The presentation will also emphasize the importance of connecting instrumental measurements with sensory perception and consumer acceptance, enabling students to translate analytical data into meaningful and real product performance.

The integration of nutrition throughout processing and formulation courses will be examined, highlighting how food processing can improve safety, bioavailability, and nutrient absorption while reducing antinutritional factors. The need for a balanced, science-based discussion of food processing, including current debates surrounding ultraprocessed foods, will also be addressed.

Finally, the presentation will explore the central role of food engineers in advancing food security by translating laboratory discoveries into scalable industrial solutions. Topics will include scale-up challenges in complex food systems and the incorporation of statistics, experimental design, empirical modeling, machine learning, and digital twins into the curriculum. Together with inline process monitoring, structural characterization, and sensory evaluation, these tools provide a framework for educating food engineers capable of designing robust, scalable, and socially responsible food systems.

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Abstract 658 | 2:35-3:00

From Insight to Impact: Translating Human Needs into Scalable Food Engineering Solutions in the AI Era

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ABSTRACT

Food Engineering education is increasingly shaped by advances in artificial intelligence, digital technologies, and sustainability imperatives. While these developments expand the analytical and computational capabilities available to future engineers, they also highlight a critical gap between technical proficiency and real-world application. In industry settings, success depends not only on solving complex technical problems, but on framing the right problems, translating human needs, and connecting solutions to business and consumer impact.

This presentation provides an industry perspective on the evolving role of the food engineer within product development and design. In practice, Food Engineers operate at the intersection of consumer science, food science, material functionality, processing, and scale-up —requiring the ability to translate abstract consumer tensions into technically feasible and commercially viable solutions. Artificial intelligence can accelerate insight generation, modeling, and optimization; however, it remains dependent on well-defined problem framing, data context, and human judgment.

A key competency gap is the ability to communicate technical challenges and solutions to diverse stakeholders. Engineers must translate complexity into clear narratives that articulate the “so what”—linking formulation, process, and performance to consumer value, business outcomes, and societal impact. This capability becomes even more critical in an AI-driven environment, where speed and information availability risk outpacing thoughtful interpretation and decision-making.

Drawing on industry experience, this contribution argues that Food Engineering education should more explicitly emphasize: (1) critical thinking and problem framing in complex, ambiguous systems; (2) translation of consumer and societal needs into product and process design; and (3) communication and storytelling skills that enable influence beyond technical domains. Integrating these human-centric competencies with AI-enabled tools will be essential for preparing engineers who can not only analyze and optimize systems, but also lead innovation and deliver meaningful impact in the food industry.

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Oral Session 24: Modeling and AI for Food Safety and Quality II

Tuesday, November 10, 2026

Co-chairs: Hongwei Zhang/Xu Zhou. 1:20 pm-3:00 pm. King 1

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Abstract 608 | 1:20-1:40

Engineering Starch Digestibility via Processing: Evidence from Experiments and AI-Assisted Review

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ABSTRACT

The food industry increasingly seeks to use processing not only to improve safety, shelf life, and functionality, but also to modulate the wholesomeness and digestive fate of foods. This talk synthesizes experimental findings on process-modified potato starch with a systematic literature review and exploratory AI-assisted evidence extraction, focusing on physical starch modification of rapidly digestible starch (RDS), slowly digestible starch (SDS), and resistant starch (RS).

Experimentally, autoclaving (121 °C, 20 min) induced granular disruption, amylose leaching, and structural reorganization, whereas high hydrostatic pressure (550 MPa, 15 min) largely preserved native starch architectures. RS increased from undetectable levels in native starch to 2.86% after autoclaving and retrogradation. Heat–moisture and citric acid-modified starches retained prebiotic activity, reducing the Firmicutes-to-Bacteroidetes ratio and Proteobacteria abundance while enriching *Roseburia*. Complementary unpublished experiments further showed that blending potato starch with high-amylose corn starch increased RS to 23.38%, exceeding weighted-average predictions.

These findings are broadly contextualized through a human-led systematic review of studies published between 2001 and 2026. Of 252 studies screened, 68 eligible studies compared autoclaving, heat–moisture treatment, and annealing. Autoclaving, particularly when followed by retrogradation, showed the greatest potential to increase RS; heat–moisture treatment generally reduced RDS and increased SDS; and annealing produced milder and more variable shifts. Conversational AI accelerated preliminary literature identification and organization but retrieved fewer studies than the human-led search, underscoring the need for expert verification.

Overall, the findings highlight the potential of processing-based routes for starch modification, the value of AI-assisted evidence mining, alongside identification of gaps related to methods standardization, improved reporting practices, and harmonized RS quantification protocols.

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Abstract 685 | 1:40-2:00

From AI-Based Machine Vision to Closed-Loop Data-Driven Optimisation of Rice Milling

Hongwei Zhang & Benjamin Ilo
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ABSTRACT

Justification:

Rice milling quality is traditionally assessed after processing using manual inspection or offline measurements, preventing timely intervention when grain breakage occurs. Recent advances in artificial intelligence (AI), machine vision and data-driven modelling provide new opportunities for real-time quality prediction and process optimisation, supporting more efficient and sustainable food manufacturing.

Objective:

This study presents the evolution of an AI-enabled framework for real-time rice quality assessment and data-driven process optimisation, demonstrating how machine vision can progress from product inspection towards intelligent closed-loop process control.

Methods:

A custom machine vision platform was developed using high-resolution imaging and YOLO-based deep learning for grain detection, classification and morphology analysis. Statistical quality metrics, including the proportions of whole, broken and brown rice, were extracted in real time. Building on these measurements, a cloud-mediated closed-loop architecture was developed in which AI-derived quality information continuously adjusted milling parameters through adaptive PWM motor control.

Results:

The machine vision system achieved classification accuracies approaching 98% for rice quality assessment and enabled robust morphological analysis under realistic milling conditions. The subsequent closed-loop optimisation system achieved a mean Average Precision (mAP@0.5) of 0.951 and reduced the broken-rice fraction from 21.04% to 6.19%, representing a 70.6% relative reduction in grain breakage. Furthermore, an empirical relationship between PWM actuation and rice breakage was established, providing the basis for future advanced control strategies and digital twins.

Significance:

The work demonstrates how AI-driven sensing can evolve from quality inspection to intelligent process optimisation. The proposed framework provides a practical pathway towards predictive, data-driven food manufacturing, with broader applications in food process control, digital twins and Industry 4.0 quality assurance.

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Abstract 632 | 2:00-2:20

From literature to database to discovery: agentic AI for food property

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ABSTRACT

Food properties are fundamental to data-driven and physics-based modeling of food processes, but most data are scattered across decades of literature. Manual extraction and organization are time-consuming and difficult to scale. The objective was to develop an AI agent system for automated extraction of food property data from scientific papers, with dielectric properties as a case study. The system used three specialized agents: Agent 1 parsed PDFs and screened papers; Agent 2 extracted data from text, tables, and figures; Agent 3 validated records with physics-based rules and exported them into a database. Ten large language models were benchmarked against an expert-curated gold standard. All models achieved precision above 95% and value accuracy above 99%, but recall, cost, and speed varied across models. A mid-sized model gave the best overall performance and was selected for full-scale extraction. The system read the papers and extracted 2,355 data records for 100 food materials in 30 minutes. Analysis of the database found a new relationship between dielectric constant and loss factor that earlier studies missed because their datasets were too small. AI agent systems provide an accurate and scalable method for data mining from food science literature.

The approach converts scattered literature into structured property databases that the food engineering community can use directly for process modeling, digital twins, and equipment design. The same architecture transfers to thermal, rheological, and other food properties, which shortens the path from published measurements to engineering practice.

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Abstract 776 | 2:20-2:40

Too Many Cooks? Physics, Data-Driven and Hybrid AI in Food

Nik Watson, Professor of Artificial Intelligence in Food, University of Leeds, UK

ABSTRACT

The modelling toolbox available to food manufacturers has never been fuller. At one end sit mechanistic, first-principles models built on heat and mass transfer, reaction kinetics and fluid dynamics: transparent and extrapolable, but hungry for parameters, characterisation data and expert time. At the other end sit purely data-driven methods, from regression and classical machine learning through deep learning and, increasingly, large language models applied to the unstructured material that plants generate in abundance, including specifications, batch records, deviation reports and operator knowledge. Between these poles lies a fast-growing family of hybrid approaches: grey-box and serial-parallel structures, physics-informed neural networks, surrogate models that embed process understanding inside data-driven architectures.

The challenge is no longer availability, it is selection. With so many methods on the table, how do you choose the right one for your problem? The answer depends on questions that are easy to skip. What decision does the model actually need to support? How much data exists, and how trustworthy is it? Will the process be operated outside its historical envelope? What degree of interpretability do you require? Who will maintain the model in two years' time? Compounding this, the landscape is shifting quickly enough that an approach dismissed as impractical eighteen months ago may now be routine, so keeping pace is itself part of the problem.

This presentation offers a practical route through the confusion. It first sets out guiding principles for matching method to problem, framed around data availability, process understanding, decision risk and lifecycle cost, alongside suggestions for staying current in a fast-moving field. It then works through case studies drawn from food manufacturing that show where mechanistic models earned their place, where data-driven methods proved sufficient, and where hybrid approaches outperformed either alone. The aim is that attendees leave with a reusable way of deciding which cook to put in charge.

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Abstract 746 | 2:40-3:00

Non-invasive ultrasonic imaging for internal food quality assessment: Application to tomato firmness

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ABSTRACT

Internal quality inspection of heterogeneous foods remains challenging because conventional non-destructive techniques frequently provide either surface information or averaged measurements that cannot describe spatial variations within the product. Ultrasound offers an attractive alternative since wave propagation isdirectly affected by the physical and structural properties of biological tissues. Exploiting these interactions through ultrasonic imaging, rather than conventional single-point measurements, could provide new opportunities for food quality assessment. Therefore, this work aims to evaluate the feasibility of ultrasonic imaging to estimate firmness changes in whole tomato fruits.

Ultrasonic measurements were carried out in water immersion using an experimental set-up consisting of 16 phased-array ultrasonic transducers operating simultaneously at 3.5 MHz. Pulse–echo measurements collected from the different arrays were combined to generate cross-sectional images of the fruit based on reflected ultrasonic energy. Image information was subsequently transformed into quantitative data using descriptors derived from pixel-intensity distributions. Ultrasonic parameters were correlated with instrumental firmness measurements during 28 days of tomato postharvest storage.

Ultrasonic imaging clearly captured the postharvest evolution of the internal acoustic response. Firm tomatoes were characterized by reflections predominantly located in the external tissues and comparatively low reflected energy internally. Softening was associated with greater apparent ultrasonic penetration, increasing internal reflected energy and producing progressively more heterogeneous spatial patterns. These changes were reflected in the image histograms, which shifted towards higher intensities during storage. Quantitative descriptors extracted from these distributions were strongly related to firmness, with coefficients of determination of up to 0.99.

The results illustrate how physical information encoded in ultrasonic wave–tissue interactions can be converted into image-derived quantitative indicators of food quality, supporting the potential of ultrasonic imaging as a non-invasive tool for internal food inspection.

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Oral Session 25: Kinetic Modeling of Food Quality and Safety

Tuesday, November 10, 2026

Co-chairs: Maria Corradini/Bruno Carciofi. 1:20 pm-3:00 pm. King 2

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Abstract 900 | 1:20-1:40

Beyond Single-Parameter Shelf Life: A Multiparameter Kinetic Framework for Heterogeneous Food Spoilage and Waste Reduction

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Abstract (word count: 300)

ABSTRACT

Fresh foods undergo simultaneous physical, chemical, and microbiological changes that are strongly influenced by intrinsic heterogeneity. However, shelf-life assessment often relies on single quality indicators or assumes uniform deterioration, potentially resulting in premature disposal, inaccurate shelf-life predictions, and ineffective mitigation strategies. This study used commercial mushrooms as a model system to demonstrate the need for multiparameter kinetics to capture heterogeneous spoilage and support safer and more effective food management strategies.

Four commercially mushroom varieties, white (WH), cremini (CR), oyster (OY), and shiitake (SH), were evaluated using consumer perception, physicochemical and colour analysis, X-ray micro-computed tomography, and microbiome profiling. Consumer responses (n = 2523) suggested that spoilage cues are commodity-dependent and revealed differences between conventional quality criteria and consumer perception. Tissue-specific analyses showed that gills consistently underwent discoloration earlier than other tissues, identifying them as a potential early indicator of internal deterioration. Microstructural characterization revealed an inverse relationship between initial porosity and structural stability: highly porous OY tissues experienced greater moisture loss and gas exchange, whereas the compact CR structure provided greater resistance to deterioration. Structural compaction and collapse preceded subsequent quality degradation. These physicochemical changes were accompanied by distinct microbiota dynamics shaped by tissue heterogeneity, initial microbial loads, and local nutrient and environmental conditions, with psychrotrophic Pseudomonas becoming dominant under refrigerated conditions.

Collectively, the results demonstrate that mushroom spoilage cannot be adequately described using a single quality attribute or uniform kinetic model. Instead, multiparameter kinetics integrating structural, physicochemical, sensory, and microbiological indicators are required to capture product-specific deterioration. Such an approach provides a foundation for heterogeneity-aware predictive models and digital twins capable of estimating quality and safety throughout the supply chain. Ultimately, these tools could enable more precise shelf-life decisions, reduce unnecessary food disposal, and support mitigation strategies (e.g., packaging redesign) that account for both microbiological and chemical safety considerations.

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Abstract 924 | 1:40-2:00

Modeling and Simulation Strategies for Pork Loin Roasting Kinetics in an Electric Oven

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ABSTRACT

Cooking meat in appliances and industrial ovens is a common daily operation worldwide. As digital technologies advance, improved modeling and simulation tools can support the optimal design of oven cavities, helping to reduce energy consumption and cooking time while delivering high-quality, safe food for households and industrial operations. In this study, a mathematical model was developed, aided by numerical and experimental methods, to describe the kinetics of roasting pork loin (M. longissimus dorsi) in an electric oven. The model consisted of mechanistic principles and constitutive equations, associated with empirical correlations, to describe the kinetics of temperature, moisture, color, and size (deformation) in a piece of meat. Initially, the model was developed in a highly controlled cavity and on a uniform section of the pork loin to establish it. After that, we expanded the model to a commercial cavity, and finally, an actual piece of meat was used for testing. A photogrammetry method was used to represent the geometry of actual pieces of meat. The model describing the food, the air, and the cavity walls was solved numerically using a multistep strategy to save time without reducing accuracy. The pork loin was assumed to be a porous medium in which protein denaturation releases intracellular water, and liquid transport results from capillary forces and pressure gradients arising from evaporation and swelling. The model described the measured cavity wall temperatures, and pork loin temperature and moisture with high accuracy. The roasting doneness level could be predicted through moisture, shrinkage, and color kinetics under different roasting conditions. So, the set of transport-phenomena equations provided a good description of piece-of-meat deformation, color development, and moisture, which are mostly addressed separately. The resulting description supports the choice of roasting parameters and the design of oven cavities, correlating product quality and energy demand at the commercial scale.

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Abstract 717 | 2:00-2:20

Blue LED Light Reduces *Salmonella* spp. and *Listeria monocytogenes* on the Surface of Pecan Kernels

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ABSTRACT

Pecans have been recalled for possible foodborne pathogen contamination. Conventional thermal methods often compromise nut quality, creating demand for nonthermal alternatives. Blue light treatment has emerged as a promising technology, yet its efficacy against pathogens on tree nuts remains unexplored. This study evaluated the efficacy of 405 nm blue LED light (BL) against foodborne pathogens on pecan kernels. A four-strain *S. enterica* and a five-strain *L. monocytogenes* cocktail were cultured on Tryptic Soy Agar for 24 h at 35–37 °C, then suspended in 0.1% sterile peptone water. Pecans were spot-inoculated at 6–10 spots with each bacterial culture (~6 log CFU/g) using 100 µl per five kernels, air-dried for 30–45 min, and exposed to BL for 4, 8, 16, 24, 48, and 72 h, corresponding to cumulative fluences of 9.36, 18.72, 37.44, 56.16, 112.32, and 168.48 J/cm^2, respectively. For each exposure time, 10 kernels (~ 20 g) were treated simultaneously and subsequently divided into two 10-g samples (5 kernels) for microbial count. The experiment was independently repeated five times, with each biological replicate analyzed in duplicate (n = 10). Data were analyzed using one-way ANOVA with Tukey's HSD. *Salmonella* populations were reduced by < 1 log within 8 h of exposure whereas populations were significantly reduced by 1.74 ± 0.15 log CFU/g ($p < 0.05$) after 72 h of exposure. For *L. monocytogenes*, the maximum reduction was 1.28 ± 0.18 log CFU/g after 48 h. Visual observation showed darkening of kernels after 24 h while firmness was significantly different after 48 h of exposure (32.26 ± 2.66 N) when compared with control (26.84 ± 2.54 N). These findings suggest that BL has potential as a nonthermal intervention for controlling foodborne pathogens on pecan kernels. Research is ongoing to enhance the antibacterial effect of BL and assess its effects on kernel quality.

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Abstract 612 | 2:20-2:40

Linking Fruit Microstructure, Mechanics, and Failure Using 4D X-ray Imaging and Discrete Element Modelling

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ABSTRACT

Context and objectives

Fruit texture is a key quality attribute in food engineering, yet its mechanistic origin remains difficult to quantify due to the complex, hierarchical structure of plant tissues. This work presents a combined experimental–computational framework to directly link microstructure to macroscopic mechanical behavior and failure in fruit tissue, with a focus on apple as a model system.

Methods

Integration of continuous scanning X-ray computed tomography (4D-XCT) with digital volume correlation (DVC) enabled *in situ*, time-resolved measurement of internal 3D deformation of tissues during compression. This approach provided access to spatial strain distributions, pore collapse, and fracture development at cellular resolution—information that is inaccessible with conventional texture testing. Microstructural descriptors, such as porosity, cell size, and intercellular contact area, were related to key mechanical properties.

A physics-based Discrete Element Method (DEM) model was then developed using realistic 3D tissue architectures derived from XCT data. The model resolved the competing roles of cell wall rupture and cell–cell debonding, governed by cell wall stiffness and intercellular adhesion energy, and reproduced experimentally observed stress–strain behavior and failure modes.

Results

Together, these methods reveal how microstructural evolution, for example during maturation—characterized by increasing porosity, larger cells, and reduced cell–cell contact—drives a transition from stiff, tough, and progressively failing tissue to softer, more brittle tissue with highly localized fracture. This shift explains key textural changes relevant to consumer perception and mechanical damage susceptibility.

Conclusions and relevance

The presented framework establishes a quantitative, multiscale methodology for predicting fruit texture from measurable structural and material properties, offering new opportunities for process design, quality control, and the engineering of plant-based foods.

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Abstract 889 | 2:40-3:00

Inactivation Kinetics of Thermophilic Sporeformers in High Protein Beverages

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ABSTRACT

High-protein beverages have become increasingly popular because of their nutritional value and role in promoting health and fitness. However, their production poses significant microbiological challenges, particularly due to thermophilic spore-forming bacteria, which can survive heat treatments and compromise product quality and safety. The aim of the study was to investigate thermal inactivation kinetics of *Geobacillus stearothermophilus* and *Geobacillus thermoleovorans* in dairy and plant-based high protein shelf-stable beverages. Model high protein beverage systems containing 5%, 7%, and 10% milk, soy and pea protein isolate, and control were evaluated for thermal treatment. The inactivation process was carried out using thermal death time (TDT) cells immersed in an oil bath at target temperatures of 115°C, 121°C, and 125°C for various times. The Weibull model was applied to assess the inactivation kinetics under these conditions, with model parameters estimated at a reference temperature of 110°C. The δ values increased with protein concentration, indicating enhanced heat resistance at higher protein levels for both the organisms. Among all the matrices, the milk protein formulation at 10% protein level exhibited the highest δ and z-values, followed by pea and soy protein based beverages. Pairwise comparisons of estimated Weibull kinetic parameters (δ and z) confirmed that protein concentration was a significant determinant of spore thermal resistance for both organisms across all matrices. These results underscore the necessity of matrix-specific kinetic parameters for accurate thermal process design and commercial sterility validation of high-protein beverages.

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Plenary Session 3. Technology Commercialization Monarchy Ballroom

Wednesday, November 11, 2026

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8:05-8:20

Pulsed Electric Field Processing: From Scientific Concept to Industrial Reality – The ELEA Story

Stefan Toepfl: ELEA Technology GmbH, Quakenbrück, Germany

ABSTRACT

Pulsed Electric Field (PEF) technology provides a compelling example of how an emerging food processing concept can evolve into industrial application. While the scientific foundations of electroporation have been established for decades, the transition from laboratory-scale experiments to reliable industrial implementation required overcoming a wide range of technical, economic, and organizational challenges.

Drawing on more than two decades of industrial experience, this presentation shares key lessons learned from the development and commercialization of PEF technology from the perspective of a technology developer and equipment manufacturer. Over time, PEF has progressed from a niche research topic to an established processing technology with applications in potato processing, fruits and vegetables, juice production, beverages, and other food sectors. Today, industrial PEF systems operate in food processing facilities around the world, delivering measurable benefits in process efficiency, product quality, and resource utilization.

Beyond the technical aspects, the presentation will reflect on key lessons learned in bringing an innovative food technology to market. Topics include technology validation, scale-up from laboratory investigations to industrial throughput, intellectual property strategies, collaboration between academia and industry, customer adoption, and the development of viable business models. Particular attention will be given to the importance of creating clear economic value for food processors, as technological superiority alone is rarely sufficient to achieve widespread market acceptance.

The presentation will also discuss current developments and future opportunities for electroporation-based technologies. These include the integration of inline sensing and advanced process control, emerging applications in fermentation processes and alternative protein production, the development of economically attractive business models for seasonal industries, and the scaling of electroporation technologies to entirely new throughput levels.

These challenges represent not only significant opportunities for innovation, but also important lessons still to be learned as food engineering continues to bridge scientific discovery and industrial implementation.

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8:20-8:35

Beyond the Grant: What It Takes to Move University Research to Market

A Founder's Perspective on Commercializing PEF Technology at Boise State University

Kristi Spence, Boise State University

ABSTRACT

Funded through an NSF Technology Innovation & Partnerships (TIP) Directorate grant focused on food and nutrition security, teams are tasked with moving research from the laboratory toward a stage of commercialization with societal impact. For the Boise State-led team, this meant, applying existing technologies in novel ways to boost the efficiency of dairy processing - taking a concept from the lab to the plant and ultimately spinning out a company to bring it to market. That transition puts fledgling university startups squarely in the valley of death, the gap between validated lab-scale research and commercial readiness. The team launched PEF Analytics, a startup commercializing the application of pulsed electric field (PEF) technology for industrial dairy processing.

Panelist Kristi Spence is a communications and marketing expert who began consulting with the Boise State team at the outset of the grant. She has since joined the Food and Dairy Innovation Center full time and is a co-founder of PEF Analytics. Her fifteen years of prior dairy industry marketing experience inform how she manages the multi-stakeholder relationships this work requires. She will share her perspective on commercializing technology from within a University as a company founder, communications expert, and University employee. The discussion will include navigating University licensing and Conflict of Interest management with a focus on the practical steps that set teams up for success.

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8:35-8:50

From Research to Market: The A+ Berry Commercialization Journey

Xu C.[1,2]

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ABSTRACT

University research generates new knowledge and technologies, but translating an innovation from the laboratory into a product that creates real-world impact is a very different challenge. This presentation shares the journey of A+ Berry, a university research-based startup built around an underutilized fruit crop, and the lessons learned in moving research toward commercialization.

The journey began with a practical challenge from aronia berry growers. Aronia is rich in polyphenols, but its strong astringency limits consumer acceptance and market development. Research aimed at addressing this challenge led to the development of processing technology to improve the sensory quality of aronia products while maintaining their nutritional value. What started as a research question eventually progressed to intellectual property, customer discovery, product development, and the creation of A+ Berry.

However, developing a technology was only the first step. Moving from the laboratory to the marketplace required navigating challenges that are not typically part of academic research, including product formulation, manufacturing, scale-up, food safety, packaging, funding, distribution, marketing, consumer education, and balancing academic and entrepreneurial responsibilities. Support from university resources, commercialization programs, government funding, industry partners, growers, retailers, and customers played an important role throughout this process. Today, A+ Berry has moved beyond its initial product and continues to expand its product portfolio, technologies, and markets, with the long-term goal of building a comprehensive platform around aronia berry.

Using the A+ Berry story as a case study, this presentation will discuss both successes and challenges encountered along the commercialization pathway and share practical lessons for researchers interested in translating food engineering innovations into marketable products. The experience demonstrates that commercialization is not simply about developing a technology or obtaining a patent; it requires understanding customers, building partnerships, adapting to unexpected challenges, and creating an ecosystem that can transform research discoveries into sustainable real-world impact.

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Oral Session 26: Circular Bioeconomy

Wednesday, November 11, 2026

Co-chairs: Ozan Ciftci/Zeynep Boz. 10:20 am-12:00 pm. Queen 4

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Abstract 955 | 10:20-10:40

Designing the Future of Food in a Circular Bioeconomy: Supercritical Fluids as Enablers

Ozan Ciftci
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ABSTRACT

The convergence of sustainability, innovation, and health is transforming how we envision the future of food. As the global population grows and challenges facing our food system intensify, creating more sustainable food systems requires innovative technologies that can simultaneously improve health, reduce waste, enhance resource efficiency, and decarbonize production. Supercritical fluid technology is emerging as a powerful platform for achieving these goals.

In particular, supercritical carbon dioxide (SC-CO_2) offers a versatile and clean processing platform that can advance circular bioeconomy principles in food design and manufacturing. Beyond replacing conventional solvent-intensive processes, SC-CO_2 creates new opportunities to develop foods and ingredients with unique structures, improved functionality, enhanced stability, and potential health benefits.

This presentation explores how SC-CO_2-based processes, including extraction, fractionation, particle formation, reaction engineering, and material development, can transform agricultural commodities, food processing byproducts, and side streams into high-value food ingredients, biomaterials, and nutraceuticals. Case studies will demonstrate applications of SC-CO_2 in sustainable food structuring, fat replacement, bioactive delivery, development of functional materials, and recovery of valuable compounds from food processing waste. Examples will highlight opportunities to integrate green processing with food design while preserving or enhancing the functional and nutritional properties of food components.

Ultimately, this presentation positions supercritical fluids not simply as alternatives to conventional processing technologies, but as strategic enablers of a future-ready food system. By connecting sustainable processing, circular resource utilization, and innovative food design, supercritical fluid technology can contribute to healthier foods, lower environmental impacts, greater utilization of agricultural resources, and more resilient and sustainable food manufacturing.

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Abstract 943 | 10:40-11:00

Regenerative Robust Gasification with Steam Methane Reforming (RRG+SMR): A carbon-negative pathway for circular mixed plastics recycling.

Bruce Welt[1], Ryan Ames[1], Cesar Moreira[1], Ziynet Boz[1] –
[1]Packaging Engineering Program, University of Florida, 1741 Museum Road, Gainesville, FL, 32611.

ABSTRACT

Food packaging increasingly relies on complex, multilayer, and metal-containing structures that are incompatible with conventional recycling. Halogenated polymers such as PVC and PVDC, metalized films, foil laminates (e.g., K-cup tops, cream cheese foils, multilayer flexible packaging), and mixed plastics collectively represent a massive, largely unrecyclable waste burden with significant greenhouse gas implications.

This study introduces RRG+SMR — Regenerative Robust Gasification integrated with Steam Methane Reforming — as a comprehensive, carbon-negative solution to convert difficult-to-recycle food packaging waste into methanol for circular manufacturing.

Models of plasma-assisted molten-bath gasification treating mixed organic MSW with in situ SMR of landfill gas (LFG) and anaerobic digestion biogas methane predict the potential to optimize syngas H_2:CO ratios. HCl from PVC/PVDC polymers was scrubbed from syngas to pretreat metal-containing waste to supplement hydrogen. Syngas yields were quantified. A life cycle assessment (LCA) was conducted for the ReaSYN Technologies, Inc. (Merritt Island, FL) RRG facility in North Florida, with grid electricity as the energy source.

SMR integration predicts an increase in methanol yield from ~200 to ~1000 gallons per ton of MSW, depending on methane and plasma steam injection. HCl pretreatment of metal-containing packaging waste generated hydrogen gas and soluble metal chlorides, further boosting methanol yield while enabling beneficial use of otherwise non-recyclable materials. LCA showed net carbon consumption of 5–15 kg CO_2-eq per kg methanol produced using grid electricity, improving by an additional ~2 kg CO_2-eq with renewable power.

RRG offers the food industry a scalable, carbon-negative route to true circularity, converting the most problematic food packaging waste streams into virgin-quality feedstocks while actively removing CO_2 from the atmosphere.

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Abstract 805 | 11:00-11:20

Digital Twin-Enabled Life-Cycle Assessment of Reusable Transport Packaging in U.S.–EU Transatlantic Food Supply Chains

Ziynet Boz, Mert Canatan, Rajeshwari Periyaswamy, Jacobo Lozano, Raquel Lozano
University of Florida

ABSTRACT

Reusable transport packaging (RTP) is an opportunity to reduce packaging waste and support circular food supply chains; however, its environmental performance depends on how reuse is implemented across the entire logistics system. This challenge becomes particularly important in potential transatlantic trades, where reusable packages can be used to transport food products from the United States to the European Union must subsequently be collected, cleaned, inspected, repositioned, and recirculated. This study develops a digital twin-enabled life-cycle assessment framework to evaluate RTP systems across U.S.–EU transatlantic supply chains. The digital twin represents interconnected physical and operational components of the reuse system, including packaging assets, product shipments, transportation modes and distances, package inventories, return flows, cleaning operations, losses, and replacement requirements. Operational and sensor-based data, including RFID-enabled package location and rotation history, can dynamically update the virtual representation of the system. Life-cycle assessment is integrated with the digital twin to quantify environmental impacts associated with packaging production, forward transportation, reverse logistics, cleaning, maintenance, losses, and end-of-life management. The framework enables scenario and sensitivity analyses to investigate how environmental performance changes with package return rates, number of rotations, loss rates, cleaning locations, transportation distances, backhauling opportunities, pool size, and trade volume. Particular attention is given to identifying environmental break-even conditions under which a transatlantic reusable system outperforms a single-use packaging alternative. The proposed approach moves beyond static comparisons of packaging materials by representing reuse as a dynamic circular system whose performance emerges from interactions among packaging design, logistics, infrastructure, and operational behavior. The framework is intended to support growers, exporters, packaging providers, logistics operators, and policymakers in evaluating where and under what operating conditions reusable transport packaging can provide measurable environmental benefits in transatlantic food supply chains while identifying potential burden shifting created by reverse logistics and reconditioning activities.

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Abstract 836 | 11:20-11:40

Valorizing Agri-Food Processing Byproducts into Plasma-Modified Biochar for Rare Earth Element Recovery

Rongge Zou, Juzhong Tan*
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ABSTRACT

Rare earth elements (REEs) are critical to sensors, catalysts, electronics, and advanced materials, yet their supply chains face increasing sustainability and geopolitical challenges. Recovery of REEs from dilute aqueous streams using low-cost, renewable sorbents offers a promising alternative to conventional resource-intensive approaches. Biochar derived from agricultural and food-processing residues provides a circular-economy pathway for REE recovery; however, pristine biochar often lacks sufficient oxygen-containing functional groups, such as carboxyl and hydroxyl groups, for effective complexation with REE^{3+} ions.

This study investigates air-based non-thermal plasma as a solvent-free surface modification strategy to enhance the REE adsorption performance of biochars derived from corn cob, cocoa husk, bamboo, and nutshell and produced at 350–700°C. Biochars are characterized for elemental and proximate composition, surface functional groups (FTIR), specific surface area and porosity (BET), and surface charge (zeta potential and pH_pzc). Baseline REE adsorption is screened using a 16-element REE standard containing Sc, Y, and lanthanides to identify high-performing biochar feedstocks. Selected biochars are subsequently subjected to plasma optimization as a function of treatment voltage and exposure time, followed by adsorption isotherm, kinetic, pH-dependent, and multi-element selectivity studies. XPS, FTIR, SEM-EDS, and XRD analyses before and after adsorption are used to elucidate REE binding mechanisms.

Preliminary characterization demonstrates substantial feedstock- and pyrolysis-dependent variation in biochar properties. Notably, biochar addition produced feedstock-dependent alkaline shifts in REE solution pH, suggesting that ash and mineral constituents substantially influence solution chemistry and must be controlled during adsorption evaluation. This study establishes a framework for engineering food- and agricultural-residue-derived biochars as functional sorbents for critical mineral recovery, linking waste valorization with circular resource recovery and supply-chain sustainability.

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Abstract 654 | 11:40-12:00

On the Economics of the Transition to more Circular Food Systems

Ahmed Chennak[1], Konstantinos Giannakas[2]* & Tala Awada[3]
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ABSTRACT

Humanity is facing complex challenges posed by population growth, climate change, and the need to increase food production amidst depleting natural resources. The transition to a more circular economy, characterized by reduced resource use and waste, is being increasingly recognized in academic, business and policy making circles as essential to meeting these challenges, with the emphasis being on the development of methods and processes that enable and facilitate the transition from linear to circular economic systems.

Even though circular economic systems comprise both market mechanisms and material flow systems and their feasibility and sustainability depend largely on their economic viability, the role of markets and the economics associated with their functioning have largely been ignored by the relevant literature. This presentation will argue the need for an increased emphasis on the economics of the circular economy and will present a general, empirically relevant, integrated multi market framework that illustrates the transition from linear to circular food systems and enables the development of technical, environmental, and economic metrics of circularity.

In addition, the presentation will highlight the socio-economic factors affecting the effectiveness and efficiency of the transition to increased circularity; key differences between the Global North and the Global South; and the policy options available to facilitate the successful transition to more circular food systems.

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Oral Session 27: Digitalization of Food Processing

Wednesday, November 11, 2026

Co-chairs:Amir Malvandi/Ashim Datta. 10:20 am-12:00 pm. Queen 5

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Abstract 903 | 10:20-10:40

Geometry-Aware Graph Neural Operators for Real-Time Multiphysics Modeling in Food Processing Digital Twins

Saeed Nazari and Amir Malvandi, Department of Agricultural and Biological Engineering
University of Illinois at Urbana-Champaign, Urbana, Illinois, 61801, USA

ABSTRACT

The digital transformation of food manufacturing is driving a transition toward data-driven, energy-efficient, and highly controlled operations. A major hurdle in this digitalization is the "observability gap," where the internal multiphysics state of a food product—characterized by coupled heat, mass, and momentum transport—remains unobserved in real time. While high-fidelity computational fluid dynamics (CFD) provides a rigorous framework for resolving these processes, its substantial computational demands preclude its use in real-time adaptive control. Furthermore, the wide geometric variability of food products across industrial lines typically forces conventional surrogate models to be re-trained or re-meshed for every new product shape.

This work presents a geometry-aware graph neural operator framework designed for the simulation of 3D multiphysics transport in heterogeneous food matrices. By performing operator approximation rather than solution approximation, the model learns a discrete transition map through permutation-equivariant message passing that transfers zero-shot to unseen meshes and irregular geometries. The architecture utilizes region-specific message passing with additive residual networks to explicitly mirror governing-physics decompositions, distinguishing between free-fluid transport, porous-media resistance, and interfacial dynamics.

Results demonstrate that the framework achieves computational speedups of two to three orders of magnitude compared to CFD. In evaluations on geometries entirely absent from the training set—specifically ellipsoidal, square, and pyramidal shapes—the model maintained near-CFD accuracy ($R^2 \geq 0.92$), whereas traditional linear reduced-order models collapsed. Furthermore, the integration of sequential data assimilation via observation nudging reduces long-horizon prediction drift by 24–53% with less than 1% additional computational overhead. This framework provides a scalable foundation for physics-consistent state estimation in energy-intensive manufacturing, allowing digital twins to detect localized high-moisture pockets or thermal gradients to ensure food safety and process efficiency.

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Abstract 784 | 10:40-11:00

Real-Time Design Use of Complex Models: AI-Based Surrogates as Enablers

Debmalya Ghosh and Silochanie Miller, Graduate Students, and Ashim Datta, Professor, Department of Biological and Environmental Engineering, Cornell University, Ithaca, New York, 14853, USA

Combining AI with mechanistic models enables truly novel possibilities in monitoring and control of process, quality, and safety, far beyond what is possible with mechanistic or AI alone.

ABSTRACT

Built on multiphysics, mechanistic models are often complex, taking longer to develop with long run times. One way to combine the two is to build a surrogate model from the results generated by the mechanistic model that can accurately reproduce 100+ times faster. Our objective is to build a real-time smartphone-based drying safety simulator app that is based on a surrogate model that, in turn, is built from an experimentally validated high-fidelity mechanistic model.

To show the universality of the process, I will first introduce a universal multiphysics framework used to model the drying process. Here food is treated as a swellable/shrinkable porous medium with multicomponent transport, evaporation/condensation, and reactions. However, runtime using this model is prohibitive for design use. To overcome this, we developed several reduced-order surrogate models that learn from the output of the multiphysics model, that is the second part of the presentation. Through systematic evaluation of dimensionality-reduction techniques and sequence-learning architectures, Transformer-based networks emerged as the most effective surrogate, reproducing the full spatiotemporal evolution of temperature, moisture, and deformation fields with near-perfect accuracy and 3+ orders-of-magnitude speedup. Finally, I will describe the server-based computing infrastructure that combines the surrogate model with data communication. Its interactive interface generates spatially resolved safety and quality indicators—such as microbial lethality and moisture uniformity, instantly from user-specified process and product parameters, not possible without the surrogate model.

Use of such surrogate models is rapidly expanding in process optimization, sensitivity analysis, real-time control and digital twins. The work here demonstrates the entire pipeline from complex mechanistic model to surrogate to server-based computing, that is the future.

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Abstract 630 | 11:00-11:20

Extrusion of ElastoViscoPlastic Food Materials

Ruud van der Sman, Wageningen University & Research, the Netherlands

ABSTRACT

In several applications food materials get extruded, like in 3D printing and manufacturing of plant-based meat analogs. During extrusion it is beneficial that food materials are shear-thinning, while after extrusion they need to retain their shape and structure – which is enabled by their (visco)elastic properties. They transition between solid and liquid states via yielding. This rheological behaviour is captured by ElastoViscoPlastic (EVP) models. In the presentation we report on a) identification of EVP model parameters from LAOS experiments using Physics-Informed Neural Networks, and b) fluid flow simulation of EVP-materials through a contraction – as occurs during extrusion in 3D printing or meat analog extrusion.

Prior to the parameter identification we performed a formal parameter identifiability analysis using the Fisher Information Matrix. This shows limitations of the LAOS protocols regarding the number of model parameters that can be identified independently. Hence, this limits the complexity of models that can be used in the model identification by PINNs. The parameter identifiability was indeed confirmed by the PINN analysis. The presented EVP models can capture the viscoelastic behaviour at small strains, the yielding at moderate strains, and shear-thinning at large strains – but fail to capture the absence of the weak-strain-overshoot at moderate strains. But, we think the latter is not critical to the food application.

Subsequently, we performed flow simulation of EVP materials through a 2:1 contraction, which is an abstraction of the flow behaviour of food inks through a constricted nozzle, and meat analogs through the transition zone between the barrel section and the cooling die. We show that strong normal stresses are built up in the contraction zone, with significant gradients in normal stress and pressure perpendicular to the flow direction. We hypothesize that these gradients ultimately lead to slip of the material along the wall.

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Abstract 600 | 11:20-11:40

Opportunities and Value in Using Factory Digital Twins for Food Processing

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ABSTRACT

This presentation will describe how to develop and use a Factory Digital Twin (FDT) to accurately model and predict the behavior of food processes. An FDT can generate significant value by rapidly investigating scenarios that would be difficult, costly, or impossible to undertake using a real-world food processing facility. For example, an FDT generates value through (1) debottlenecking – identifying and reducing process inefficiencies, (2) engineering design/retrofit analysis – eliminate potential flaws and optimize the design using FDT results before physical implementation, (3) facility fit – use FDTs to determine at which facility a new product should be processed, (4) scheduling and planning that maximizes throughput. It can also be utilized in concert with emerging on-line analytical tools to create powerful machine-learning tools that can yield real-time predictive models that can optimize yield and ensure quality and food safety. FDTs have the potential to spread quickly through the industry because they are knowledge intense but incrementally inexpensive. The presentation will review how rapid advances in Artificial Intelligence (AI) are making FDTs much easier to build, analyze, and use with widely available tools.

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Abstract 883 | 11:40-12:00

Assessment of the cold chain food preservation performance and the T-TAP cold chain management platform

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ABSTRACT

Reducing food losses, particularly of refrigerated animal products because of their high cost and large contribution to environmental degradation is an urgent task. New refrigeration systems have improved energy efficiency, but food losses remain at 20-30%. A key reason was the lack of science-based tools to assess food preservation performance when designing and operating cold chain units. To fulfil this need, Tecnologico de Monterrey developed the **Refrigeration Performance Indicator (RPI)** which uses time-temperature data and predictive microbiology models. By definition, values of RPI ≤1, =1, and >1 indicate excellent, good and poor refrigerated preservation performance, respectively, whereas values >> 1 indicate situations requiring urgent attention. We will review how RPI has been used to evaluate the impact on the food preservation performance of residential refrigerators, the weakest cold chain unit, as affected by compressor technology, door openings, ambient temperature, refrigerator load, food matrix/microflora, and food placement. Also presented will be **RPI** applications to assess temperatures observed during transportation. New indicators were developed for short shelf-life products which are produced and shipped immediately to customers. This consideration led to a second indicator of cold chain performance, extent of lag phase completion (**LPC**) with values beginning at 0 and reaching 1 when microorganisms begin growth. In this talk, we will present the Transportation Temperature Analysis Platform **(T-TAP)** to automatically assess the refrigerated transport preservation performance considering **LPC** and **RPI** values. Data collected during commercial refrigerated shipping will be used for illustration. Using probabilistic engineering calculations to generate probabilistic distributions for LPC and RPI allows the following decision refinement. If 80 or 95% of LPC values are below 1, the lag phase is considered incomplete for spoilage and pathogen microorganisms, respectively. Furthermore, if 80 or 95% of RPI values are below 1, T-TAP will accept the shipment, respectively.

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Oral Session 28: Modeling and AI for Food Safety and Quality III

Wednesday, November 11, 2026

Co-chairs: Jordan Pennells/Timothy Andersen. 10:20 am-12:00 pm. Queen 6

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Abstract 605 | 10:20-10:40

The Intelligent Extrusion Platform, Two Years On: Building and Using Hybrid Intelligence in Food Manufacturing

Authors: Jordan Pennells, Kai Knoerzer
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ABSTRACT

Extrusion produces breakfast cereals, snack foods, aquafeed and plant-based meat, yet product development remains slow, expensive and reliant on expert intuition. Reaching a new product typically requires repeated physical trials, each costing thousands of dollars and weeks of turnaround, partly because the knowledge that could reduce them is scattered across thousands of publications and difficult to apply in practice. At CoFE24 we presented an early prototype of CSIRO's Intelligent Extrusion Platform and shared the vision behind it with this community. The platform is now live, built on a manually curated corpus of more than 300 peer-reviewed studies, 1,500 experimental samples and 140 ingredients published between 1990 and 2023. Three key modules cover interactive exploration of the extrusion literature, a prediction engine for product outcomes, and a domain-specific chatbot assistant that answers from the corpus and cites its sources. Furthermore, external engagement has been conducted through invite-only beta testing, comprising eight walkthrough sessions with nineteen external testers across five countries, including three equipment manufacturers. The platform embodies what we describe as Hybrid Intelligence, a deliberate division of labour in which the researcher frames the problem and sets the constraints, AI works at speed across a curated and traceable evidence base, and the result is validated against reality. Moreover, this way of working shaped both the prediction engine workflow, where predictions are confirmed by experimental trial, and the construction of the platform itself, which was developed with AI coding assistance. Future development is directed at the gaps beta testing exposed, including screw profile considerations, ingredient functionality beyond macronutrient composition, and validation studies quantifying trial reduction. As AI becomes embedded in industrial research, we propose this cycle as a template for digital decision support across food manufacturing, and expect it to extend wherever expertise is scarce and trials are expensive.

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Abstract 893 | 10:40-11:00

Rapid Quantification of Vitamins C, B5, and B9 in Ethyl Cellulose-Coated Formulations Using Near-Infrared Spectroscopy and Automated Machine Learning

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ABSTRACT

Background: Water-soluble vitamins C (L-ascorbic acid) and B9 (folate) can degrade during processing and storage of fortified foods, requiring formulation overages to maintain label claims. Vitamin B5 (pantothenic acid), while more stable, is commonly co-formulated in B-complex products. Microencapsulation with ethyl cellulose (EC) can improve vitamin stability, but rapid, non-destructive methods for quantifying vitamins in EC-coated, food-relevant formulations remain limited. To our knowledge, NIR quantification of vitamins B5 and B9 in EC-coated formulations has not been previously reported.

Methods: Near-infrared (NIR) spectra were acquired from Glanbia's EC-coated vitamin formulations, vitamin standards, and uncoated formulations, comprising 363 spectra from 121 replicate batches across six sample sets. A SpecAutoML framework jointly optimized spectral preprocessing and regression hyperparameters using Bayesian optimization across six machine-learning algorithms. Performance was evaluated using batch-aware GroupKFold and leave-one-group-out validation.

Results: Joint optimization reduced pooled RMSE by up to 34% compared with the best manually selected preprocessing strategy and by 31–42% relative to a commonly used SNV plus first-derivative Savitzky–Golay pipeline. The best individual SpecAutoML models achieved out-of-fold R^2 values of 0.994, 0.982, and 0.990 for vitamins C, B5, and B9, respectively, with RPD values of 7.5–12.7. An equal-weight ensemble achieved comparable performance (R^2 = 0.992, 0.981, and 0.986; RPD = 7.2–11.4). Bland–Altman analysis showed negligible systematic bias, while leave-one-group-out validation produced R^2 values of 0.92–0.99 across the six sample sets, demonstrating robust generalization to unseen batches.

Conclusions: SpecAutoML enables accurate NIR quantification of vitamins C, B5, and B9 in EC-coated formulations using rigorous batch-aware validation. The framework provides a rapid, non-destructive approach with potential applications in formulation optimization, routine quality control, and kinetic degradation studies of encapsulated vitamins in fortified foods.

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Abstract 646 | 11:00-11:20

Engineering Sprayable Structured Network-Forming Surfactant Coatings for In Situ Active Food Packaging

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ABSTRACT

The increasing demand for sustainable food packaging has created a need for active coating technologies that extend shelf life while reducing reliance on synthetic additives. This study developed a sprayable structured network-forming surfactant (SNFS) coating composed of Poloxamer 188 (P188), sodium dodecyl sulfate (SDS), and limonene for in situ active food packaging.

The formulation undergoes rapid sol-gel transformation after spraying under mild conditions, forming stable gel coatings directly on packaging surfaces without chemical crosslinking or high-temperature processing. The physicochemical properties of the coating, including gelation behavior, mechanical strength, antimicrobial activity, antioxidant capacity, and storage stability, were evaluated.

Preliminary results showed that the P188/SDS/limonene formulation rapidly formed stable gel coatings within seconds after spraying. When applied to fresh strawberries, the coating extended shelf life by at least five days while maintaining desirable antimicrobial and antioxidant performance.

These findings demonstrate the potential of sprayable SNFS coatings as scalable active food packaging for fresh produce and provide a practical strategy for improving food quality, reducing food waste, and supporting sustainable food manufacturing.

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Abstract 926 | 11:20-11:40

Cell Growth and β-glucan content of microalgae Euglena gracilis as influenced by Agitation during Heterotrophic Fermentation Using Corn Steep Liquor

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ABSTRACT

Microalgae *Euglena gracilis* efficiently accumulates β-1,3-glucan (paramylon), which is a prebiotic food ingredient, in heterotrophic fermentation under stress conditions, including mechanical shear, in stirring tank bioreactors due to agitation. However, higher mechanical shear can damage the cells of *E. gracilis* which do not have walls, impacting both cell density and paramylon content. Optimizing the maximum shear stress that cells can take and still grow and produce paramylon requires further research. We aim to utilize the corn steep liquor (CSL) as a low-cost fermentation growth media under varying shear conditions, thus, adding value to this high-BOD coproduct of corn wet milling industry.

Preliminary fermentation using basal Hutner medium (sugar content 17.7g/L) in the stirring bioreactor at 300 rpm, 27.5 °C, and pH 3.5 achieved cell density of 3.7 g/L with paramylon content of 0.49 g/g dry cell weight. It was also observed that microalgae cells had elongated morphology and higher cell density at low agitation (120 RPM), while the high shear stress (300 RPM) caused the cells to have a rounded morphology and higher paramylon accumulation. E. gracilis will now be cultivated heterotrophically in stirring tank bioreactors at 150, 300, 450, and 600 RPMs on commercial CSL medium at equivalent sugar and nitrogen content. The agitation rate determines impeller tip speed, and energy dissipation rate. Cell morphology, cell biomass concentration, and paramylon content will be compared for various fermentation conditions and media variations.

We expect the study to be useful in utilizing CSL to replace or supplement the costly basal media while maximizing paramylon production by microalgae *E. gracilis.* These findings will establish the fermentation parameters for paramylon production and downstream recovery. This will also provide the corn wet milling industry alternative to drying the CSL for low value animal feed ingredient which saves in energy cost. The CSL fermentation broth after paramylon recovery will have its BOD hugely reduced for further environmentally friendly disposal.

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Abstract 719 | 11:40-12:00

Title: Deep learning-enabled rapid detection and classification of bacteria in food systems

Deep learning-enabled rapid detection and classification of bacteria in food systems
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ABSTRACT

Traditional culture-based techniques for detecting microbes, including pathogen and spoilage microbes, require significant time, while molecular approaches require trained personnel, extensive facilities, and are costly to implement. To bridge this gap, deep learning (DL)-based detection of micro-organisms is an emerging paradigm for rapid, low-cost pathogen screening in food systems and processing environments.

Objective: To develop and evaluate DL frameworks for rapid detection and classification of foodborne bacteria across two case studies: cross-magnification generalization of bacterial microcolony classification, and real-time detection of bio-aerosolized bacteria.

Methods: In case study 1, *B. subtilis*, *E. coli*, *L. innocua*, and *S. enterica* microcolonies and food debris from cheese/chicken were imaged at 20x, 40x, and 60x; the Segment Anything Model (SAM) was fine-tuned for segmentation, and CLIP/FLYP with few-shot adaptation was developed to transfer models trained on low-magnification (20×) microscopy to high-magnification (60×) targets across four bacterial species. In case study 2, aerosolized *E. coli* 609, *S. enterica*, and *P. fluorescens*, together with environmental contaminants, were captured on agar, incubated for 3 h, imaged, and analyzed with YOLOv11 and Faster R-CNN for detecting and classification.

Results: SAM-based localization achieved 0.94 pixel-level sensitivity and 0.87 specificity. Zero-shot 20×-to-60× transfer yielded only 48.2% image-level accuracy, but few-shot adaptation (k=32) raised object-level accuracy to 84.6%, versus a 68.4% baseline. For bioaerosol detection, YOLOv11 outperformed Faster R-CNN (mAP@50: 99.5% vs 90–93%; precision: 99.1% vs 89%; recall: 98.6% vs 90%), with roughly 40-fold faster inference (6.6 ms vs 280 ms per image).

Relevance: These studies demonstrate that DL-based detection can deliver rapid, affordable, and field-deployable pathogen screening, addressing a critical food engineering need for real-time process monitoring, environmental surveillance, and improved food safety outcomes across the food industry.

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Oral Session 29: Advances in food processing

Wednesday, November 11, 2026

Co-chairs: Job Ubbink/Jenshinn Lin. 10:20 am-12:00 pm. King 1

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Abstract 880 | 10:20-10:40

Study on the Collet Extrusion of Brown Rice and Foxtail Millet for Functional Puffed Snacks

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ABSTRACT

Foxtail millet (*Setaria italica* L.) is a nutrient-rich cereal with potential for development of functional extruded snack products. This study investigated the effects of foxtail millet flour (FMF) incorporation (0, 30, 40, and 50%) and die temperatures (DT; 100°C, 110°C, and 120°C) on physicochemical, functional, and antioxidant properties of brown rice-based extrudates produced by Collet extrusion. The results showed that both FMF incorporation and DT significantly ($p < 0.05$) influenced the quality attributes of extrudates. Hardness (1.50 to 4.29 kg_f). Bulk density (0.14 to 0.20 g/cm^3), water absorption index (WAI; 6.05-7.55 g/g), water solubility index (WSI; 7.40-11.88%), ash content (1.41% to 1.92%), total phenolic content (TPC; 91.24-248.17 mg GAE/100g) and DPPH radical scavenging activity (38.31-64.48%) increased significantly with increasing both DT and FMF incorporation. In contrast, the radial expansion ratio decreased from 2.86 to 2.05 with the inclusion of FMF, while lightness (L*) was reduced and redness (a*) and yellowness (b*) generally increased with FMF incorporation. Moisture content (4.04-4.42%) decreased significantly with increasing DT but was not significantly affected by FMF. Collectively, the incorporation of 30–40% FMF processed at 120°C DT provides an optimal balance among physical quality, functional properties, and antioxidant capacity. This study demonstrated the potential of foxtail millet as an ingredient for developing extruded snacks, supporting its use in sustainable, health-oriented snack product formulation.

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Abstract 707 | 10:40-11:00

Materials Science of Whey Permeate Powders

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ABSTRACT

Whey permeate is a major co-product from cheese manufacturing, with the US being the world's largest exporter. For export, whey permeate is commonly converted into a powder by concentration, lactose crystallization and spray drying. Whey permeate powder (WPP) is a non-standardized product of highly variable composition. We recently proposed and validated a two-phase structural model for WWP, with a crystalline core consisting of a-lactose monohydrate crystals embedded in an amorphous, rubbery matrix that is enriched in non-lactose constituents, primarily galactose, glucose, several organic acids, peptides and minerals. This model explains the high instability of WPPs, leading to powder caking and browning. Here, we report on an on-going hybrid correlational-mechanistic study that provides for detailed, quantitative insights in the role of individual permeate constituents in WPP caking and browning. Based on a shelf-life study of 15 WPP samples from four US producers, we establish a correlation heat map linking aggregate parameters for caking and color formation to individual permeate constituents. The roles of constituents identified in this way are quantified by mechanistic studies based on model systems employing spray-dried lactose containing systematically varying amounts of low-M_w compounds. We find that the degree of caking and browning during storage negatively correlates with the glass transition temperature (T_g) of the WPPs. The T_g in turn negatively correlates with the content of galactose and lactic acid, and, for commercial WPPs, to a lesser extent with the glucose content. The protein and peptide content only weakly correlate with both T_g and the degree of browning, while the impact of minerals is more complex, in particular in relation to the physical stability of WPPs. Our results help to establish a systematic basis to optimize WPP processing and formulation, allowing for effective upcycling avenues for this major class of dairy co-products.

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Abstract 669 | 11:00-11:20

Twin-Screw Extrusion Texturization of Kafirin-Rich Sorghum Protein Concentrate for Meat Analogue Applications: Process Optimization and Critical Control Points

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ABSTRACT

Sorghum (*Sorghum bicolor*) is a drought-tolerant cereal whose dominant storage protein, kafirin, is underutilized because its hydrophobic, disulfide-cross-linked structure resists texturization. Converting sorghum protein concentrate (SPC) into meat analogues would valorize an underused grain, yet its extrusion behavior remains undefined. This study quantified the effects of feed moisture, barrel temperature, and screw speed on extrudate texture, established the role of NaCl, and identified the processability limits of SPC-based formulations. SPC (63% protein) from alkaline–ethanol extraction was blended with pea protein isolate (PPI) and NaCl at 60 : 38.5: 1.5. A 2^3 factorial design (moisture 40/50%, barrel temperature 140/150 °C, screw speed 400/500 rpm) was executed on a co-rotating twin-screw extruder, augmented with three center points, two validation replicates, a no-salt control, and a 100% SPC control. Extrudates were characterized by texture profile analysis, uniaxial compression, 24-h swelling, color, and proximate and amino acid analysis.

Feed moisture was the dominant variable, its effect on hardness (−836 g) exceeding all other terms; lowering moisture from 50% to 40% converted a soft, water-losing extrudate into a firm, water-absorbing one. Optimal conditions (40% moisture, 150 °C, 400 rpm) gave hardness of 4,760 ± 293 g in validation replicates (CV = 6.1%) at 0.040 kWh/kg. NaCl acted as a binary control point: adding 1.5% raised hardness 54% and reversed water uptake from −6.2% to +4.8%. Pure SPC could not be extruded, whereas the salt-free blend could identifying PPI as the source of melt strength. The optimized extrudate contained 72.1% protein, water-holding capacity 1.30 g/g, the only measurable emulsifying capacity among sorghum samples (1.6%), and 2.66% lysine, undetected in pure SPC.

These results define processing windows and critical control points for scaling sorghum-based texturized protein and show that protein complementation delivers processability and nutritional balance for food and aquafeed applications.

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Abstract 702 | 11:20-11:40

One-Step Solvent-free Mechanochemical Esterification Strategy for Hydrophobizing Fibers Extracted from Agricultural Byproducts

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ABSTRACT

Justification: Fiber-rich agricultural byproducts are renewable feedstocks for sustainable packaging, but their abundant hydroxyl groups cause high moisture sensitivity and poor compatibility with hydrophobic matrices. Conventional esterification commonly requires the use of solvents, catalysts, and intensive purification. A one-step mechanochemical route could reduce chemical use while improving fiber functionality.

Objectives: To develop and validate a one-step solvent-free dry mechanochemical esterification strategy using stearic acid (SA) and acetic anhydride (AA) to hydrophobized and esterify fibers extracted from agri-food byproduct materials, and to evaluate their feasibility for packaging-relevant applications.

Methods: Cellulose nanofiber, hemp hurd (HH), hemp-hurd lignoholocellulose (HH-LHC), and wine grape pruning fibers were considered as substrates. Processing variables included AA loading of 1–7 g per gram of dry fiber and milling times of 1–6 h under fixed mechanical conditions of 500 rpm and a constant ball-to-fiber ratio. Preliminary screening also compared 1-5 g of SA per 1 g of hemp hurd or LHC. Modified fibers were characterized by FTIR, degree of substitution (DS), mean hydrogen-bond strength, DSC, TGA, water-related properties, and heat-seal performance. Data were analyzed by ANOVA and Fisher's LSD test ($p<0.05$).

Results: FTIR spectra showed enhanced carbonyl C=O, aliphatic C–H, and C–O–C signals after mechanochemical esterification treatment. DS increased from 0.16–0.20 for untreated or milled hemp hurd and 0.09–0.11 for LHC to 0.33 for HH-LHC/1SA/1AA and 0.43 for HH/1SA/1AA, while hydrogen-bond strength decreased to 0.39–0.47. DSC thermograms showed treatment-dependent thermal transitions. The HH/5SA/5AA sample exhibited the strongest melting event near 70–90 °C and crystallization near 40–50 °C, suggesting substantial fatty-acid incorporation but also possible residual free SA. Lower reagent loading produced weaker transitions. In summary, dry mechanochemical esterification is feasible for modifying agri-food fibers, although reagent loading must be optimized to maximize esterification while minimizing unreacted SA and preserving processability.

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Abstract 960 | 11:40-12:00

RGB-to-Hyperspectral Reconstruction for Sweet Potato Inspection: Spectral Accuracy and Generalization Across Cultivars

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ABSTRACT

Hyperspectral imaging (HSI) provides spatial and spectral information for assessing sweet potato quality, but its cost, data volume, and acquisition requirements limit its adoption in processing facilities. Reconstructing hyperspectral images from RGB images offers a potential approach to overcoming these limitations. However, whole-image evaluation can mask reconstruction errors within the product, while overall spectral metrics can hide differences in reconstruction accuracy between the visible and near-infrared (NIR) regions. This study evaluated deep learning architectures for RGB-to-hyperspectral reconstruction of sweet potatoes, focusing on product-specific accuracy, wavelength-dependent performance, and generalization across cultivars. Reconstruction accuracy was assessed within sweet potato regions of interest (ROIs), with visible and NIR performance reported separately. Model generalization was evaluated using unseen cultivars. ROI-based evaluation yielded lower peak signal-to-noise ratio (PSNR) values than whole-image evaluation, revealing errors that were less apparent when background pixels were included. Reconstruction errors were concentrated in the NIR region, and model performance declined on unseen cultivars. These findings show the importance of product-focused evaluation, separate assessment of spectral regions, and cross-cultivar validation when developing reconstruction models for food inspection. Improving NIR reconstruction and robustness to cultivar variation is essential to advance RGB-based spectral imaging for practical sweet potato quality assessment.

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Oral Session 30: Food Structure Modeling

Wednesday, November 11, 2026

Co-chairs: Filiz Koksel/Haotian Zheng. 10:20 am-12:00 pm. King 2

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Abstract 589 | 10:20-10:40

Gas-Assisted High-Moisture Extrusion of Meat Analogues: Insights into Extrudate Structure Using Low-Intensity Ultrasonics

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ABSTRACT

High-moisture extrusion is a key technology for producing plant-based meat analogues, yet process control remains largely empirical due to limited real-time insight into structure development during extrusion. This work demonstrates how non-destructive sensing can enhance process understanding, control, and product consistency. Three complementary studies investigated nitrogen-, air, and carbon dioxide-assisted extrusion of pea- and soy-protein-based high-moisture meat analogues (HMMAs). An air-coupled low-intensity ultrasound system was integrated at the die end of the extruder as a rapid material characterization tool.

Gas injection (0–500 kPa) enabled controlled bubble formation within the protein matrix, with X-ray microtomography confirming gas entrapment above critical pressures (≥350–450 kPa). These microstructural changes produced pronounced acoustic responses, including large reductions in ultrasonic velocity (from ~1600–1700 m/s to ~120–130 m/s) and substantial increases in attenuation (>1.5 mm^{-1}), providing clear signatures of matrix porosity and compressibility. Ultrasonically derived longitudinal modulus effectively differentiated gas-free HMMAs from porous ones, in agreement with cutting force and texture profile analysis. Importantly, ultrasound detected subtle matrix changes brought about by nitrogen, air or carbon dioxide dissolution into the matrix even when conventional texture metrics (e.g., hardness, chewiness, etc.) showed limited sensitivity.

Low-intensity, air-coupled ultrasonics enabled rapid, contactless probing of HMMA structure without altering the material, making it well suited for integration into extrusion processing lines. The technique was sensitive to both gas-induced porosity and matrix compressibility, highlighting its potential as a real-time proxy for internal structure development. These attributes position ultrasonics as a promising tool for inline monitoring, feedback control, and future AI-driven process optimization. Together, these results establish gas-assisted extrusion as a tunable structuring approach and air-coupled ultrasonics as a sensing technology capable of supporting data-driven monitoring and advanced control strategies, advancing smart extrusion toward more robust, efficient, and quality-consistent manufacturing of alternative protein products.

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Abstract 921 | 10:40-11:00

Rational design of protein ingredients for clean label food formulations:

foam, emulsion, and gel aspects

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ABSTRACT

Due to the increased market demand for high protein foods, different protein isolates have been developed for enabling various consumer foods. Protein isolate ingredients are widely used in different processed foods not only for enriching the protein content but also for forming different colloidal structures: foam, emulsion, and gel. However, due to intensive heat treatments such as ultra-high-temperature (UHT) treatment and retort often required for ready–to-drink and ready-to-eat products, the technical functionalities of protein ingredients may be impaired. For instance, UHT treatment may induce uncontrolled protein aggregation resulting in decreased colloidal stability, foaming property, and emulsifying properties. Regarding gelled foods, such as plant protein-based yogurt alternatives, it is a challenge to achieve high protein content and smooth texture at the same time. Non-protein stabilizers and texturizers are often used for tackling the mentioned challenges. Assembling proteins into mesoscopic scale colloidal particles with controlled size and structural features had shown promising results regarding improvements of protein ingredient functionality. This presentation showcases three major examples of modifying food protein ingredients for cleaner label formulation opportunities. In the three examples proteins were assembled into colloidal particles or partially hydrolyzed through different manufacturing methods for 1) improving heat stability; 2) fine tuning texturizing properties of protein beverages and yogurt alternative products; 3) altering interfacial behaviors for improving foam stability and for modulating emulsion digestion fate.

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Abstract 681 | 11:00-11:20

From Food Microstructure to Material Function: Foundation Models and Machine Learning for Quantitative Food Engineering

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ABSTRACT

Food microstructure governs the texture, stability, processing behavior, digestion, and sensory quality of many complex foods, including emulsions, gels, dairy products, and plant-based alternatives. However, quantitative interpretation of microscopy images remains a major bottleneck because conventional image analysis relies heavily on manual annotation, handcrafted features, and application-specific algorithms with limited generalizability. This work presents an integrated artificial intelligence framework that combines foundation models, self-supervised learning, semantic segmentation, and machine learning to establish quantitative relationships between food microstructure and material functionality.

Confocal laser scanning microscopy and scanning electron microscopy datasets covering diverse protein gels and emulsion gels were analyzed using multiple vision foundation models and self-supervised representation learning approaches. Fine-tuned segmentation models substantially reduced annotation requirements while maintaining high segmentation accuracy across different food matrices. Quantitative structural descriptors extracted from segmented images were subsequently integrated with formulation and processing variables to develop machine learning models capable of predicting rheological properties, including storage modulus and fracture behavior. Gaussian process regression and other nonlinear learning algorithms demonstrated strong predictive performance while providing uncertainty estimates valuable for formulation optimization.

The proposed framework enables rapid, reproducible, and scalable characterization of heterogeneous food structures without extensive manual image processing. Beyond improving analytical efficiency, the approach establishes a data-driven pathway linking formulation, processing, microstructure, and macroscopic functionality. Such capabilities support accelerated development of next-generation foods, including plant-based proteins, precision-fermented ingredients, dairy alternatives, and dysphagia-friendly products. More broadly, this work illustrates how recent advances in computer vision foundation models can transform quantitative food engineering by enabling intelligent characterization, predictive material design, and future inverse design of complex food systems.

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Abstract 750 | 11:20-11:40

Understanding the mechanism of cold gel formation in reconstituted micellar casein dispersions

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ABSTRACT

The cold gelation of micellar casein concentrate (MCC) presents a major challenge in the development of high-protein, ready-to-drink dairy beverages, particularly during refrigerated storage. This study examined the effect of protein concentration on the cold-gelling behavior of MCC and investigated the micellar changes responsible for this phenomenon. Reconstituted MCC dispersions containing 5–23% protein were characterized using particle size analysis, ζ-potential, soluble calcium measurements, urea-PAGE, transmission electron microscopy, and rheological methods. Upon cooling from 60 to 5°C, the hydrodynamic diameter of casein micelles increased from approximately 120 to 150 nm, while the ζ-potential became more negative, changing from −22 to −26 mV. TEM observations revealed micellar swelling and closer packing at lower temperatures. Increased serum Ca^{2+} levels and migration of β-casein into the serum phase were associated with the development of a more diffuse, sponge-like micellar structure.

The cold-gelling transition (CGT) temperature increased as protein concentration increased, with model fitting identifying a threshold concentration of approximately 16.4%, above which CGT rose sharply. During storage at 5°C, gel networks continued to develop, as indicated by increasing storage modulus (G′) and reduced frequency dependence, reflecting the formation of a stronger elastic structure. Analysis using the phenomenal soft-sphere model showed that changes in material properties, particularly the maximum volume fraction of casein micelles (ϕ_{max}), enhanced interactions among MCC structures (β), resulting in greater gel strength during prolonged storage. Overall, the findings indicate that MCC cold gelation is mainly governed by concentration-dependent micellar swelling, deformation, and jamming. These results provide valuable guidance for designing stable casein-based, high-protein beverage formulations.

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Abstract 603 | 11:40-12:00

Engineering Natural Blue Color and Digestive Fate in Yogurt Using Pectin-Iron-Anthocyanin Ternary Complexes

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ABSTRACT

Stable natural blue colorants remain difficult to achieve. Anthocyanins are attractive colorants with potential health relevance, but in acidic matrices, they usually appear red or colorless. Direct iron-anthocyanin complexation can generate blue hues but often leads to aggregation and precipitation. Therefore, complexation-based strategies are needed to stabilize color while controlling interactions with the food and digestive environment. Furthermore, it remains unclear how such strategies affect their digestive fate.

This work evaluated whether pectin-bound iron can serve as an anchoring platform for anthocyanins, thereby enabling blue color formation, improving physical stability, and modulating digestive release in an acidic protein gel.

Iron-enriched apple pectin was prepared and complexed with purified blackcurrant anthocyanins or individual cyanidin and delphinidin derivatives. Complexation was characterized and quantified by spectroscopy, colorimetry, LC-MS, and color. Pre-formed pectin-iron-anthocyanin (PIrA) complexes were incorporated into bovine milk before fermentation to produce set-type yogurts and compared with controls containing non-enriched pectin, free iron, anthocyanins, or non-pre-complexed combinations. Fermentation, color, texture, hysteresis, and anthocyanin bioaccessibility (INFOGEST static digestion) were evaluated.

PIrA complexation produced blue-shifted spectra and structure-dependent binding. Delphinidin derivatives bound more strongly than cyanidin derivatives, with lower dissociation constants, and PIrA reduced color loss and prevented iron-anthocyanin sedimentation during storage. In yogurt, pre-complexed PIrA generated a distinct blue hue at pH~4.2, while non-pre-complexed iron-anthocyanin systems showed visible dark precipitation. Fermentation reached a similar final pH across formulations, indicating that PIrA did not inhibit acidification. PIrA yogurts maintained mechanical properties and serum separation comparable to anthocyanin-enriched controls. During digestion, PIrA reduced the filtrable anthocyanin fraction, reaching 9.26% bioaccessibility at the end of the intestinal phase, suggesting stronger matrix retention and possible delivery of a larger fraction to the colon.

This study demonstrates how hydrocolloid-ion-polyphenol interactions can be engineered to integrate natural color stabilization and digestive functionality in fermented foods.

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Poster Presentations: Monday, November 9

Monday, November 9, 2026, 3:00 pm-3:50 pm. Kona Ballroom

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Poster Session 1: Student Poster Competition Semi-Finalists

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Abstract 667 | Poster 1

Enhancing the Quality of Soy Protein Ingredients using Supercritical Carbon Dioxide Technology

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ABSTRACT

Soybeans contain 35-40% protein; however, their food applications are limited by undesirable volatile compounds that reduce flavor and consumer acceptance. This study investigated supercritical carbon dioxide (SC-CO_2) processing as a sustainable approach to (1) improve the aroma and physicochemical properties of soy protein isolate (SPI), (2) develop nanoporous SPI aerogels, and (3) produce a protein-rich alternative cheese. To improve SPI flavor, lipid extraction and volatile removal were performed using hexane (H1: 60 °C; H2: H1 followed by SC-CO_2 treatment) and SC-CO_2 treatments: S1 (40 MPa, 60 °C, 4 h), S2 (S1 followed by additional SC-CO_2 treatment), and S3 (lipid removal at 40 MPa, 60 °C, 4 h followed by aroma removal at 15 MPa, 60 °C, 3 h). SPI samples were characterized for volatile compounds, functional properties, protein structure, and rheological behavior. Treatment S3 achieved the greatest reduction in volatile compounds (6.99 μg/g vs. 0.30 μg/g). All treated SPI samples exhibited shear-thinning behavior, while FTIR analysis indicated increased β-sheet and β-turn structures. Further, SPI hydrogels were prepared at pH 6-10 and converted into aerogels by SC-CO_2 drying. Strong gels formed at pH 7-10, with hardness increasing at higher pH. The aerogels exhibited high specific surface areas (222-278 m^2/g), mesoporous structures (8-11 nm), low densities (~0.21 g/cm^3), high porosities (~83%), and interconnected three-dimensional porous networks. Then, the aerogels were subsequently incorporated into a protein-rich alternative cheese and evaluated for color, chemical changes, meltability, texture, rheological properties, and volatile compounds. Compared with cheeses prepared from commercial, hexane-treated, and SC-CO_2-treated SPI, the aerogel-based cheese exhibited improved flavor and enhanced textural and rheological properties. Overall, SC-CO_2 processing produced SPI ingredients with improved aroma and functionality, enabling the development of nanoporous aerogels and high-protein alternative cheese for food applications.

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Abstract 714 | Poster 2

Jamming-Induced Protein Gelation

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ABSTRACT

Protein gelation is dominated by heat-set gels, a model that denatures the protein, requires high temperature, and, potentially, additional inducing chemicals. We show that protein, using β-lactoglobulin (β-lg), can gel through jamming, with no thermal or chemical trigger. The gel was fabricated by gradually removing solvent via ultrafiltration coupled with vacuum centrifugation. Gel structure was then resolved by cryo-SEM and USAXS/SAXS, revealing a shift from stacked two-dimensional sheets to a connected, rod-like network of β-lg octamers and larger oligomers. DSC and FTIR deconvolution confirmed that the protein stays fully native throughout the sol-gel transition. Flow-sweep measurements across increasing protein concentration clearly distinguished the sol-gel transition, occurring at concentrations as low as 70 mg/mL. Gel rheology behaves as a colloidal fluid until a threshold is reached, beyond which it diverges following different power law. These observations further reveal that jamming-induced gelation arises from weak attractive interactions between protein surfaces rather than random close packing alone.

For food applications, an in vitro digestion experiment was carried out to compare the digestibility of heat-induced versus jamming-induced whey protein gels. Gastric breakdown matched between both gels. A much lower degree of hydrolysis was observed in the intestinal phase of the jamming-induced gel (28.7% vs. 73.5% for the heat-induced gel), owing to its more intact structure and reduced exposure to gastrointestinal enzymes. Despite this, the jamming-induced gel released significantly more soluble protein throughout digestion, 5.75-fold and 4-fold higher in the gastric and intestinal phases, respectively, resulting in greater overall bioaccessibility.

Practically, we demonstrated a non-thermal, additive-free, and native-structure protein gel of exceptional density (28% β-lg; 40-43% whey) that shows high bioaccessibility and potentially prolonged satiation. This work establishes jamming as a novel route for food protein gelation and expands the design space for edible soft matter beyond conventional heat-set gels.

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Abstract 817 | Poster 3

Development and Functional Evaluation of Glycogen-Like Particle-Added Scaffolds for Post-Harvest Metabolic Regulation in Cultivated Meat

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ABSTRACT

Cultivated meat scaffolds have primarily been developed to support cell attachment, survival, and tissue formation during culture. However, metabolic processes such as ATP regeneration and lactate production continue in muscle cells after harvest and are accompanied by pH decline, and these changes may affect final meat quality. In this study, glycogen-like particles (GLPs), highly branched α-glucans structurally similar to glycogen, were incorporated into gelatin–alginate–microfiber-based scaffolds to evaluate their cell compatibility during culture and their potential to modulate post-harvest metabolism.

When bovine muscle cells were treated with GLPs under PBS conditions, lactate dehydrogenase (LDH) activity and lactate production increased compared with the PBS control, suggesting that GLPs may influence glycolytic lactate production. Scaffolds containing 0, 1, 3, and 5% GLP were then fabricated. Increasing GLP content decreased swelling ratio, porosity, and weight loss while increasing compressive strength. FT-IR analysis also revealed peak shifts and signal changes in the O–H region, indicating alterations in intermolecular interactions and scaffold network organization. Notably, 1% and 3% GLP scaffolds showed enhanced initial cell attachment, viability, and total ATP levels, suggesting that moderate GLP incorporation contributed to a cell-supportive microenvironment.

Finally, cell–scaffold constructs were exposed to post-harvest conditions in PBS at 25°C for 24 h. As GLP content increased, LDH activity and lactate production increased, whereas pH decreased; increases in ATP levels and changes in total AMPK levels were also observed. These findings suggest that GLP-added scaffolds may promote glycolytic ATP regeneration and lactate accumulation under nutrient-limited post-harvest conditions, thereby modulating post-harvest metabolism and potentially influencing quality-related changes in cultivated meat.

Overall, GLP-added scaffolds may function as multifunctional cultivated meat platforms that support cell growth during culture while modulating post-harvest energy metabolism. Together, these findings demonstrate a scaffold strategy integrating cellular support during culture with quality-relevant metabolic regulation after harvest.

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Abstract 908 | Poster 4

Characterization of Mealworm (*Tenebrio molitor)* Proteins obtained by Alkaline and Enzyme-assisted Extraction Methods

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ABSTRACT

Introduction: Insect rearing is gaining recognition as an alternative protein source. Limited research has examined the impact of extraction methods on the functional properties of mealworm (*Tenebrio molitor*). These properties influence the quality and sensory characteristics of food formulations.

Objective: To characterize the properties of mealworm protein obtained by alkaline and enzyme-assisted extraction.

Methods: Dried mealworms were ground and defatted with 95% ethanol. Alkaline extraction was performed using 0.25 M NaOH followed by isoelectric precipitation with 1 N HCl. Enzymatic hydrolysis was carried out using Alcalase 2.4L. Extracted protein was freeze-dried and powdered. Samples were analyzed for foaming capacity, foam stability, water holding capacity (WHC), oil holding capacity (OHC), color (L*a*b*), and moisture content. Protein content was analyzed using Pierce BCA Protein Assay Kit to calculate protein yield. Protein structure was characterized using Fourier-transform infrared (FTIR) spectroscopy. Experiments were conducted in triplicate. Statistical analyses were performed using ANOVA followed by Tukey's HSD post-hoc test ($p < 0.05$).

Results: Alkaline extraction showed a significantly higher protein yield (30.98 ± 1.27 %) than enzyme-assisted extraction (25.71 ± 1.48 %). Both approaches showed no significant difference in foaming capacity and foam stability of the extracts ($p>0.05$). Alkaline extraction significantly increased the WHC of the extract compared to enzyme-assisted extraction but showed no significant effect on the OHC. Alkaline extracts (10.67 ± 1.83 %) showed significantly lower moisture content than enzyme-assisted extracts (20.95 ± 2.20 %). The extracts differed in color by $\Delta E = 9.31 \pm 2.77$. The Amide I peak position did not differ significantly between the extracts, but differences in normalized Amide I band shape were observed.

Significance: These findings demonstrate that extraction pathways alter mealworm protein functional properties and protein yield, offering guidelines for tailoring insect proteins to food formulations.

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Abstract 917 | Poster 5

Effects of Palm Oil Powder and Feed Moisture Content on the Textural and Physical Properties of High-Moisture Meat Analogue Containing *Undaria pinnatifida*

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ABSTRACT

Mimicking the texture and juiciness of meat remains challenging in high-moisture meat analogues (HMMAs). This study evaluated the effects of palm oil powder (POP; 0, 2, 4, and 6%) and feed moisture content (FMC; 45, 50, and 55%) on the textural properties, degree of texturization, water-holding capacity (WHC), water solubility index (WSI), color, and sensory evaluation of HMMAs produced by twin-screw extrusion. The formulations contained wheat gluten, pea protein, and *Undaria pinnatifida*. Increasing the POP concentration decreased hardness (8.67 – 1.13 Kgf), springiness (2.81 – 1.78 mm), cohesion force (0.92 – 0.86), gumminess (57.60 – 5.60 N), and chewiness (161.03 – 10.07 N*mm), presumably due to the disruption of the protein network. Higher FMC reduced hardness, springiness, gumminess, and chewiness while increasing cohesion force. WHC increased at 2% POP but decreased at 6% (4.34 – 3.93 g/g), while FMC had no significant effect. POP at 2 and 4% maintained WSI, whereas 6% POP increased WSI (7.25 – 10.99 %), indicating greater molecular disruption and reduced structural integrity. The degree of texturization exceeded 1 in treatments 0% POP FMC 45% (1.15) and FMC 55% (1.02), 2% POP FMC 50% (1.06) and FMC 55% (1.05), 4% POP FMC 50% (1.02), and 6% POP FMC 55% (1.01), indicating greater anisotropy and a more pronounced fibrous structure. POP addition decreased a* (-2.81 – -4.14) and increased b* (17.82 – 21.81) while maintaining L* (55.86 – 67.42). Sensory evaluation at 50% FMC showed the highest acceptance at 4% POP, indicating a favorable balance of texture and moisture perception. These findings demonstrate that moderate POP incorporation, particularly 4% at 50% FMC, can improve the quality and sensory acceptance of HMMAs, thereby providing a practical formulation strategy for developing juicier, more meat-like plant-based products. **Keywords:** *Undaria pinnatifida*, high-moisture meat analogue, palm oil powder, twin-screw extrusion, textural properties, physical properties

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Abstract 945 | Poster 6

Role of lipid phase structuring in tailoring the microstructural and rheological properties of yeast protein-based emulsion gels toward cream cheese analogs

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ABSTRACT

The development of high-protein cheese analogs with desirable texture remains a major challenge due to the complex structure–function relationships governing protein–lipid interactions. In this study, yeast protein (YP) was investigated as a novel functional ingredient for formulating high-protein emulsion-based cheese analogs containing different lipid phases, including canola oil, coconut oil, beeswax (BW) oleogel, and rice bran wax (RBW) oleogel. Lipid phase structure significantly influenced droplet organization, microstructure, water-holding capacity, and rheological behavior. Among the formulations, the YP–coconut system exhibited the finest dispersed structure (D[3,2] ≈ 2.7 μm), the highest water-holding capacity (~98%), and the greatest storage modulus ($G' \sim 3.5 \times 10^5$ Pa), exhibiting rheological behavior most comparable to commercial cream cheese. In contrast, the canola oil system formed larger dispersed domains and exhibited the lowest water-holding capacity (~80%) and weakest gel network, whereas the oleogel-containing systems exhibited intermediate stiffness but lower deformation tolerance under large strain. Large-amplitude oscillatory shear (LAOS) further revealed distinct nonlinear deformation mechanisms, distinguishing the ductile response of the YP hydrogel from the more brittle behavior of the BW system and the intermediate responses of the coconut oil and RBW formulations. Overall, this study demonstrates that tailoring lipid phase structure provides an effective strategy for regulating the microstructure and nonlinear mechanical behavior of high-protein yeast protein-based emulsion gels. These findings establish fundamental structure–function relationships and highlight the potential of yeast protein as a sustainable ingredient for developing next-generation plant-based cream cheese analogs.

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Abstract 633 | Poster 53

Geometry-Aware Digital Twin Framework for Multiphysics Transport in Drying of Porous Food Materials with Data Assimilation

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ABSTRACT

Industrial drying is among the most energy-intensive operations in food manufacturing, yet dryers are still controlled from boundary settings alone while the internal state of the product—its spatially distributed temperature, moisture, and phase composition—remains unobserved in real time. This observability gap forces conservative operating margins and limits control over product quality and drying uniformity. High-fidelity CFD resolves the coupled heat, moisture, and phase-change transport but is far too slow for real-time use, and conventional surrogates must be re-trained or re-meshed for every new product shape on a drying line. Our objective is a fast, geometry-agnostic surrogate that predicts the full internal drying state across arbitrary food geometries and stays accurate over long drying times.

We present a Tri-State Additive Physics (TSAP) graph neural network coupled with sequential data assimilation for three-dimensional convective drying of hygroscopic porous foods. The network mirrors the governing physics: a shared message-passing backbone captures common transport, while additive residual networks encode the terms unique to the air domain (Navier–Stokes), the porous interior (Brinkman–Darcy drag), and the evaporative interface. A CFD model validated against laboratory potato-slice drying ($R^2 = 0.951$; RMSE = 0.055 kg/kg) generated 240 cases, 192 used for training.

The TSAP surrogate sustains a low rollout error (≤ 0.011) over 333 min of drying and generalizes to unseen ellipsoidal, square, and pyramidal shapes—where a POD-based baseline fails—reducing per-field error 2.7–13×. It further reveals that acceptable bulk moisture can mask persistent high-moisture pockets, so spatial resolution matters for quality. Assimilating virtual surface-imaging observations cuts prediction drift 24–53% at under 1% added cost. For the food industry, this establishes a scalable route to real-time, spatially resolved monitoring for more energy-efficient, uniform, and higher-quality drying.

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Abstract 868 | Poster 54

Simultaneous Real-Time Measurement of Particle Size and Moisture Content Using SWIR Imaging

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ABSTRACT

Spray drying is widely used in the food, agricultural, and pharmaceutical industries to convert liquid feeds into dry powder products. Particle size and moisture content are critical quality attributes that influence product stability, flowability, rehydration properties, and energy consumption during drying. However, these properties are commonly measured using separate offline methods, with moisture content often determined through destructive laboratory testing that provides delayed process feedback. Real-time inline measurement of both particle size and moisture content would enable improved process monitoring, feedback control, and optimization while reducing the risk of over-drying and unnecessary energy use.

To address this need, a multimodal imaging system was developed for simultaneous measurement of particle size, shape, and moisture content. Individual droplets were suspended using a 40 kHz acoustic levitator to provide a controlled, non-contact drying environment for calibration model development. A halogen light source and a 1450 nm band-pass filter were used to illuminate droplets at a wavelength corresponding to a strong water absorption band. Shadow images were acquired using a short-wave infrared (SWIR) camera and segmented from the background using Otsu thresholding. Spectral-spatial features, including pixel intensity and local binary pattern descriptors, were extracted from the droplet region. Simultaneously, an RGB camera captured visible-light images to monitor droplet position, size, and morphological changes throughout drying. Moisture content was determined gravimetrically from droplet mass measurements before and after drying and used to develop a Least Absolute Shrinkage and Selection Operator (LASSO) regression model.

The proposed system achieved strong moisture prediction performance, with $R^2 > 0.92$ and RMSE < 4%, while simultaneously tracking particle size and morphology in real time. The results demonstrate the potential of SWIR imaging for non-destructive, continuous monitoring of multiple critical quality attributes, providing a foundation for advanced process control and energy-efficient spray-drying operations.

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Abstract 898 | Poster 55

Toward Predictive Design of Plant-Based Meat Analogs: A Physics-Informed Model Linking Extrusion Settings to Texture

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ABSTRACT

The development of plant-based meat analogs is limited by the lack of quantitative descriptors linking material behavior, fibrous structure and texture across diverse formulations and process conditions. Current methods for characterizing structure and texture are often destructive, labor intensive, and not suited for predictive product design. This study combines rheological characterization, spectral imaging, and artificial intelligence as the foundation for a digital twin of the high-moisture extrusion (HME). Such a twin requires rapid, in-line sensing of extruded products, delivered noninvasively by spectral imaging, together with material parameters from rheological measurements relating to textural attributes such as elasticity, firmness, and fibrousness.

A space-filling experimental design of 105 HME trials was generated spanning across eleven variables: four formulation and seven processing. Extrudates were characterized by creep–recovery, small-amplitude oscillatory shear, texture measurements, and spectral imaging. Each creep–recovery curve contributed hundreds of time-dependent compliance values, interpreted using a unified fractional model

$$J(t)=\frac{\varepsilon(t)}{\sigma}=\frac{1}{\Gamma(\alpha+1)}\left(\lambda_1 t^{\alpha} H(t)-\lambda_2(t-t_m)^{\alpha} H(t-t_m)\right),$$

where λ_1 represents stiffness, α the degree of viscoelasticity, and (λ_1–λ_2) recoverability. Each image cube contributed thousands of spectra, reduced to moisture maps and a Digital Anisotropy Index (DAI). The fractional model described creep and recovery with $R^2 \approx 0.97$, and band-importance analysis localized the fiber signal to a visible band and moisture at 980 nm.

A physics-informed neural network (PINN), augmented by a Wasserstein GAN, predicts fractional parameters (α, λ_1, λ_2) and imaging descriptors from formulation and processing variables, with the constitutive relationship imposed as a physical constraint. These fingerprints let the PINN rapidly predict viscoelasticity, stiffness, and fibrousness across a broad range of conditions. Models reached $R^2 > 0.70$; PINN accuracy is reported per parameter as RMSE and MAE. Coupled with constrained inverse optimization, the PINN runs backward through a graphical interface, converting the target into feasible formulations and extrusion setpoints.

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Abstract 902 | Poster 56

Physics-Based and Artificial Intelligence Modeling of Texture Development in High Moisture Extruded Plant-Based Meat Analogs

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ABSTRACT

High moisture extrusion (HME) is widely used to produce plant-based meat analogs (PBMAs) with fibrous structures, yet process optimization remains challenging because texture development results from complex interactions among formulation, processing conditions, rheology, phase behavior, and transport phenomena. Conventional trial-and-error approaches are costly and time intensive, while many mechanistic models rely on simplified non-viscoelastic rheological descriptions that inadequately represent protein melt behavior. This study combines physics-based modeling and artificial intelligence (AI) to improve understanding and prediction of PBMA texture within a physics-informed framework linking mechanistic understanding with data-driven prediction.

A physics-based finite element model (FEM) of the HME cooling die was implemented in COMSOL Multiphysics using conservation equations for mass, momentum, and energy coupled with the Cahn-Hilliard equation for spinodal phase separation. Protein melt rheology was described using the nonlinear viscoelastic Giesekus model. In parallel, an AI model of the overall extrusion process was developed using a fast flexible space-filling experimental design comprising 105 runs evaluating six processing and five formulation variables. Partial least squares regression with K-fold cross-validation was used to identify key parameters governing texture development.

The viscoelastic FEM model predicted more realistic velocity fields and texturization patterns than simplified rheological models like power law and Bingam model used in previous studies. Simulation trends were qualitatively validated using dye injection experiments in pilot-scale twin screw extruder and scanning electron microscopy. AI analysis indicated that processing variables accounted for 69% of texture variation, compared with 22% for formulation variables. Barrel temperature in the final two sections was the dominant factor, followed by cooling die temperature, with significant interactions involving protein composition and moisture content. These findings highlight the complementary roles of mechanistic modeling and AI, with AI enabling identification of complex interactions across high-dimensional processing and formulation spaces that are difficult to capture comprehensively through mechanistic modeling alone.

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Abstract 780 | Poster 85

A Time-Shift Method for Improved Microbial Survival Modeling During Thermal Processing with Come-Up Time

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ABSTRACT

Objectives:

Microbial survival models are essential for designing and validating thermal processes that ensure food safety while minimizing quality loss and processing costs. In practice, microbial inactivation begins during the come-up time (CUT) before the target temperature is reached, creating a non-isothermal period that contributes to cumulative lethality. Conventional approaches that ignore this transition can bias kinetic parameter estimates, reduce predictive accuracy, and compromise process design and validation. This study aims to develop a Time-Shift Method (TSM) that explicitly accounts for the CUT effect while preserving the mathematical structure and simplicity of conventional survival models.

Methods:

The proposed TSM transforms non-isothermal survival data into an equivalent isothermal representation by estimating a single time-shift parameter for each thermal history. This preprocessing step allows standard kinetic models, such as the first order (log-linear), Weibull, Geeraerd, and log-logistic models, to be applied without modification. The method was systematically evaluated using simulated survival datasets under single- and multiple-temperature histories with varying noise levels and further validated with published microbial inactivation data.

Results:

The TSM consistently recovered the intrinsic kinetic parameters while clearly separating process-dependent CUT effects from microbial survival behavior. The resulting parameters accurately predicted survival under independent dynamic temperature profiles, with root-mean-square errors generally below 0.2 log units on simulated data. When applied to published experimental datasets, the TSM produced physically more interpretable estimates—characterized by systematically larger inactivation-rate parameters and smaller Weibull shape parameters—than conventional methods, while maintaining comparable fitting accuracy. The proposed TSM offers a simple, robust, and model-independent framework for analyzing microbial survival under dynamic thermal conditions, with strong potential to improve predictive microbiology and support thermal process validation, optimization, and food-safety management.

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Abstract 854 | Poster 86

UV-C Treatment for Reducing *Botrytis* Spoilage in Blueberries: From Chamber to Conveyor

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ABSTRACT

Fresh-market blueberries undergo minimal postharvest washing or sanitation, allowing spoilage fungi such as *Botrytis cinerea* to proliferate during storage. Ultraviolet-C (UV-C) offers a nonchemical intervention, but treatment of intact fruit is challenging due to complex surface geometry limiting uniform UV exposure.

This study evaluated the ability of UV-C to delay *B. cinerea* spoilage of blueberries and examined translation from controlled chamber treatment to a roller-conveyor system designed to improve UV-C exposure of the fruit surface.

In the chamber experiment, blueberries were inoculated with *B. cinerea* at the stem scar and treated at doses of 0, 136, 272, 408, or 544 mJ/cm², then stored at 4°C for 60 days. In the roller-conveyor experiment, whole-surface-inoculated blueberries were rotated at 100 rpm while exposed to UV-C from the top and sides, receiving approximately 408 mJ/cm² before storage at 4°C or 25°C. Time to visible mold development was analyzed using accelerated failure time (AFT) survival models.

Results showed that responses to chamber treatment varied among replicates, and no consistent dose-dependent relationship was observed. However, 272 and 408 mJ/cm² significantly delayed mold development at 4°C, increasing estimated time to spoilage by 54.4% and 66.3%, respectively, relative to untreated controls ($P < 0.05$). These estimates should be interpreted cautiously due to substantial right censoring during refrigerated storage. In the conveyor experiments, UV-C treatment significantly delayed spoilage, increasing estimated postharvest life by 58.1% at 25°C and 71.0% at 4°C ($P < 0.0001$). These results demonstrate the potential of UV-C to delay *B. cinerea* spoilage in blueberries and highlight the importance of treatment configuration for achieving effective exposure on irregular whole-fruit surfaces. The multi-angle roller-conveyor configuration represents a promising step toward practical UV-C applications for extending postharvest shelf life of fresh produce.

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Abstract 647 | Poster 87

Development of a Novel ThermoElectric-based Single-Stream Heat Exchanger to Improve Energy Efficiency in Liquid Food Pasteurization

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ABSTRACT

The substantial energy and water requirements of conventional High-Temperature-Short-Time (HTST) systems, along with significant thermal losses and complex system design, create an opportunity for more sustainable pasteurization technologies. We propose a ThermoElectric (TE)-based Single Stream (TESS) heat exchanger as an electrified, energy-efficient alternative to the HTST system. The TESS exchanger actively recovers thermal energy from the pasteurized liquid to preheat the raw liquid using TE devices without an additional heating medium. The objectives of this study are to demonstrate the TESS concept through physical prototyping and comprehensively evaluate its energy efficiency against HTST systems through multiphysics modeling. A laboratory-scale TESS prototype with 72 TE modules was fabricated to investigate thermal performance under conditions relevant to liquid food pasteurization. Experimental data collected include fluid temperatures at three locations (Inlet, after heating, and outlet) and electrical power input (current and voltage) across a range of operating parameters, including electrical current (0.5, 1.0, and 1.5 A) and flow rates (266.5 and 419.6 mL/min). The lab-scale TESS prototype showed about 30% improvement in energy efficiency compared to the HTST system of similar size under equivalent processing conditions and a lower pre-cooling exit temperature, further decreasing secondary cooling demands. A multiphysics-based model of the TESS prototype by integrating analytical and numerical approaches, was developed to simulate the active thermal recovery process. The simulation integrated the physics of heat generation and transfer through TE devices, fluid flow, and heat transfer in liquid. The simulation results showed that a small temperature difference on the two sides of TE devices and a small direct current applied to the TE devices were important to maintain high energy efficiency of the TESS heat exchanger.

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Abstract 839 | Poster 88

Pulsed electric field processing differentially impacted gastric softening and mass transfer in apple and carrot

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ABSTRACT

Pulsed electric field (PEF) processing modifies the cellular structure of plant tissues and may consequently influence texture breakdown and mass transfer during gastric digestion. This study investigated the effect of PEF treatment on softening kinetics and mass transfer into apple and carrot tissues during static in vitro gastric digestion. Apple and carrot cubes were treated with PEF at 1.25 kV/cm using different numbers of pulses (up to 64 pulses). PEF-treated samples were then subjected to 180 min static in vitro gastric digestion in triplicate for each treatment. Hardness, moisture content, and acid uptake were measured at 30 min intervals. Softening kinetics were evaluated using the empirical Weibull model, while a two-stage Fickian model was developed to characterize acid and moisture transfer.

PEF significantly reduced Young's modulus in both apple and carrot ($p < 0.0001$), decreasing from 1.97 ± 0.27 to 0.57 ± 0.05 MPa and from 3.73 ± 0.22 to 0.69 ± 0.04 MPa, respectively, after 64 pulses. During gastric digestion, half softening time increased from 55.3 ± 6.2 min for raw apple to an average of 136.8 ± 33.6 min in PEF-treated apple, whereas PEF did not significantly affect carrot softening kinetics after either 8 or 64 pulses. PEF-treated apple showed higher moisture content after 120 min ($p < 0.0001$) and higher acidity after 180 min ($p = 0.0295$) gastric digestion than raw apple. Overall, PEF-induced structural modifications affected gastric digestion in a matrix-dependent manner. In carrot, PEF altered mass transfer without significantly affecting softening kinetics. In apple, PEF resulted in faster mass transfer but slower softening, demonstrating that enhanced moisture and acid uptake did not necessarily translate into faster structural breakdown. These findings may improve understanding of how PEF-induced structural modifications influence gastric digestion and support the application of PEF for structural modification in novel food design.

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Abstract 874 | Poster 89

Cost and environmental trade-offs of soybean processing for fuel, protein and feed production

ABSTRACT

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Soybean processing connects agricultural production with food, feed, and fuel markets, yet the economic and environmental implications of routing soybean products across these competing end uses remain poorly understood. Traditionally, soybean meal has been primarily directed to animal feed, while soybean oil has largely served food applications. Growing markets for plant-based proteins and biofuels, however, are creating new opportunities to redirect these processing streams. This study evaluates five soybean processing scenarios that allocate oil and meal toward different combinations of food protein, animal feed, and fuel applications, and examines the conditions under which alternative configurations may provide economic and environmental advantages. A conventional crushing system producing food-grade oil and feed meal serves as the baseline, with alternative scenarios incorporating plant protein and biodiesel production. Mass and energy balances support the techno-economic analysis and life-cycle assessment, complemented by sensitivity analysis to identify key performance drivers. The results indicate that system economics depend on the combined utilization of both oil and meal streams rather than either independently. While meal demand supports soybean crushing economics, downstream oil use, particularly when considering food and biofuel markets, significantly influences overall profitability. Shifts in protein markets may expand the role of soybean meal beyond animal feed toward food-protein applications. Together, these findings illustrate how processing and market decisions shape the economic and environmental performance of the soybean supply chain and offer insights to guide future resource allocations as food, feed, and fuel demands continue to evolve.

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Poster Session 2: Food Materials, Alternative Proteins & Nutrition

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Abstract 578 | Poster 7

Innovative Bioprocess Approaches for Functionalization of Plant-Based Ingredients for Food Applications

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ABSTRACT

Bioprocessing has long been used to enhance the sensory, nutritional, and functional quality of raw materials. Recently, interest in its application to improve the functional properties of plant-based ingredients significantly increased. With the high consumer demand for sustainable protein, legumes specifically pea, chickpea, and lentil have become leading candidates for plant-based protein development. However, their utilization remains limited by several challenges including undesirable "beany" volatile compounds, poor functional properties (solubility, gelation, emulsification, and texturization), and reduced nutritional value due to the high antinutrients. This study investigated innovative bioprocessing strategies using solid-state bioprocessing (SSB) utilizing *Lactiplantibacillus plantarum* to improve the functional, nutritional, and flavor attributes of pea protein flour (PPF). Bioprocessing conditions were optimized across varying water contents (10–50%), incubation temperatures (30–37 °C), and fermentation times (6–24 h). Results demonstrated that 40% moisture achieved an optimal water activity (0.953) to support microbial growth, while SSB at 37 °C for 24 h induced a pH reduction from 6.5 to 5.7, indicating active fermentation. Bioprocessing significantly improved functional properties of PPF such as oil holding capacity, gel strength, and texturization behavior, highlighting its potential for structured food applications. Nutritional quality was enhanced through a 40–60% reduction in antinutrients such as phytic acid and tannins. Volatile compound profiling further revealed substantial modifications in aroma-active compounds, including the degradation of aldehydes associated with grassy and beany off-flavors. The findings demonstrate that tailored bioprocessing can serve as a single-step and scalable strategy to functionalize plant protein ingredients while improving flavor and nutritional value. These innovations support the development of next-generation plant-based foods with improved performance in diverse food engineering applications.

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Abstract 596 | Poster 8

Gut-Bone Axis Modulation by Lactiplantibacillus plantarum GXS77: From Enhanced Intestinal Calcium Absorption to Skeletal Health

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ABSTRACT

Inadequate intestinal calcium absorption is a primary driver of bone metabolic disorders such as osteoporosis, which impose a substantial global health burden. While dietary probiotics represent a promising intervention strategy, the molecular mechanisms linking specific probiotic strains to systemic bone health via the gut-bone axis remain incompletely understood. This study aims to characterize a novel probiotic strain, *Lactiplantibacillus plantarum* GXS77, and to elucidate its multi-target mechanisms in enhancing calcium bioavailability and promoting bone homeostasis.

GXS77, isolated from traditional fermented pickle juice, demonstrated robust gastrointestinal survivability (83.18% at pH 3.0) and strong adhesion to Caco-2 monolayers (28.60 ± 2.05 CFU/100 cells). Metabolic profiling revealed high-yield production of short-chain fatty acids (SCFAs), including acetate (10.95 g/L) and butyrate (0.14 g/L). Real-time fluorescent calcium tracking (Fluo-4 AM) confirmed that GXS77-derived SCFAs directly triggered intracellular calcium influx, elevating the peak response by 11.0% compared with pH-matched controls. Whole-transcriptome sequencing (RNA-seq) and Western blotting revealed a dual-pathway mechanism: concurrent upregulation of the transcellular cascade (TRPV6: 2.2-fold; Calbindin-D9k: 5.1-fold) and the paracellular pore-forming protein Claudin-2 (5.3-fold). Furthermore, downstream skeletal effects were investigated: Western blotting confirmed that GXS77 treatment significantly promotes osteoblast differentiation marker expression, supporting bone formation. Ongoing investigations include the assessment of its inhibitory effects on osteoclast differentiation and validation of calcium absorption and bone density improvements in animal models.

These findings demonstrate that GXS77 enhances mineral bioavailability through coordinated intestinal epithelial reprogramming and bone cell regulation. This work provides a molecular foundation for developing fermentation-derived probiotic interventions targeting osteoporosis prevention, with direct relevance to functional food design and precision nutrition strategies in food engineering.

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Abstract 607 | Poster 9

Beyond Protein Quantity: Sex- and Age-Specific Digestion Models for Future Food Engineering

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ABSTRACT

The growing alternative-protein sector is increasingly challenged by health-related concerns around food's digestive fate – from digestibility and protein quality to ultra-processing. In vitro digestion models offer a scientific platform to elucidate the digestive trajectories of novel and traditional foods. This talk will offer attendees a glimpse into recent advances in sex- and age-specific digestion models that recreate the gut physiology of healthy men, women, and older adults, and how these are applied to explore protein digestion from a quality, rather than quantity, standpoint.

First, these models will be used to examine the digestive fate of amyloid-like protein architectures (Refael et al., 2024). ThT analysis and TEM demonstrate process-induced formation of amyloid-like assemblies from α-lactalbumin, β-lactoglobulin, and ovalbumin, all showing reduced susceptibility to gastrointestinal proteolysis (Refael et al., 2024). Human fecal fermentations, followed by 16S rRNA gene sequencing and bioinformatic analysis, further indicate that fibrilization preserves microbial diversity, supports a low Firmicutes/Bacteroidetes ratio, and protects butyrate-producing genera such as *Roseburia* and *Clostridium*, similarly to prebiotics. Second, the models will distinguish the digestive fates of cow milk and oat-based milk alternatives in men and women based-on LC-MS proteomics (Mashiah et al., 2025). Female digestive effluents showed higher oat-protein breakdown efficiency, whereas male effluents lean toward improved bovine-milk protein breakdown, with clear differences in release of amino acids and bioaccessible peptides. Finally, unpublished data will be used to discuss protein quality metrics, including DIAAR, through ANOVA and PCA comparisons of OPA, pH-stat, pH-drop, and amino acid analyses. The talk will show that such metrics vary with male, female, and elderly digestive physiology, highlighting the need to integrate protein quality assessment with consumer-specific physiology in food engineering and design of future foods.

Refael et al (2024). Food Hydrocolloids, 151, 109820.

Mashiah et al, (2025). Food Research International, 214, 116610.

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Abstract 843 | Poster 10

Influence of Drum-Dryer Temperature on Functional and Pasting Properties of Breadfruit Flour Compared to Dehydrator Drying

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ABSTRACT

Breadfruit (*Artocarpus altilis*) is a climate-resilient crop with increasing potential for value-added processing in the Pacific Basin. However, flour quality varies widely across processors, largely due to differences in drying methods and thermal profiles. Local processors currently rely on dehydrator drying, a low-temperature convective method that preserves starch integrity but can be slow and yield inconsistent functional performance. Drum drying, by contrast, offers rapid, high-intensity thermal processing, yet its effects on breadfruit starch functionality across different operating temperatures remain poorly characterized. This study compares a conventional dehydrator process to three drum-dryer temperature settings to quantify how thermal intensity influences the functional and pasting behavior of breadfruit flour. Breadfruit puree was drum-dried at 140, 160, and 180 °C, with slices dried at 60 °C using a dehydrator as a control. Resulting flours were milled and evaluated for functional properties including water absorption capacity, swelling capacity, and solubility, and were further characterized using shear-based starch pasting analysis. Clear differences emerged between convective dehydrator drying and drum drying across temperature levels. Dehydrator-dried flour maintained higher granular integrity, resulting in greater swelling capacity and higher peak viscosity. As drum-dryer temperature increased, flours exhibited progressively greater starch modification, reduced peak viscosity, increased solubility, and altered pasting curve profiles indicative of extensive gelatinization. These trends demonstrate a direct link between thermal intensity and starch transformation mechanisms relevant to product performance. The results provide insight into how controlled drum-dryer operating temperatures can be used strategically to tailor breadfruit flour functionality, support process optimization, and improve consistency across regional processing operations.

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Abstract 614 | Poster 11

Exploring low moisture extrudates as a substrate for solid state fermentation to develop a novel chickpea tempeh with enhanced functionalities

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ABSTRACT

Tempeh, a product of fungal fermentation of peas, is a great alternative source of protein with supplementary bioactive and functional benefits. Traditionally, the peas need to be soaked for 16-20 hours and boiled before fermentation. This causes leaching out of water-soluble nutrients. To minimize these losses, peas can be preprocessed through low-moisture extrusion, which conserves nutritional profile and degrades antinutritional factors(ANF). It modifies macronutrient structure, rendering them and attached phytochemicals more bioavailable. The extrudates' porous matrix provides easier nutrient access to the fungi, facilitating the tempeh fermentation.

This study explores low moisture extrudates as advantageous substrates for tempeh fermentation. Chickpeas were used as their balanced starch and protein composition made them an ideal candidate for both extrusion and fermentation. Chickpea flour was subjected to low moisture extrusion under varied temperature, moisture, feed-rate, and screw speed profiles to yield extrudates with desired expansion and porosity. These were rehydrated before fermenting with *Rhizopus oligosporus* for 36 hours at 32℃.

Extrudates prepared at 1 kg/h feed rate with 20% feed moisture at 450RPM and temperatures 80 - 180 ˚C in a twin screw extruder with a 1mm hole die had the highest expansion (ER: 2.77) and protein (23.43%). Tempeh made from extrudates (ET) were physically similar to traditional tempeh (TT) in terms of mycelial coverage, color and intactness. Nutritionally ET had 14.8% higher protein, 15.6% higher mineral, 30.1% lower fat and 38.4% lower ANF content than TT. ET also comprised a 63% richer polyphenols content which could justify its 103.5% more efficacious antioxidant capacity.

In conclusion, our study establishes a synergy between low-moisture extrusion and solid-state fermentation in manufacturing a nutritionally and functionally profound tempeh. Further studies are required to assess its impact on shelf-life and sensorial attributes.

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Abstract 623 | Poster 13

Processing performance and quality characteristics of low-calorie madeleines prepared with tartaric acid-treated resistant starch

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ABSTRACT

Tartaric acid is a naturally occurring organic acid that accounts for most of the acidity in grapes. Tartaric acid-treated starch contains a high level of resistant starch (RS), which resists enzymatic digestion and provides lower metabolizable energy than conventional starch. This study investigated the feasibility of incorporating tartaric acid-treated resistant starch into a conventional baking process and evaluated its effects on processing performance, product structure, quality characteristics, and starch digestibility in low-calorie madeleines.

Madeleines were prepared by replacing wheat flour with tartaric acid-treated resistant starch (99% RS) at substitution levels of 5%, 10%, 15%, and 20% (TA-5%, TA-10%, TA-15%, and TA-20%). The effects of starch substitution on baking performance were evaluated by measuring specific volume, color, texture profile, and in vitro starch digestibility. The addition of tartaric acid-treated resistant starch produced madeleines with an appearance comparable to that of the wheat flour control, indicating acceptable processability during baking. As the substitution level increased, the L^* and b^* values gradually decreased. The specific volume was 1.30 mL/g for the control and 1.37, 1.23, 1.04, and 1.09 mL/g for TA-5%, TA-10%, TA-15%, and TA-20%, respectively, showing an overall reduction in expansion with increasing resistant starch substitution. Texture profile analysis showed that the TA-10% formulation exhibited textural properties most similar to those of the control, suggesting an optimal balance between processability and product quality. *In vitro* digestibility analysis demonstrated that resistant starch content increased with increasing substitution levels, indicating reduced starch digestibility and lower caloric availability.

These findings demonstrate that tartaric acid-treated resistant starch can be successfully incorporated into conventional cake-processing systems to develop low-calorie bakery products while maintaining acceptable product quality. This study provides engineering insights into the application of high-RS ingredients for process optimization and the development of functional baked foods.

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Abstract 628 | Poster 14

Differential effects of betanin and vulgaxanthin I on the antioxidant capacity of rat plasma

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ABSTRACT

Betalains are pigments with antioxidant properties; however, their metabolic fate and roles in systemic antioxidant responses remain unclear. This study examined time-dependent effects of betanin and vulgaxanthin I on plasma antioxidant capacity and characterized their metabolic profiles. Ninety male SPF Cmdb rats received a single intragastric dose of betanin (10 mg/kg), vulgaxanthin I (10 mg/kg), or water. Blood samples were collected 15, 30, 60, 90, and 120 min post-administration. Hydrophilic (ACW) and lipophilic (ACL) antioxidant capacities were measured using photochemiluminescence (PCL) spectroscopy. Plasma betalains and metabolites were extracted via solid-phase extraction and analyzed by LC–MS. Neither native betanin nor vulgaxanthin I was detected. Eleven betanin-derived metabolites, primarily betalamic acid and its decarboxylated, deglycosylated, and dehydrogenated derivatives, were identified. Betanin induced a rapid, sustained increase in ACW from 15 to 120 min, whereas vulgaxanthin I exhibited a weaker, transient effect between 30 and 60 minutes. ACL remained unchanged until 90 min but decreased significantly at 120 min in the betanin group. Betanin and vulgaxanthin I elicit distinct time-dependent antioxidant responses in vivo. The absence of native betanin and presence of multiple metabolites indicate extensive biotransformation following gastric administration.

Acknowledgements: Funded by the Minister of Science under,,the Regional Initiative of Excellence Program".

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Abstract 631 | Poster 15

Consumers Preferences for Sensory Characteristics and Nutritional Values of Goat Meat

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ABSTRACT

Goat meat is increasingly recognized as a lean, nutritious, and sustainable alternative to traditional red meats such as beef, lamb, and pork. However, it remains unfamiliar to many mainstream U.S. consumers. This study evaluated U.S. consumers' sensory preferences for goat meat and examined associations between sensory preferences and consumers' gender, generation group, and prior goat meat consumption. A total of 120 adults participated in a goat meat tasting survey at the Sunbelt Ag Expo in Moultrie, Georgia. Participants evaluated goat meat for appearance, juiciness, texture, flavor, and aftertaste using a 9-point hedonic scale (9 = like extremely, 5 = neither like nor dislike, and 1 = dislike extremely). Differences in sensory preferences by gender, generation group, and prior goat meat consumption were analyzed using two-tailed Fisher's exact tests.

Among participants, 65% reported being aware of the nutritional value of goat meat, 63% had previously consumed goat meat, and 37% were first-time goat meat consumers. Flavor received the highest proportion of participants rating it "like extremely" (56%), followed by appearance (50%), juiciness (45%), texture (42%), and aftertaste (42%). A marginal difference in texture preference was observed between first-time and previous goat meat consumers ($P = .081$), whereas a significant gender difference was observed for texture preference ($P = .010$). No significant generational differences were observed for appearance ($P = .316$), juiciness ($P = .108$), texture ($P = .207$), flavor ($P = .338$), or aftertaste ($P = .905$).

Overall, U.S. consumers demonstrated favorable acceptance of goat meat, with flavor receiving the highest preference rating. Consumer acceptance was generally consistent across generation groups, while texture preference differed significantly by gender. These findings provide evidence that can inform consumer education, marketing strategies, and industry outreach efforts aimed at increasing acceptance and expanding the U.S. goat meat market.

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Abstract 637 | Poster 16

Modification of *β*-Lactoglobulin by genetically engineered microbial laccase

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ABSTRACT

β-Lactoglobulin (BLG) accounts for approximately 10-15% of total milk proteins. Besides being an important nutrient of dairy products, it also represents a serious health risk in cow's milk-allergic (CMA) patients as it is known as one of the major milk allergens. Laccase (E.C.1.10.3.2) is a multi-copper oxidoreductase enzyme, which exhibits great potential as food ingredients to be extensively used in food systems. It has been reported that cross-linking of allergenic protein by laccase might offer a promising way for reducing its allergenic potential. Besides that, this way of protein processing at the same time boosts the protein antioxidative capacity using quite natural tools. However, the large-scale application of laccase is currently hindered by its low production yield, high cost, and difficulty in recovery under industrial conditions. *Geobacillus* sp. JS12, a thermophilic bacterium from the *Geobacillus* genus, produces laccase with high thermal stability and applicability in high-temperature environments. Both microbial laccases from the *Escherichia coli* and *Pichia pastoris* expression systems exhibited activity with 2,6-dimethylphenol (2,6-DMP). Regarding the laccase treatment of BLG, both sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) and Fourier transform infrared spectroscopy (FTIR) results demonstrated structural modifications in BLG. Future studies could further investigate its potential for reducing milk allergens and evaluating changes in its allergenicity.

This study is supported by a research grant from National Science and Technology Council (NSTC 113-2221-E-029-002-MY3).

Keywords: Laccase, Genetic Engineering, *Escherichia coli*, *Pichia pastoris, β*-lactoglobulin, Cow's Milk-allergic

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Abstract 644 | Poster 17

Exploring the influence of pea protein hydrogel structure on *in vitro* protein digestion

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ABSTRACT

Pea protein is increasingly used to form hydrogels that provide structure to plant-based foods, so understanding its digestion behavior is critical for food product design. Previously, ultrasound-treated pea protein was shown to form a hard, fine-stranded hydrogel, while untreated protein formed a soft, particulate one. In this study, these two hydrogels, along with a non-gelled pea protein dispersion, were prepared to investigate how hydrogel microstructure influences *in vitro* protein digestion. Hydrogels at a protein concentration of 12.5% (w/w) were subjected to an *in vitro* digestion protocol. Structural changes during digestion were evaluated by confocal microscopy, particle size distribution (PSD), and apparent viscosity, while protein digestibility was quantified using the OPA assay. After the oral phase, the dispersion and soft hydrogel retained a particulate microstructure, whereas the hard hydrogel preserved its fine-stranded network and exhibited higher viscosity. Following the gastric phase, the PSD showed partial disintegration of both hydrogels. However, the soft hydrogel exhibited greater fragmentation, evidenced by the formation of smaller particles. The viscosity of the gastric phase increased in the soft hydrogel but decreased in the dispersion and hard hydrogel. Despite these structural differences, the degree of hydrolysis (OPA) did not differ significantly among systems after this phase, ranging from 16.22 ± 3.01 to 24.54 ± 1.54%. Upon completion of the intestinal phase, all systems showed extensive protein degradation observed by microscopy, although the hard hydrogel retained a population of large particles (100–1000 μm) and the highest viscosity (6.56 ± 2.00 mPa·s). The soft hydrogel exhibited the greatest digestibility (53.56 ± 5.52 %), whereas the hard hydrogel had significantly lower digestibility (30.04 ± 6.53 %), likely due to the persistence of its structure throughout digestion, limiting enzyme accessibility. This study demonstrates that controlling hydrogel microstructure represents an effective strategy to modulate pea protein digestibility in plant-based foods.

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Abstract 664 | Poster 18

α-Amylase and α-Glucosidase Inhibition by Nine Tea and Herbal Leaf Extracts: Solvent-Dependent Selectivity Verified by HPSEC

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ABSTRACT

Inhibiting the carbohydrate-hydrolyzing enzymes α-amylase and α-glucosidase is a well-established strategy for moderating postprandial blood glucose and managing type 2 diabetes, and plant leaf extracts are widely screened as natural sources of such inhibitors. Most screening relies on colorimetric assays, yet the pigments and reducing sugars in crude extracts can bias these readouts, and many studies report inhibition without independent confirmation. This study screened a panel of tea and herbal leaf extracts and, critically, confirmed key findings with two verification methods chosen specifically to rule out the artifacts that can distort colorimetric inhibition data. Nine leaves—green tea, Earl Grey, Pu-erh, yerba mate, mulberry, banaba, jujube, Siberian ginseng, and moringa—were prepared by hot-water extraction (HWE) and 70% ethanol extraction (EE). Inhibition of α-amylase (3,5-dinitrosalicylic acid) and α-glucosidase/maltase (GOPOD) was expressed as IC_{50}. Selected results were cross-checked by (i) a blank-corrected in vitro assay that subtracts each extract's intrinsic absorbance by comparing the reaction against an inhibitor-only blank, and (ii) high-performance size-exclusion chromatography (HPSEC), which judges inhibition from the size of the residual starch substrate rather than from any color reaction. Inhibition depended on both leaf and solvent: mulberry strongly inhibited α-glucosidase ($IC_{50} \approx 18–27$ μg/mL) but not α-amylase, whereas jujube inhibited α-amylase only as its ethanol extract ($IC_{50} \approx 1.8$ mg/mL), not its hot-water extract. Although HPSEC was assessed qualitatively, both independent methods consistently corroborated the colorimetric outcomes—e.g., that HWE jujube and mulberry extracts show no α-amylase inhibition while green tea extract is inhibitory. Because these checks either remove the extract's own color contribution or avoid color detection altogether, their agreement provides artifact-resistant evidence, giving food and nutraceutical developers a practical verification workflow for bioactivity claims in crude plant extracts.

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Abstract 676 | Poster 19

Engineering a 3D-printed core–shell hydrogel system for probiotic protection during digestion and storage

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ABSTRACT

Research Justification:

Probiotic viability can decline substantially during food processing, storage, and gastrointestinal digestion, limiting the effectiveness of probiotic-containing foods. Engineering protective delivery systems that maintain cell viability while enabling release under intestinal conditions is therefore important for developing stable functional food products.

Objective:

This study aimed to engineer a pH-responsive, 3D-printed core–shell hydrogel system to improve probiotic stability during storage and simulated gastrointestinal digestion.

Methods:

A 10-strain premix containing Lactobacillus and Bifidobacterium was incorporated into a pregelatinized starch-based core and surrounded by an alginate–pectin hydrogel shell using coaxial 3D food printing. The effects of printing, storage at 4 and 23 °C for 33 days, short-term exposure to 50 °C for 2 h, and sequential simulated oral, gastric, and intestinal digestion on probiotic viability were evaluated.

Results:

The printing process did not adversely affect probiotic viability. Refrigerated storage provided the greatest protection, with encapsulated probiotics maintaining 64.37% survival after 33 days at 4 °C. In comparison, unencapsulated probiotics declined below 5% by day 18 at 4 °C and day 15 at 23 °C and exhibited negligible survival by day 33. During simulated digestion, encapsulated probiotics retained 97.22%, 83.33%, and 82.70% viability after the oral, gastric, and intestinal phases, respectively. Corresponding retention values for unencapsulated probiotics were 93.62%, 10.92%, and 6.30%.

Relevance to the Food Engineering Profession and Food Industry:

These findings demonstrate that coaxial 3D food printing can integrate material formulation, structural design, and pH-responsive functionality into a single manufacturing process. The developed system offers a promising engineering platform for producing shelf-stable functional foods with improved probiotic protection and gastrointestinal delivery.

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Abstract 684 | Poster 20

Optimization of severity index—dependent gelation behavior of subcritical water—treated bioactive hydrolysates from green plum seeds (*Prunus mume* Siebold & Zucc.) in protein matrices using machine learning

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ABSTRACT

This study investigated the effects of severity index (SI)—based subcritical water (SW) processing on the physicochemical and functional characteristics of green plum seed (GPS) hydrolysates, and thermal gelation behavior of hydrolysates in isolated soy protein (ISP) matrices and applied machine learning—based Bayesian optimization to determine a gelation condition. GPS hydrolysates produced at different SI conditions were incorporated into ISP matrices, and their colloidal properties and storage (G′) and loss (G″) moduli during heating and cooling were evaluated. Random Forest was used for Bayesian optimization of the heating and cooling stage rheological responses. An SI—dependent transition point was observed at log R_0 6.4, where brix and reducing sugar content were maximized. Above this transition point was associated with increased protein recovery, total phenolic content, a shift toward low molecular weight fractions, and the formation of thermal derivatives, coinciding with enhanced physiological activities. Physicochemical and functional characteristics of the GPS hydrolysates exhibited SI—dependent patterns. The GPS hydrolysate exhibited a charge reversal at log R_0 6.4 and the particle size changed nonlinearly, and observed smallest of particle size and highest of ζ—potential at log R_0 8.0. Rheological responses differed between thermal stages. The strongest heating stage elastic modulus development was observed at log R_0 8.0, and the strongest elastic cooling network was formed at log R_0 4.8. Among the evaluated regression models, the Random Forest model showed the best performance in G' and G" predictions with an R^2 of 0.99 and a Q^2 of 0.98—0.99. Through Bayesian optimization that considered G' and G", log R_0 7.8 was derived as the optimal condition. Consequently, this study demonstrated that SI—based SW processing combined with machine learning—based optimization provides a useful strategy for upcycling GPS into functional food ingredients and controlling the gel formation of hydrolysates in plant protein—based food systems.

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Abstract 716 | Poster 21

Encapsulation of camu-camu by freeze-drying: influence of wall material blends on physicochemical properties, bioactive protection, and stability.

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ABSTRACT

Camu-camu (*Myrciaria dubia)* is an Amazonian fruit of growing interest due to its exceptional vitamin C content and phenolic compounds; however, the susceptibility of these bioactives to degradation limits their stabilization and incorporation into food systems. This study aimed to determine the influence of wall-material composition on the physicochemical, functional, and thermal properties, bioactive protection, and storage stability of freeze-dried camu-camu powders. Gum arabic (GA), maltodextrin (MD), and inulin (IN) were evaluated individually and in binary and ternary combinations using a mixture experimental design. Physicochemical and technological characterization included moisture content, water activity (a_w), tapped density, hygroscopicity, water solubility index (WSI), and drying yield, while functional performance included vitamin C and phenolic encapsulation efficiencies and antioxidant capacity by FRAP and DPPH. Thermal stability was evaluated by thermogravimetric analysis (TGA), and vitamin C retention was monitored over 30 days. Moisture contents (1.52–3.21%) remained below the 4% level considered desirable for dried powders, while a_w values (0.026–0.044) were below the threshold required to support microbial growth. High solubility (94.2–96.6%) and powder recovery (82.2–88.3%) were achieved. Phenolic and vitamin C encapsulation efficiencies ranged from 88.0–98.5% and 14.3–97.8%, respectively. The incorporation of MD and IN favored bioactive protection and antioxidant performance, achieving vitamin C encapsulation efficiencies of up to 97.8%, FRAP values of up to 49.9 mg TE/g, and DPPH IC_{50} values as low as 4.80 mg encapsulated powder/mL. Encapsulated systems showed greater early-storage vitamin C retention (71.3–83.0%) than the non-encapsulated freeze-dried extract (22.2%). TGA indicated adequate thermal stability under conditions relevant to food processing. Overall, the evaluated encapsulating systems contributed to preserving camu-camu bioactives while maintaining suitable technological characteristics, offering a promising approach to generate value-added ingredients with functional potential for the food industry and promote the valorization of underexploited Amazonian fruits.

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Abstract 724 | Poster 22

Valorizing Rice Flour into *Neurospora crassa* Mycoprotein via Enzymatic Liquefaction

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ABSTRACT

The demand for sustainable alternative proteins has risen sharply, driven by concerns over the environmental footprint of conventional livestock production, including greenhouse gas emissions, land use, and water consumption. Microbial proteins have emerged as promising candidates, and Neurospora crassa mycoprotein offers efficient production and favorable nutritional quality. Beyond serving as a standalone protein, N. crassa mycoprotein is a potential ingredient in the hybrid production of meat, where it can partially replace animal protein to reduce cost and environmental impact while preserving texture and nutritional value.

Rice flour was evaluated as a first-generation feedstock for N. crassa mycoprotein. Milled white rice (<0.42 mm) was enzymatically pretreated using three industrial formulations to yield three hydrolysates: a previously optimized Bacillus licheniformis α-amylase protocol (7.5% substrate, 85 °C, 85 min) applied alone, and combined with Aspergillus oryzae enzymes applied either concurrently or sequentially (2 μL g^{-1} solids). The hydrolysates were standardized to 30 g/L reducing sugar and used as the carbon source in Vogel medium (pH 5.5, 30 °C, 145 rpm, 1% w/v sodium nitrate) at a 50 mL working volume, in triplicate, for 6 days. A second fermentation run was conducted to determine the enzymatic activity of the hydrolysates. Dry cell weight (gravimetric), specific growth rate, and reducing sugar concentration were monitored throughout.

Peak biomass reached 23.7–28.8 g/L within 24–48 h, with a maximum specific growth rate of 2.2–2.3 day^{-1}, before declining beyond 48 h. The sequential treatment achieved the highest sugar utilization (81.8%) and protein enrichment (40.4% crude, 30.6% true), yielding a volumetric protein concentration of 10.9 g/L, compared with 8.1 g/L for the single-enzyme hydrolysate. These findings confirm rice flour as a viable carbon source for mycoprotein bioprocessing.

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Abstract 727 | Poster 23

Non-isothermal oxidation kinetics of pecan oil containing selected antioxidants using differential scanning calorimetry

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ABSTRACT

Pecan oil is rich in unsaturated fatty acids, making its oxidative stability an important consideration during processing and storage. The addition of antioxidants is a common strategy to retard lipid oxidation. The objective of this study was to evaluate the effect of selected antioxidants on the non-isothermal oxidation kinetics of pecan oil using differential scanning calorimetry (DSC). Four treatments were evaluated: pecan oil without added antioxidants (control) and pecan oil containing 500 ppm of α-tocopherol, butylated hydroxyanisole (BHA), or butylated hydroxytoluene (BHT). Samples were subjected to non-isothermal oxidation under an oxygen atmosphere at five linear heating rates (1–9 °C/min). DSC thermograms were analyzed to determine the start temperature of oxidation (Ts), which was subsequently used to estimate the apparent activation energy (Ea) and pre-exponential factor using an isoconversional kinetic approach. At the highest heating rate, the Ts increased from 179 ± 1°C for the control to 188 ± 0.5, 192 ± 0.7, and 197 ± 0.5°C for α-tocopherol, BHA, and BHT, respectively. These results indicate that all antioxidants delayed the initiation of oxidation, with BHT producing the greatest effect, followed by BHA and α-tocopherol. The corresponding values of Ea were 100 ± 7, 99 ± 8, 95 ± 5, and 84 ± 5 kJ/mol, respectively. The Ea values represent the cumulative contribution of multiple oxidation reactions occurring within the lipid matrix, including reactions involving intermediate compounds with their own kinetic parameters. Thus, changes in reflect the complexity and temperature dependence of the overall oxidation process. Overall, non-isothermal DSC provided a rapid approach to characterize the oxidative stability of pecan oil and differentiate the effects of selected antioxidants on its oxidation kinetics. The results provide kinetic information relevant to antioxidant selection for improving the oxidative stability of pecan oil.

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Abstract 728 | Poster 24

Modulating linear and nonlinear viscoelasticity of whey protein isolate gels using yeast protein particles: Implications for dysphagia foods

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ABSTRACT

High-protein foods for individuals with dysphagia require sufficient nutritional density while maintaining mechanical properties compatible with safe oral processing. Whey protein isolate (WPI) readily forms strong heat-set gels, whereas yeast protein (YP) has limited intrinsic gelling ability. This study investigated how YP particles modulate the thermal structuring, linear and nonlinear viscoelasticity, and dysphagia-relevant texture of WPI gels under two formulation strategies: WPI substitution at constant total protein concentration and YP addition at constant WPI concentration. WPI–YP systems were heated at 85 °C for 30 min and characterized using thermo-time sweeps, frequency and strain sweeps, large-amplitude oscillatory shear (LAOS), water-holding capacity, confocal laser scanning microscopy, particle size analysis, and International Dysphagia Diet Standardisation Initiative (IDDSI) testing. At constant total protein concentration, increasing YP substitution progressively reduced gel stiffness, deformation tolerance, and water retention by weakening the continuous WPI network. IDDSI classification decreased accordingly; for example, at 12.5 wt% total protein, WPI-rich formulations were classified as Level 6, whereas higher YP substitution shifted the systems to Level 4. In contrast, when WPI concentration was fixed, YP addition increased gel stiffness and deformation resistance, particularly at 11.25 wt% WPI near the gelation threshold, consistent with a hydration-driven crowding effect that promoted network connectivity. LAOS further showed composition-dependent changes in intracycle strain stiffening, energy dissipation, and yielding behavior that were not captured by small-strain measurements alone. These findings demonstrate that YP can act either as a network-softening substitute or as a reinforcing particulate modifier depending on formulation strategy, providing a protein-based approach for tailoring high-protein, dysphagia-oriented foods without relying on polysaccharide thickeners.

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Abstract 737 | Poster 25

Effect of Dairy Protein Source and Homogenization Pressure on Foaming Behavior

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ABSTRACT

Dairy proteins are valued for their ability to form and stabilize foams in aerated products. These properties are dependent on the protein source and processing conditions. This study investigated the influence of protein source and homogenization pressure on the foam performance of selected dairy protein ingredients. Whey protein concentrate (WPC), milk protein concentrates 80 (MPC80) and micellar casein concentrate 85 (MCC85) were dispersed in deionized water and homogenized at 20.7, 34.5 and 48.3 MPa to produce 27 treatment conditions. Foaming properties were analyzed by dynamic foam analysis. Circular dichroism (CD) spectroscopy and particle size distribution were used to provide complementary information on protein conformation and particle aggregation. Factorial analysis of variance showed that protein source was the dominant factor governing foam stability ($F = 16.52$, $p < 0.001$), with concentration a moderate contributor and pressure not significant overall; Tukey post hoc testing confirmed significant differences among all three proteins. WPC exhibited the lowest foam stability, with foams collapsing within 44 to 77 s, whereas MPC80 exhibited the greatest stability, exceeding 611 s. MCC85 showed intermediate, pressure-dependent foam stability, ranging from 68 to 538 s. Particle size analysis showed WPC produced larger and more variable particles, with a mean D50 of 720 μm compared with 314 and 329 μm for MPC80 and MCC85, respectively. A principal component analysis on 14 variables confirmed protein type as the largest source of variance, explaining 37.0% of the total variance, higher than concentration and pressure combined. CD-derived protein conformation correlated significantly with initial bubble count ($r = -0.443$, $p = 0.021$) and initial bubble area ($r = 0.465$, $p = 0.015$). These results demonstrate that protein source is the major determinant of foam stability rather than homogenization pressure, with statistical evidence of the relationship between molecular conformation and foam performance, providing support for ingredient selection for aerated food applications.

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Abstract 741 | Poster 26

Development of Alginate Oligosaccharide/Pectin/Bacterial Cellulose Hydrogel Microcapsules for Encapsulation and Immobilization of Probiotics for Potential Oral Delivery

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ABSTRACT

Justification: Maintaining probiotic viability during gastrointestinal transit remains a major challenge for effective probiotic delivery. Combining prebiotic oligosaccharides with structurally reinforced hydrogel matrices may provide a strategy for improving structural stability and enabling efficient synbiotic delivery. **Objective:** This study aimed to develop a semi-interpenetrating polymer network (semi-IPN) synbiotic delivery system integrating alginate oligosaccharides (AOS), low-methoxyl pectin (LMP), and bacterial cellulose (BC) to enhance microcapsule structural stability and probiotic survival during gastrointestinal digestion. **Methods:** AOS were produced from sodium alginate through microwave-assisted H_2O_2 depolymerization. BC was incorporated as both a structural reinforcing component and an immobilizer for probiotic immobilization. AOS, LMP, and probiotic-loaded BC were formulated into microcapsules using an emulsification/internal gelation approach. Microcapsule size and rheological properties were characterized, and the protective effect of the microcapsules on *Lactobacillus acidophilus* ATCC™ 314 was evaluated using simulated gastrointestinal digestion. **Results:** Microwave-assisted H_2O_2 treatment substantially accelerated depolymerization from several hours to 15 min. The resulting AOS/LMP/BC microcapsules had an average diameter of approximately 50 μm with a narrow size distribution. Incorporation of BC promoted the formation of a semi-IPN structure and increased the storage modulus (G′) compared with formulations without BC, indicating enhanced network strength. BC incorporation also improved probiotic protection by combining encapsulation with probiotic immobilization. The viability of *L. acidophilus* ATCC™ 314 in BC-containing semi-IPN microcapsules remained above 10^6 CFU/g following in vitro gastrointestinal digestion. **Conclusions:** Integration of AOS, LMP, and probiotic-loaded BC produced semi-IPN microcapsules with enhanced structural strength and improved probiotic protection during simulated gastrointestinal digestion. **Significance:** This study provides a strategy for integrating prebiotic oligosaccharides, hydrogel encapsulation, and BC-mediated probiotic immobilization within a single delivery platform, with potential applications in the development of functional foods and synbiotic products.

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Abstract 744 | Poster 27

Engineering Self-Oxygenating Scaffolds for Scalable Volumetric Cultivated Meat Production

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ABSTRACT

Justification: The scalable production of thick, whole-cut cultivated meat is limited by insufficient oxygen transport within volumetric constructs, which compromises cell viability and myogenic development.

Objective: To develop an edible scaffold that provides localized oxygen supplementation and aligned structural guidance for scalable volumetric cultivated meat production.

Methods: A self-oxygenating scaffold (SOS) was fabricated by incorporating zein-encapsulated calcium peroxide oxygenating nanoparticles (ONPs) into aligned electrospun gelatin nanofibers. Oxygen release behavior, cytocompatibility, cellular responses under simulated hypoxia, myogenic progression during extended culture, and transcriptomic changes were evaluated relative to conventional scaffolds.

Results: Zein encapsulation regulated calcium peroxide hydrolysis, enabling sustained localized oxygen supplementation while limiting rapid peroxide-associated reactive oxygen species generation. The aligned nanofibrous architecture provided anisotropic contact guidance for muscle-like cellular organization. Under simulated hypoxia, SOS constructs maintained higher cell viability and reduced HIF-1α activation than conventional scaffolds. During extended culture, SOS supported myogenic progression without overt cytotoxicity. Transcriptomic analysis indicated remodeling-associated redox responses, suggesting bioactive effects beyond oxygen supplementation.

Conclusions: Integrating oxygen management and anisotropic structural cues in a single edible scaffold simultaneously addresses mass-transfer and tissue-organization constraints in volumetric cultivated meat.

Significance: This food-compatible SOS provides a scaffold-engineering strategy for producing thicker, viable, and structurally organized whole-cut cultivated meat, supporting the scalable manufacture of next-generation cultivated meat products.

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Abstract 748 | Poster 28

Influence of Psyllium Husk on the Rheological and Functional Properties of Meat Batters

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ABSTRACT

The incorporation of dietary fiber ingredients into common food products, such as processed meat products, has gained attention as a reformulation strategy because it may provide consumers with important nutrients without changing their dietary habits. However, fiber incorporation may alter the functional and structural properties of processed meat systems. **Psyllium husk (*Plantago ovata*), rich in soluble fibers, particularly arabinoxylans, has structural and physicochemical properties that make it a promising ingredient for incorporation into meat batters and may contribute to the functional properties of meat batters**. **The objective of this study was to evaluate the effects of increasing levels of psyllium husk powder (PHP) inclusion on the rheological and functional properties of thermally processed meat batters.** Four formulations were prepared independently during a single production day: a control (CON) and treatments containing 1%, 2%, or 3% PHP. Each treatment was evaluated using four independent replicates (n = 4/treatment). Response variables were analyzed as a completely randomized design using PROC GLIMMIX in SAS, and least squares means were separated using a Tukey HSD adjustment. Dynamic rheological temperature-ramp tests were performed to simulate industrial thermal processing. **Results demonstrated that the incorporation of PHP did not affect pH, cooking loss, or hardness ($P > 0.05$). However, storage modulus (G′) at the final heating temperature (72 °C) was significantly lower in batters containing 3% PHP than in control samples, indicating a weaker gel network during thermal gelation.** Psyllium husk also significantly affected ($P < 0.05$) color characteristics, with increasing inclusion levels producing progressively darker (lower L^*), redder (higher a^*), and more yellow (higher b^*) meat batters. **These results indicate that PHP can be incorporated at 1% and 2% while maintaining key physicochemical and textural properties, whereas 3% PHP may reduce gel strength. These findings provide insight into PHP functionality and support the development of fiber-enriched meat products.**

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Abstract 754 | Poster 29

High-Pressure Processing of Hydrolyzed Sesame Protein: Gelation for Next-Generation Protein-Rich Foods

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ABSTRACT

The growing demand for protein-rich foods, driven by increasing consumer interest in health, has intensified the need for protein ingredients combining nutritional value with tailored functionality. Hydrolyzed proteins are attractive due to their enhanced accessibility during digestion; however, hydrolysis compromise protein-protein interactions and gel forming ability. This study investigated high pressure processing (HPP) as a strategy to modulate the structure, hydrolysis, and gel forming properties of sesame protein. Therefore, developing processing strategies capable of tailoring the functionality of hydrolyzed proteins represents an important challenge in food engineering. This study investigated HPP as a clean-label strategy to engineer the gelation behavior of hydrolyzed sesame protein. Sesame protein was pretreated by HPP at 200, 400, and 600 MPa/10 min/25 °C, followed by *Alcalase* hydrolysis for 2 min. HPP pretreatment increased the degree of hydrolysis by 29.74, 8.99, and 54.99% at 200, 400, and 600 MPa, respectively, compared with the unprocessed sample (0.1 MPa). Structural analysis revealed pressure-dependent changes in secondary structure, including reductions of 68.07 and 5.92% in α-helix content at 200 and 400 MPa, respectively. In contrast, β-sheet content increased by 19.22% at 200 MPa, β-turn by 5.41% at 400 MPa, and random coil by 34.63% at 600 MPa. These structural modifications translated into distinct gelation behaviors. Viscoelastic analysis showed that the 400 MPa treatment exhibited the highest G′ values, indicating greater structural resistance. Frequency sweeps confirmed the predominance of elastic behavior (G’ > G”) and the highest G′ values at 400 MPa. Conversely, 200 MPa reduced gel rigidity, while 600 MPa markedly decreased the viscoelastic module, suggesting disruption of the gel network. Overall, 400 MPa provided the most favorable balance between structural modification and gel formation, demonstrating the potential of HPP to engineer hydrolyzed sesame protein into a functional, clean-label ingredient for next-generation protein-rich foods.

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Abstract 757 | Poster 30

Dynamic textural evolution of surimi gels during simulated mastication using a biomimetic texture analysis system

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ABSTRACT

To objectively evaluate the dynamic biomechanical changes that occur during mastication, a multidimensional, biomimetic texture evaluation system is needed that goes beyond conventional texture analysis. Existing methods for measuring food texture typically rely on simple two-cycle compression tests, which have limitations in reflecting the complex physiological factors that occur during actual human mastication, such as salivary secretion, enzymatic starch degradation, oral temperature, and mastication rate. This study introduces a method for analyzing the dynamic textural properties of surimi gels using a biomimetic texture analysis system. At 85% deformation, all surimi gel samples exhibited an overall decrease in peak load as simulated mastication progressed, while also displaying a nonlinear pattern characterized by a transient increase in load during intermediate stage of repeated compression. As compression speed increased from 5 mm/s to 10 mm/s, the initial peak load consistently increased. In the control group (0% starch), increasing the compression speed resulted in a 12.0% increase in initial peak load at 23°C and a 16.1% increase at 37°C. Furthermore, when the temperature was increased from room temperature to simulated oral temperature, the pattern of textural change in the surimi matrix varied depending on starch content. In the control group, the initial peak load decreased from 1,562.7 ± 105.2 g at 23°C to 1,255.7 ± 165.8 g at 37°C, whereas in the experimental group containing 5% starch, the initial peak load increased from 989.3 ± 57.6 g to 1,266.7 ± 102.8 g. These results demonstrate that repeated-compression analysis can capture dynamic textural behaviors during simulated mastication, including progressive load reduction and transient load recovery, as well as their dependence on compression speed, temperature, and starch content. The proposed biomimetic texture analysis system therefore provides a promising approach for characterizing the dynamic mechanical breakdown of surimi gels under mastication-relevant conditions.

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Abstract 760 | Poster 31

Mapping processing-induced deformation through oscillatory rheological descriptors in ice cream

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ABSTRACT

This study establishes a framework to relate processing-induced deformation during ice cream churning to equivalent oscillatory rheological descriptors. The framework was demonstrated in standard ice cream (13% fat and 4% protein) formulated with three whey-to-casein ratios (13/87, 20/80, and 59/41). The proposed framework enabled the establishment of relationships among rheological descriptors (critical strain, S-factor, and T-facor), microstructure (relative fat density), and functional properties (overrun and meltdown rate). Within the linear viscoelastic region, the viscoelastic strength indices were related linearly ($R^2>0.92$) to microstructure through relative fat density, indicating that stronger networks are associated with higher levels of fat organization. Outside the linear viscoelastic region, the critical strain was inversely related to overrun ($R^2>0.99$), indicating that mixes yielding at lower strain incorporated more air during batch churning. Large-amplitude oscillatory shear (LAOS) analysis showed that the S-factor correlated with meltdown rate, suggesting that elastic contributions of the matrix play an important role in delaying structural collapse during melting, whereas the T-factor was related to the onset of meltdown through changes in viscous response. Finally, meltdown rate was inversely related to microstructure through relative fat density, indicating that more interconnected structures slowed liquid drainage.

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Abstract 761 | Poster 32

Sequence-controlled ion assembly regulates Na^+/K^+ availability in gellan gum-based NaCl–KCl particles for enhanced saltiness and reduced KCl-associated bitterness

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ABSTRACT

Partial replacement of sodium chloride (NaCl) with potassium chloride (KCl) reduces sodium content, but KCl-associated bitterness limits its use. This study examined whether salt addition sequence regulates Na^+ and K^+ availability in gellan gum (GG)-based NaCl/KCl particles and improves the saltiness–bitterness balance without changing final composition. Feeds containing 2.5% (w/v) each of NaCl and KCl and 0.1 or 0.2% (w/v) GG were prepared by simultaneous addition (Sim), KCl-first addition (KNa), or NaCl-first addition (NaK), and spray-dried. Pre-drying ionic environments and post-drying ion–GG associations were examined by $^{23}Na/^{39}K$ NMR and FT-IR, respectively. Ion release in distilled water and simulated saliva, sensory attributes, and performance on fried peanuts were evaluated. NMR attenuation was strongest for ^{39}K in KNa and ^{23}Na in NaK, consistent with restricted mobility of the first-added cation. FT-IR showed sequence-dependent shifts in GG carboxylate bands, suggesting partial retention of pre-drying ion–GG associations. Spray drying produced low-density hollow particles (2.56–6.28 μm; 0.19–0.21 g/mL) smaller and less dense than crystalline salts. In both media, KNa showed higher Na^+ and lower K^+ release than NaK, resulting in higher saltiness and lower bitterness. On fried peanuts, GG-containing formulations achieved 36–75% adhesion, compared with <20% for conventional salts, while KNa retained a favorable saltiness–bitterness balance. Thus, salt addition sequence can regulate Na^+/K^+ availability within GG, providing a process-based strategy to improve reduced-sodium salt systems without additional taste-masking agents.

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Abstract 766 | Poster 33

High Speed Multi-Material 3D Food Printing System for Scalable Production of Plant-Based Meat Analogs

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ABSTRACT

Scalable fabrication of structured meat analogues requires multimaterial printing systems capable of reproducing heterogeneous protein–fat architectures while maintaining high throughput and spatial precision. Here, we developed a parallel multimaterial 3D printing platform for high-throughput production of whole-cut-inspired meat analogues with programmable distributions of protein- and fat-rich domains. The system employs a parallel Y-junction architecture that enables simultaneous extrusion through eight nozzles and programmable millimeter-scale switching between protein and fat-emulsion inks. To ensure reliable operation across the parallel printing channels, the rheological properties of a xanthan-gum-modulated soy protein ink and a protein-stabilized fat-emulsion ink were synchronized to provide compatible yielding, shear-thinning behavior, and rapid post-shear recovery. Microbial transglutaminase was further incorporated to improve structural stability during mild thermal post-curing. The optimized printing system produced geometrically consistent filaments across all eight nozzles while minimizing interfacial spreading during material transitions. Parallelization increased nominal mass throughput from 0.22 g min^{-1} for a single channel to 1.77 g min^{-1} for eight channels, enabling fabrication of a 91.2 cm^3 heterogeneous whole-cut-inspired construct within 20 min of active extrusion. The printed constructs achieved 87.0% fidelity to the programmed digital geometry and 80.3% protein-domain fidelity relative to a pork-belly-derived morphological reference. Moreover, programmable control over local protein-to-fat-emulsion ratios enabled composition-dependent modulation of textural properties. These results establish parallel multimaterial 3D printing as a scalable manufacturing approach for producing structurally heterogeneous meat analogues with controlled internal architecture and composition.

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Abstract 787 | Poster 34

Linking Thermal Processing and Matrix Composition to Probiotic Spore Survival and Functionality in Inulin-Enriched Fermented Milk

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ABSTRACT

Developing extended-shelf-life (ESL) probiotic fermented milk requires thermal processing that retains viable probiotics while maintaining product functionality. This study evaluated how thermal treatment intensity, pH, and inulin incorporation influence probiotic survival, matrix structure, rheology, and protein digestibility. Fermented milk containing *Bacillus coagulans* (BC) or *Bacillus subtilis* (BS) at 10^9 CFU/mL, with or without inulin, was prepared at pH 4.0 and 4.2 and compared with probiotic-free heated controls (CON) and non-heated (NH) samples. Heated formulations received 1× or 3× F'_0 treatments, calculated using a 95°C reference temperature and 1-min reference time appropriate for acidified foods.

Thermal processing resulted in approximately 1–2 log reductions in probiotic populations, with BC exhibiting greater thermal resistance than BS. BC maintained $\geq 10^8$ CFU/mL during refrigerated storage in selected 1× F'_0 treatments, while no survivors were detected in probiotic-free CON samples, demonstrating effective inactivation of background microflora while retaining heat-resistant BC spores. Matrix functionality was strongly dependent on processing and formulation: inulin generally reduced G′, while pH 4.0 and higher F_0 promoted stronger gel networks. CON exhibited stronger networks than probiotic-containing formulations, with confocal microscopy corroborating these differences through smaller protein aggregates in probiotic-containing systems. In vitro digestion showed that BC increased final hydrolysis by approximately 12–15% relative to CON in selected treatments, particularly with inulin, while higher F'_0 and pH 4.0 generally promoted greater hydrolysis. SDS-PAGE corroborated treatment-dependent differences in protein breakdown. FTIR spectroscopy indicated minimal changes in protein secondary structure, suggesting that functional changes were associated primarily with higher-order organization and protein accessibility.

Collectively, these findings provide a basis for designing thermal processes and formulations for ESL probiotic dairy products with simultaneous objectives of probiotic retention and matrix functionality. Future work will focus on validating these relationships during process scale-up and extended storage of ESL probiotic dairy beverages.

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Abstract 788 | Poster 35

High pressure homogenization and moderate heating to form pea protein-polysaccharide adducts for applications in high protein and fiber yogurt-like acid gels

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ABSTRACT

There is a growing interest in protein- and fiber-enriched foods; however, such foods often exhibit phase separation (e.g., early syneresis or precipitation), weak gel formation, and poor texture/mouthfeel due to incompatibility between proteins and polysaccharides. We propose overcoming this incompatibility through high pressure homogenization (HPH) and heat treatment processing. HPH involves pumping liquid samples through one or more valves under extreme pressure conditions (>100 MPa), thus inducing structural modifications and unfolding of proteins which can enhance their interaction with polysaccharides. Moreover, combined thermal treatment can form stable, strong covalent bonds between the biopolymers. Formation of such protein-polysaccharide adducts typically requires heat treatment of several hours, whereas our combined approach could be relatively energy- and time- efficient,

Our method has enabled protein-fiber adduct formation with four different dietary fiber sources: (1) corn fiber (resistant maltodextrin), (2) oat β-glucan, (3) soy soluble polysaccharide, and (4) gum acacia. Oat β-glucan adducts showed the highest degree of grafting (~50%) followed by gum acacia > soy soluble polysaccharide > corn fiber. Degree of grafting greatly affected physicochemical properties such as particle size, zeta potential, hydrophobicity, etc., which resulted in unique functional traits. Corn fiber adducts with a low degree of grafting (~19%), small particle size (~30 μm), and high surface hydrophobicity formed self-supporting glucono delta lactone induced yogurt-like acid gels with ~10x increase in gel strength compared to its untreated control. Conversely, acid gels made with high degree of grafting adducts with increased particle size (> 200 μm) and aggregation, such as oat β-glucan and gum acacia, showed resistance to in-vitro digestion, indicating potential for slower gastrointestinal digestion. Overall, this work provides a new strategy for formation of protein-polysaccharide adducts with unique physicochemical properties that can be fine-tuned for functional applications.

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Abstract 789 | Poster 36

Title: Interfacial Engineering of *Aspergillus oryzae* Biofilm–Oleogel Hybrid Composites via Plant Protein–Based Adhesion for Structured Food Systems

Interfacial Engineering of Aspergillus oryzae Biofilm–Oleogel Hybrid Composites via Plant Protein–Based Adhesion for Structured Food Systems

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ABSTRACT

Replicating the complex lipid–protein matrix of animal tissues remains a primary technical bottleneck in alternative protein design, particularly regarding structured fat mimetics. While fungal mycelia and oleogels offer promising structural networks, integrating these immiscible hydrophilic and hydrophobic phases into a cohesive matrix remains challenging.

Objective: To address this, this study engineered hierarchical hybrid food structures by integrating *Aspergillus oryzae* biofilms with ethyl cellulose–stearic acid (EC-SA) oleogels using plant protein adhesives (zein and wheat gluten) to bridge the hydrophilic fungal surface and hydrophobic lipid phase.

Methods: *Aspergillus oryzae* biofilms were cultivated under static conditions, and EC-SA oleogels were prepared via thermal dissolution. Plant protein coatings were applied to the fungal biofilm surfaces prior to oleogel integration. Interfacial adhesion mechanisms were characterized using contact angle wettability analysis, scanning electron microscopy (SEM) for surface morphology, and SDS-PAGE to evaluate non-covalent bonding and mechanical interlocking. Textural performance was evaluated via texture profile analysis (TPA), and thermal stability was assessed by measuring oil leakage and cooking weight loss. Data were analyzed using ANOVA ($p<0.05$).

Results: Zein exhibited superior adhesive performance compared to wheat gluten ($p<0.05$), primarily driven by its amphiphilic properties and enhanced molecular compatibility with the fungal mycelia network. The engineered hybrid composites effectively immobilized liquid oil within the fungal matrix, achieving a significant reduction in oil leakage and thermal weight loss during cooking ($p<0.05$). TPA revealed that the cooked composites possessed hardness values ranging from ~3 to 13 N, closely matching some traditional processed meat products.

Relevance: From a food engineering perspective, this work establishes scalable design rules for interfacial adhesion between immiscible biopolymer–lipid phases without chemical modification. For the food industry, this platform offers a sustainable, clean-label approach for creating realistic fat tissue mimetics; ultimately enhancing textural fidelity and thermal stability in plant-based foods while replacing saturated animal fats.

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Abstract 816 | Poster 37

Replacing Pea Protein with Canola Protein Concentrate Produced by Reactive Extrusion for Meat Analog Application

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ABSTRACT

Plant-based meat analogues rely heavily on refined protein ingredients, such as soy and pea protein isolates, to achieve desirable textural and structural properties. However, these highly refined ingredients contribute substantially to production costs, creating a need for alternative protein sources that are functional, cost-effective, and readily available. Canola meal, a major by-product of vegetable oil production, is an abundant and inexpensive source of high-quality protein but remains underutilized in human foods. In this study, canola protein was rapidly extracted from canola meal using enzymatic reactive extrusion (eREX), a process which combines extrusion with limited enzymatic hydrolysis. eREX followed by a 5-min alkaline extraction increased protein recovery and produced a canola protein concentrate (CPC) that was enriched in essential amino acids and exhibited enhanced functional properties, including improved solubility and oil-binding capacity. This CPC was then used to partially replace pea protein isolate (PPI) at replacement levels of 0%, 5%, 10%, and 15% for the production of whole-muscle-type meat analogues by high-moisture extrusion. The resulting extrudates were evaluated for textural properties, structural characteristics, protein digestibility, and economic feasibility. Partial replacement of PPI with CPC progressively decreased extrudate hardness, while the degree of texturization increased with CPC incorporation up to 10% replacement. In vitro digestion experiments showed no significant differences in protein digestibility following CPC incorporation, demonstrating that partial replacement did not compromise protein digestibility. Techno-economic analysis projected a progressive reduction in operating costs, from 3.04 USD/kg for the PPI-only meat analogue to 2.73 USD/kg at 15% CPC replacement. These findings demonstrate the potential of enzymatically extracted CPC as a cost-effective partial substitution for PPI for high-moisture meat analogues, while providing a value-added pathway for canola meal utilization.

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Abstract 841 | Poster 38

Effects of Formulation Moisture, Extrusion Screw Speed, and Storage Temperature on the Shelf-Life Stability of High-Moisture Extruded Pea Protein Meat Analogs

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ABSTRACT

High-moisture extrusion (HME) is widely used to produce plant-based meat analogs with fibrous, meat-like textures; however, their shelf-life stability remains insufficiently characterized. This study investigated the effects of extrusion screw speed, formulation water content, and storage temperature on the physicochemical and textural stability of pea protein isolate-based HME meat analogs. Samples were produced at two screw speeds (200 and 300 rpm) and two water contents (60% and 65%) and stored for up to 90 days at 4°C or −20°C. Water content, texture profile analysis (TPA), pH, and CIE color (L*, a*, b*) were periodically evaluated. pH remained stable across treatments and storage conditions (7.57–7.74). Storage resulted in consistent color changes, with L* increasing by 0.2–3.3 and a* decreasing by up to 1.0, while changes in b* were less consistent (−1.2 to +0.9). Water content remained relatively stable in the 60% formulation, whereas the 65% formulation exhibited greater changes during storage, suggesting increased susceptibility to water redistribution. Samples stored at −20°C generally exhibited lower hardness (15,283–21,890 g) and chewiness (11,429–16,851 g) than those stored at 4°C (15,468–24,398 g and 12,063–22,764 g, respectively), indicating greater textural softening during frozen storage. Cohesiveness (0.652–0.895) and springiness (0.975–1.045) showed no consistent relationships with storage temperature or screw speed. Increasing formulation water content from 60% to 65% reduced initial hardness by approximately 32% (23,897 vs. 16,225 g), demonstrating a substantial formulation effect on texture. Overall, formulation water content and storage temperature were more influential than screw speed in determining product stability. These findings provide practical benchmarks for formulation optimization, storage selection, and shelf-life quality control of HME plant-based meat analogs.

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Abstract 852 | Poster 39

Physicochemical, Nutritional, and Volatile Profiles of Dark Chocolate Bars with *Moringa oleifera* as a Partial Cocoa Powder Substitute

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ABSTRACT

Background and Objectives: Climate change, increasing temperatures, and other environmental stresses threaten cacao production, creating interest in more sustainable ingredients for chocolate products. *Moringa oleifera* is a nutrient-dense, drought- and heat-tolerant crop with potential as a partial cocoa substitute. This study investigated the effects of replacing cocoa powder with *Moringa* leaf powder on the physicochemical, nutritional, rheological, antioxidant, and volatile properties of chocolate bars.

Methods: Cocoa powder was substituted with *Moringa* leaf powder at levels ranging from 0% to 75%. The resulting chocolate formulations were evaluated for physicochemical and rheological properties, proximate and mineral composition, antioxidant properties, and volatile profiles. Volatile compounds were characterized using solid-phase microextraction coupled with gas chromatography–mass spectrometry (SPME-GC-MS).

Results: *Moringa* incorporation substantially altered chocolate texture and nutritional composition. Hardness decreased from 25.06 kg in the control to 12.84 kg at 25% substitution. Protein content decreased slightly from 8.33% in the control to 7.27% at 75% substitution, whereas calcium increased from 73.56 to 569.73 mg/100 g and iron increased from 13.61 to 28.12 mg/100 g. Antioxidant capacity decreased with increasing *Moringa* concentration. A total of 36 volatile compounds were identified. *Moringa* substitution introduced lipid oxidation-associated volatiles, including hexanal and 1-octen-3-ol, which are associated with fatty, grassy, and green sensory notes. Meanwhile, cocoa-characteristic volatiles decreased with increasing substitution. Notably, tetramethylpyrazine was no longer detected at substitution levels ≥50%.

Significance: Partial replacement of cocoa powder with *Moringa* leaf powder substantially enhanced calcium and iron contents while altering texture, antioxidant properties, and aroma chemistry. These findings demonstrate the potential of *Moringa* as a sustainable cocoa-replacement ingredient while highlighting formulation trade-offs between nutritional enhancement and preservation of characteristic chocolate flavor.

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Abstract 861 | Poster 40

Innovative Processing Strategies for Sustainable Production of Cowpea Protein Ingredients

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ABSTRACT

Introduction: Growing demand for sustainable protein ingredients has accelerated the search for alternative plant proteins which are extracted through green processing technologies. Although soy and pea proteins dominate the plant protein market, concerns related to allergenicity, GMO status, and supply sustainability have diverted interest in underutilised legumes like cowpea (*Vigna unguiculata*). Cowpea contains 22-30% protein and offers -remarkable potential as a sustainable ingredient source. However, its utilization is limited by conventional protein extraction methods employing harsh chemicals and energy intensive processes. Thus, this study explores the potential of Natural Deep Eutectic Solvents (NADES) as an environmentally friendly approach for cowpea protein extraction in comparison with conventional alkaline solubilization-acid precipitation (AE-IP) method. **Method:** NADES was formed by mixing choline chloride and glycerol. Key NADES-protein extraction assisted processing variables, such as water content in the solvent (0-80%), total solid concentration (5%-15%), and extraction time (30-100 min) were optimized in response to protein extraction yield and protein purity, using central composite design under Response Surface Methodology (RSM). The resulting protein isolates were evaluated for structural, functional, and nutritional properties using stablished methods. **Results:** Under the optimized extraction condition, the NADES-assisted process achieved comparable protein extraction yield and significantly higher protein purity compared to AE-IP. The NADES-derived protein isolates exhibited larger particle size, greater surface hydrophobicity, more hydrophobic tertiary/quaternary structure, and improved emulsification properties, indicating that solvent-mediated processing influenced ingredient functionality without compromising extraction efficiency. **Significance:** This study demonstrates the efficiency of NADES for producing sustainable and nutritious cowpea proteins. This method offers sustainable solutions for cowpea protein extraction by minimizing the use of harsh chemicals and preserving or improving functional and nutritional properties.

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Abstract 862 | Poster 41

Salt-Assisted Alkaline Processing to Improve Protein Recovery from

Cowpea (Vigna unguiculata)

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ABSTRACT

Introduction: Cowpea (*Vigna unguiculata*) is a protein-rich legume containing 22-30% protein and represents a promising -protein ingredient for food applications. Alkaline solubilization-isoelectric precipitation (AS-IP) is the most used extraction process for cowpea protein; however, protein recovery is often limited at moderate alkaline conditions, whereas extraction at high pH can adversely affect protein structure and downstream functionality. Therefore, this study developed and optimized a salt-assisted alkaline extraction process to improve protein recovery and purity while maintaining desirable protein characteristics. **Method:** A two-stage processing approach was evaluated. In the first stage, cowpea flour was subjected to alkaline solubilization at pH 7- 10 with NaCl concentrations of 0- 0.5 M, followed by isoelectric precipitation. Extraction performance was assessed based on protein extraction yield (%) and protein purity (%). The selected extraction condition was further modified by incorporating NaCl (0, 0.1, 0.3, and 0.5 M) in second stage, either before or after isoelectric precipitation. The resulting protein isolates were evaluated for recovery, structural characteristics, functional, and nutritional properties. **Results:** Salt addition during the initial alkaline solubilization stage significantly ($p< 0.05$) reduced protein extraction yield across all pH levels. Therefore, extraction at pH 8 without salt was selected as the baseline, achieving 61% extraction yield and 86% protein purity. Introducing a post-precipitation salt-dispersion in second stage enhanced both extraction yield (65%) and purity (92%). Compared with conventional extraction (pH 7 and pH 8 without salt), the modified process produced isolates with lower surface hydrophobicity, higher zeta potential, and larger particle, and with improved protein solubility and emulsifying properties. SDS-PAGE profiles and molecular weight distribution remained identical across the extraction methods. **Significance:** Post isoelectric salt dispersion improved protein recovery and functionality of cowpea by modifying surface properties, zeta potentials, and particle size. This approach will help to industrially produce cowpea proteins with tailored functional properties.

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Abstract 867 | Poster 42

Tailoring Wheat Gluten Matrices for Meat Analogs: Influence of Matrix Composition and Cold Shearing on Deformation Capacity

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ABSTRACT

Manipulating wheat gluten to form fibrillar structures is a promising strategy for producing meat analogs. The deformation capacity of gluten raw matrices reflects their ability to form anisotropic structures and can be tailored through compositional and process manipulations. This study evaluated the individual and interactive effects of the proportions of water, oil, and salt relative to commercial wheat gluten (W/CWG, O/CWG, S/CWG) and processing time (t) during cold shearing on the raw matrices' dimensionless maximum deformation. A Box-Behnken design with 4 factors and 3 levels (27 samples) was analyzed by factorial ANOVA. Deformation capacity increased with longer shear times and lower water content. Intermediate concentrations of oil and salt resulted in a peak and a valley in deformation, respectively. Mechanistically, shear time promotes protein chain realignment, while excess water dilutes intermolecular interactions, reducing plasticity. Moderate oil levels act synergistically through plasticization and hydrophobic interactions to enhance structural continuity, whereas high oil concentrations disrupt the matrix. Salt shifts the network stabilization mechanism: its absence favors hydrophobic interactions and hydrogen bonds, while high concentrations promote ionic stabilization and electrostatic shielding.

Regarding interactions, shearing time recovered extensibility in highly hydrated matrices by promoting structural reorganization. In the time-salt interaction, intermediate salt levels consistently hinder deformation regardless of shearing time, reinforcing the hypothesis of negative bond interference. For the water-salt interaction, low hydration combined with high salt increased deformation, suggesting salt compensates for reduced plasticity through ionic interactions. Finally, the oil-salt interaction showed that adding oil at high salt concentrations slightly increased deformation, indicating maximum matrix connectivity when oil-induced plasticity and hydrophobic interactions meet salt-promoted charge stabilization. These findings provide guidance for tailoring dough properties for plant-based meat analogs.

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Abstract 873 | Poster 43

Marine-Derived Fibrous Scaffolds Fabricated by Slime Webbing for Cultivated Seafood Applications

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ABSTRACT

The development of cultivated seafood requires food-compatible scaffolds that support cell attachment while maintaining structural stability under hydrated culture conditions. Fibrous scaffolds are particularly promising because their high surface area, interconnected structure, and controllable fiber organization can provide a suitable environment for cell–material interactions and tissue organization. Although electrospinning is widely used for fibrous scaffold fabrication, its reliance on high-voltage equipment and considerations related to solvent selection and fiber collection may limit its suitability for food applications. Here, we employed "Slime Webbing," a mechanical fiber-forming technique that directly draws fibers from aqueous precursor solutions and enables repetitive layering to construct aligned multilayer scaffolds. Fish collagen–chitosan (FC/C), fish gelatin–chitosan (FG/C), and fish collagen–gelatin–chitosan (FCG/C) systems were compared under identical fabrication conditions to investigate the effects of protein matrix composition on precursor behavior and scaffold functionality.

Precursor solutions were characterized for shear-dependent rheological behavior, while the resulting scaffolds were evaluated for fiber morphology and alignment, chemical interactions, hydration-induced structural changes, swelling, mass stability, mechanical properties, and initial cell attachment. All formulations exhibited shear-thinning behavior but showed distinct scaffold characteristics depending on the protein matrix. FC/C exhibited limited swelling and structural changes after hydration, whereas FG/C showed pronounced water uptake and pore development. FCG/C displayed intermediate hydration behavior. FG/C also exhibited relatively high Young's modulus, low mass loss during immersion, and the highest initial cell attachment, indicating a favorable balance between hydration and structural integrity.

This study demonstrates the effectiveness of marine-derived materials and the innovative "Slime Webbing" technique for fabricating aligned fibrous scaffolds. It further highlights the relationship between scaffold physicochemical properties and biological performance, providing a basis for engineering food-compatible scaffold structures and contributing to the development of structurally organized cultivated seafood for future food production.

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Abstract 879 | Poster 44

Specific Mechanical Energy as a Measure of Degree of Processing for Modulating In Vitro Digestive Outcomes in Extruded Foods

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ABSTRACT

Introduction: Degree of processing can alter food structure and nutrient accessibility. In extrusion, degree of processing can be represented by specific mechanical energy (SME), influencing starch transformation, matrix structure, and bioactive accessibility. Understanding these interactions is important for designing foods with targeted nutritional responses. **Objective:** This study investigated how degree of processing (SME) affects digestive and bioactive responses from extrudates made from sweet potato, cassava, and grape pomace flours. **Methods:** Extrudates were produced at four SME levels (600, 1000, 1500, and 2000 kJ/kg) and subjected to simulated oral (2 min), gastric (180 min), and intestinal (180 min) digestion. Glucose release, total starch, rapidly and slowly digestible starch (RDS, SDS), predicted glycemic index (pGI), total phenolic and flavonoid content (TPC, TFC), and FRAP antioxidant capacity were evaluated. Experiments were conducted in duplicate on a dry-weight basis and analyzed by one-way ANOVA followed by post-hoc Student's t-tests ($p < 0.05$). **Results:** Digestive and bioactive responses varied with SME. Total starch did not differ significantly among treatments. At 600 SME, RDS was 105.4±15.3 mg/g and pGI was 54.4±1.9, both values were significantly lower than 1500 SME samples but higher than 2000 SME samples. At 1500 SME, RDS (147.8±18.4 mg/g), SDS (71.9±7.9 mg/g), pGI (65.4±1.7), and intestinal glucose release at 180 min (391.6±9.9 mg/g) were higher than all other treatments. At 2000 SME, pGI (49.5±1.6) was significantly lower than 600 and 1500 SME samples, while intestinal glucose release (306.5±4.7 mg/g) was lower than other treatments. Samples from 2000 SME had higher TPC (9.47±1.59 mg GAE/g) and FRAP antioxidant capacity (66.35±0.83 μmol/g) than other treatments. Overall, 2000 SME showed potential for a desirable balance between digestive and bioactive outcomes. **Significance:** SME can influence digestive and nutrient release outcomes, supporting the design of extruded foods with targeted nutritional profiles.

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Abstract 887 | Poster 45

Towards Ethical Industrial Slaughter of Yellow Mealworm (*Tenebrio molitor*) Larvae: A Statistical Approach to Optimizing Hot Water Immersion Processing

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ABSTRACT

Yellow mealworm (*Tenebrio molitor*) larvae have emerged as a promising sustainable protein source for food and feed, offering potential benefits for reduced land use and climate impact. Despite more than 300 billion individual mealworms being reared annually, no welfare standards exist for slaughtering these farmed insects to mitigate potential pain and distress. This gap likely stems from limited research on insect welfare, which could otherwise inform standard procedures for producers to minimize suffering during processing. This study aims to develop optimized conditions for ethical industrial slaughter of yellow mealworm using statistical modelling, while evaluating the impact of humane slaughter methods on insect product quality. For this, individual larvae were immersed in hot water across a range of temperatures (32–100 °C), recording each trial by camera to determine time-to-death based on paralysis following seizure. Statistical modelling approaches, based on the Weibull distribution and the Baranyi-Type Survival Model were applied to estimate survival probability over treatment time. Additionally, proximate composition and lipid oxidation were evaluated under different temperatures (47, 80, and 100 °C), selected from model outputs to represent a range from humane to non-humane conditions. All modelling approaches, including Baranyi and Weibull variations accounting for non-isothermal conditions and cumulative heat damage, produced sigmoidal survival curves. The Baranyi model provided the best fit (lowest RMSE) at most temperatures tested, except 44 °C. Regarding product quality, ash and protein content did not differ significantly across treatments, though 47 °C yielded the lowest fat content; lipid oxidation was similar across all temperatures. Overall, higher temperatures (≥ 80 °C) achieved humane slaughter (≤ 1 s time-to-death for 99% of larvae) without compromising product quality relative to milder treatments. By identifying conditions that simultaneously protect insect welfare and preserve product quality, this work supports the adoption of ethical and economically viable practices for insect slaughtering.

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Abstract 888 | Poster 46

Plant-Based Meat Analogue: The Role of Formulation, Die Length, and Die Temperature on Product Quality and Energy Efficiency

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ABSTRACT

This study examined the combined impacts of formulation, die length, and die temperature on the physicochemical quality, textural attributes, and energy efficiency of plant-based meat analogues produced via high-moisture extrusion. Three formulations, including PPI, SPI, and CS in ratios of 60:20:20, 40:40:20, and 20:60:20, utilizing two die lengths (0.6 cm and 14.5 cm) at three die temperatures (120, 130, and 140℃). The findings indicated that all processing variables and their interactions substantially affected product quality. Extrudates manufactured with the 0.6 cm die typically demonstrated increased hardness and chewiness, signifying denser structures, whereas the 14.5 cm die facilitated fiber alignment and structural anisotropy. In addition to SPI content, improved texturization, cutting strength, and chewiness, especially under 14.5 cm processing and higher-temperature environment conditions. The maximum level of texturization (1.41) and enhanced fiber structure were attained with the 20:60:20 formulation utilizing the 14.5 cm at 130℃. Radial expansion increased with SPI content and temperature, to a maximum value of 1.40. The SME was significantly influenced by the formulation and die type, with larger PPI ratios necessitating increased energy input, whereas SPI-rich formulations demonstrated enhanced flowability and reduced energy consumption. The results emphasize that optimizing protein content, die design, and processing temperature is essential for attaining a desirable meat-like texture and enhancing extrusion energy efficiency.

Keywords: die design, energy efficiency, plant-based meat analogues, protein formulation, textural properties

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Abstract 897 | Poster 47

Characterizing nanoscale origins of fibrous texture in high-moisture extruded texturized pea protein and chicken breast meat using X-ray scattering

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ABSTRACT

Consumers are increasingly seeking more sustainable and climate-friendly food options, leading to a shift toward plant-based products. Texturized plant-based proteins, such as high-moisture meat analogs (HMMA) manufactured using a high-moisture extrusion (HME) process, fulfill this. However, there is limited understanding of the characterization of the fibrous or meaty texture of HMMA relative to chicken meat. Therefore, this study examines the structural features at the nanometer length scale in extruded HMMA made with pea protein, compared with those in chicken meat, using small-angle X-ray scattering (SAXS).

A modular custom-designed long rectangular cooling die (total length 352 mm, width 38 mm, and height 12.7 mm) was used to produce pea protein HMMA. The HME process involved varying the cooling media inlet temperatures from 60 °C to 90 °C to assess their impact on the structure of pea protein HMMA. The SAXS data were fitted to a fractal aggregate model and Legendre polynomials to extract structural features and nematic alignment. The macroscale anisotropy of HMMA was measured by cutting strength analysis using a texture analyzer.

The extrudates, once cut and opened, revealed a visually parabolic fibrous structure. SAXS indicated that the HMMA structure consists of semicrystalline pea protein globulins, which are packed into 30 to 40 nm rough spheroid-shaped particles. These particles are aggregated into interconnected mass-fractal structures that exhibit some nematic alignment, presumably forming the larger parabolic fibrous structure. In contrast, chicken meat had a larger particle size of ~200 nm and 5x higher nematic alignment. Moreover, the edges of the extrudates showed more densely packed semicrystalline globulins (smaller d-spacing), larger spheroid particles, and increased nematic order compared to the HMMA in the middle of the extrudates. Overall, these results reveal the nanoscale origins of fibrous texture and point to strategies for designing texturized plant proteins that more closely mimic animal meat.

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Abstract 904 | Poster 48

Beyond Browning: Unravelling Acrylamide Formation Kinetics in Plant-Based Burgers

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Abstract (word count: 298)

ABSTRACT

Plant-based burger analogues (PBBs) are increasingly consumed as alternatives to conventional burgers, but their complex formulations may promote acrylamide (AA) formation during thermal processing. Despite growing interest in PPBs' chemical safety, limited information is available on the kinetics of AA formation under controlled cooking conditions and its relationship with key process and product attributes. This study evaluated AA formation during grilling and its relationships with moisture, asparagine, colour, and dimensional changes to support predictive modelling and process optimization.

Commercially available PBBs from different protein sources, including soy (SB), pea (PB), quinoa (QB), and sweet potato (SPB) were compared with a beef burger (BB -control). Burgers were grilled at 140, 160, 180, and 200 °C for up to 6 min. Temperature profiles, moisture content, and colour parameters (L*, a*, b*, and browning index, BI) were monitored throughout grilling. AA and asparagine concentrations were quantified using LC-MS. All measurements were performed at least in triplicate. Kinetic models were used to characterize changes during grilling.

Moisture content decreased by approximately 7–34% during grilling, promoting conditions favourable for Maillard reactions and AA formation. BI increased rapidly, exceeding 100 AU after 4 min for all burger types and temperatures. AA content increased significantly during grilling, ranging from 76.3±5.0 to 701±109 µg/kg across burger types and processing conditions, while asparagine concentrations decreased. The decrease in asparagine content was correlated with AA formation (> 0.759), supporting its role as a key AA precursor. In contrast, the relationship between BI and AA was inconsistent among burger types.

The results demonstrate that AA formation during grilling of plant-based burger analogues is closely associated with the kinetics of moisture loss, and asparagine depletion. The kinetic relationships established in this study provide a basis for developing predictive models that integrate heat and mass transfer with AA formation kinetics.

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Abstract 934 | Poster 50

Determine the Impact of processing conditions on protein gel physiochemical characteristics and bioactive components concentration in yogurts

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ABSTRACT

Despite extensive research on yogurt texture, the extent to which varying fermentation temperatures impact yogurt gel structure and the retention of delicate bioactive proteins remains unknown. The study *aims* to evaluate the extent to which two fermentation temperatures (37°C and 40°C) impact the physicochemical characteristic and bioactive proteins profile of Greek yogurt.

Physiochemical properties of yogurt gel structure were evaluated, measuring titratable acidity, water holding capacity and employing differential scanning calorimetry (DSC) to analyze the crystallization exothermic enthalpy and melting endothermic enthalpy. Bioactive milk proteins were quantified by ELISA.

Results showed that fermentation at 40ºC generates slightly higher total acidity in the yogurt gel matrix (1.57±0.01%) compared to that yield from 37ºC (1.52±0.01%). The yogurt fermented at 40°C showed a higher water holding capacity of (88.20±0.02%) compared to the yogurt fermented at 37°C (81.50±0.03%). The yogurt fermented at 40°C successfully traps higher concentrations of specific bioactive whey proteins, resulting in elevated levels of immunoglobulin A (IgA) (51.9±12.3 µg/ml) and IgM (55.7±52.06 ng/ml) compared with the yogurt fermented at 37°C (IgA: 47.5±6.0 µg/ml; IgM-not detectable;). Conversely, lactoferrin concentration was found to be higher in yogurt fermented at 37°C (730.0 ±90.8 pg/ml) compared with 40°C (242.0±84.8 pg/ml). The DSC results showed that lower crystallization and melting enthalpies were observed for the 40ºC yogurt compared with the 37ºC yogurt gel matrices, indicating that less energy was involved in the phase transition. The crystallization exothermic enthalpy results were 189±22.1 J/g and153.7±41.1 J/g for the yogurt fermented at 37°C and 40°C, respectively. The melting endothermic enthalpy were 212 ±5.3 J/g and 162 ±39.3 J/g for the yogurt fermented at 37°C and 40°C, respectively.

In conclusion, a 40°C fermentation enhances the casein-whey protein matrix and immunoglobulin retention through increased gel acidity, a 37°C temperature better preserves specific proteins like lactoferrin.

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Abstract 938 | Poster 51

Interplay between protein concentration and oleogel structuring in modulating the microstructure and whipping performance of faba bean protein-stabilized oleogel emulsions

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ABSTRACT

The demand for dairy-free plant-based whipped cream has grown significantly with increasing consumer interest in clean-label and sustainable dietary alternatives. Here, we investigated the role of faba bean protein isolate (FPI) concentrations (0.5-5 wt%) and oleogel structuring (0-10 wt% beeswax in canola oil) in modulating the microstructure, rheology, and whipping performance of an exclusively protein-stabilized, surfactant-free FPI in oleogel-based aerated oleogel-in-water emulsions. Comprehensive characterizations of rheological properties, microstructure, melting behavior, and mechanical whipping performance were conducted before and after aeration. In the emulsion, lower FPI concentrations at a fixed 10 wt% oleogel concentration facilitated inter-oil droplet cross-linking due to weaker interfacial protein coverage on the oil-droplet surface, thereby promoting the formation of flexible gel-like networks, resulting in a larger average size but weaker gel strength. Following mechanical aeration, lower FPI concentrations exhibited higher average particle size, greater viscoelasticity, and lower shape-height reduction (%SHR), indicating the formation of a robust fat-protein-air composite network. Notably, the 0.5 wt% FPI-stabilized sample demonstrated higher viscoelastic moduli compared to commercial whipped cream despite the complete absence of low-molecular-weight surfactants. Meanwhile, systematically increasing the beeswax concentration (0-10 wt%) at a fixed FPI concentration of 0.5 wt% resulted in increased overrun, reduced %SHR, and improved small-deformation viscoelasticity. Furthermore, the heat treatment (90 °C, 30 min) of the emulsion containing 10 wt% wax and 0.5 wt% FPI maintained viscoelasticity and whipping performance comparable to the unheated control, confirming the thermal stability of the developed system. Overall, whipped creams with 0.5 wt% FPI and 5-10 wt% beeswax-based oleogel system yield a stable multiscale fat-protein-air composite structure with promising rheological integrity and whipping performance, establishing an economically scalable, surfactant-free strategy for plant-protein-driven clean-label whipped creams.

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Abstract 958 | Poster 52

Encapsulation of Spirulina Platensis by Spray Drying Using Composite Wall Materials to Improve Functional Properties and Enable Targeted Release

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ABSTRACT

Spirulina platensis offers a uniquely dense package of protein, essential amino acids, and pigments such as C-phycocyanin, yet its intense blue-green color and fishy, algal off-notes continue to shut it out of mainstream food formulations, leaving much of its nutritional promise untapped by the food industry. To address this barrier, we set out to determine how composite wall material chemistry could be engineered to protect Spirulina's bioactivity while reshaping its physical and sensory behavior for practical food use. Six spray-dried microcapsule systems were formulated by pairing gum arabic with maltodextrin, whey protein isolate, citric acid, and β-cyclodextrin at a fixed 1:2 core-to-wall ratio, then evaluated for encapsulation efficiency, particle size, color, water activity, moisture, C-phycocyanin retention, in vitro digestibility, antioxidant capacity, flowability, and solubility, alongside FTIR and SEM analysis to probe matrix structure. Encapsulation efficiency exceeded 90% in every formulation, peaking in citric acid- and β-cyclodextrin-modified systems, while protein-based capsules formed the smallest, most uniform particles (Dv50 2.15–4.20 μm) and carbohydrate-based systems delivered coarser powders with superior flowability. Citric acid crosslinking pushed antioxidant activity to 95.6% and digestibility to 76.2%, whereas β-cyclodextrin's inclusion-complex chemistry deliberately traps bioactives, cutting immediate digestibility and antioxidant accessibility in favor of delayed release, and whey protein isolate formulations reached solubility as high as 84.7%. Together these results map a clear structure–function relationship between wall material chemistry and functional performance, giving food engineers a concrete, tunable toolkit for deciding whether a Spirulina ingredient should dissolve instantly, protect its antioxidants through processing, or release its bioactives on a delay — a distinction that directly determines whether this underused microalga can finally scale into beverages, supplements, and fortified foods across the food industry.

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Poster Session 3: Modeling, AI, Sensing & Engineering Education

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Abstract 591 | Poster 57

Measuring Student Learning Gains with Take-Home Puncture-Resistance Kits for Packaging Materials: Development, Validation, and Pre/Post Quiz Evidence

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ABSTRACT

Limited laboratory access constrains hands-on learning in food engineering and packaging mechanics, particularly in hybrid delivery and at institutions without specialized instrumentation. This project developed and evaluated two take-home experimental kits, **plastic-film** and **paper** puncture resistance, which were designed to be safe, affordable, and repeatable for at-home use. Kit design was informed by ASTM-style puncture concepts and was iteratively refined by comparing trends in peak puncture force across material types and thicknesses against benchtop validation runs (e.g., texture analyzer/probe measurements) to ensure the simplified platform captured directionally correct mechanical behavior. Each kit includes a handheld digital force gauge, mounting platform, caliper, and preparation tools, paired with concise instructional videos and guided worksheets to standardize procedures and support data interpretation .

To quantify student learning, we implemented aligned **pre- and post-quizzes** targeting (i) puncture mechanics concepts, (ii) variable identification and experimental design, (iii) interpretation of force–displacement behavior and comparative material response, and (iv) variability/error sources. Kits were deployed across multiple course offerings using coded survey links to connect quizzes and user-experience feedback while maintaining anonymity and enabling section/site comparison. Results demonstrate **pre-to-post improvement** on targeted learning outcomes, with the largest gains in interpreting experimental outputs and linking mechanical response to material structure and package performance; item-level analysis reveals persistent misconceptions (e.g., thickness vs. toughness; peak force vs. energy-to-puncture) that guided iterative revisions to prompts and worksheets. The poster shares kit design/validation, assessment blueprint and item analysis, and adoption lessons for scalable, evidence-based hands-on packaging education.

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Abstract 601 | Poster 58

Engineering the Narrative: A High-Impact Course Framework for AI-Integrated Scientific Communication in Higher Education

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ABSTRACT

While food engineering students demonstrate high technical proficiency, a significant power skill gap persists in their ability to translate complex data for non-technical stakeholders, regulatory bodies, cross-functional industry teams, and resource allocation. This presentation details the design and implementation of a high-impact course, Scientific Writing and Data Storytelling, which provides a modular blueprint for modernizing communication training through the strategic integration of Generative AI. The course is structured around a scaffolded, four-module progression:

● Technical Foundation: Developing literature reviews and peer-review proficiency. ● Narrative Translation: Utilizing the And, But, Therefore (ABT) framework to convert technical manuscripts into accessible scientific content. ● Visual Literacy: Moving from high-density technical data to high-level process storyboards. ● Oral Advocacy: Synthesizing content into a final TED-talk style pitch. Central to this pedagogical model is the AI-as-Co-Pilot framework. To prevent cognitive atrophy, the loss of critical reasoning due to over-automation, students interact with custom-designed AI Persona Bots (e.g., Skeptical Plant Manager, Safety & Compliance Auditor, Non-Technical CFO, and Patent Attorney). These bots provide iterative, persona-based dialogue, requiring students to justify their editorial choices and maintain a human-in-the-loop approach.

Teaching peer review alongside AI editing fosters critical reasoning and promotes communication skills. While AI streamlines mechanical editing, peer review juxtaposes human interpretation, forcing students to further justify editorial choices, develop relational intelligence, and refine their judgment. This integrated training ensures they leverage automation ethically and remain indispensable, ethically minded leaders in an automated professional landscape.

This framework provides actionable strategies for ethical AI use for rapid prototyping of course materials and rubrics, as well as a replicable methodology for fostering relational intelligence in engineering students. By treating communication as an engineered system, this course ensures that future food scientists remain indispensable, ethically minded leaders in an increasingly automated professional landscape.

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Abstract 602 | Poster 59

Finite-Element Modeling of Non-Isothermal Pulse-Protein Melt Flow in a Twin-Screw Extruder

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ABSTRACT

Twin-screw extrusion is widely used for the production of texturized plant-protein ingredients; however, the coupled flow, deformation, and heat transfer are difficult to characterize experimentally. This study develops a three-dimensional, non-isothermal finite-element model to investigate pulse-protein melt flow and temperature development in a co-rotating twin-screw extruder. The material is represented as an incompressible, laminar, single-phase generalized Newtonian fluid under low-Reynolds-number conditions. Shear- and temperature-dependent viscosity is described using the Carreau-Yasuda constitutive equation, and viscous dissipation is incorporated into the energy formulation as an internal heat-generation mechanism. The model represents a barrel zone of a 30 mm-diameter, 20L/D extruder, with measurements obtained from extrusion trials conducted at 400 rpm and 17 kg/h throughput.

Predicted melt-temperature rise is compared with temperatures measured at two axial locations. The model also resolves pressure, velocity, shear rate, apparent viscosity, viscous dissipation, and temperature fields that cannot be measured directly during extrusion.

Sensitivity analyses evaluate how assumptions for rheological and thermophysical properties affect predicted temperature development. This work demonstrates the application of finite-element modeling to investigate coupled momentum and thermal transport during pulse-protein extrusion.

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Abstract 665 | Poster 60

Toward Fast and Optimal Robotic Pick-and-Place Operations in Meat and Seafood Kebab Production

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ABSTRACT

Barbecue kebab skewers typically consist of various meat choices, including chicken, lamb, pork, or seafood, and vegetables such as onion and pepper. Traditionally, manual kebab-making is a time-consuming and labor-intensive process, which is considered to be replaced by automation solutions. Currently, automated skewering machines have two different strategies. The first one is to use rotating scrappers and cups with a respective depth to ensure only one item can be loaded into each cup. All the cups are arranged into sequential cup rows and cup lines for skewering operations. However, the cups are frequently left empty because the rotating scrapper design often blocks any items falling into cups. Thus, some processing facilities still need extra labor to manually fill these empty cups. Another solution is the pick-and-skewer method by using robot arms and real-time image processing equipment, which cannot process irregular food pieces, such as shrimps (C-shape). In this study, we developed advanced robotic pick-and-place operations on moving conveyors as a novel fully automated handling and feeding system to prepare and connect the skewering operations to establish unattended kebab production lines. Unlike the pick-and-skewer method, by using greedy nearest-neighbor, and backtracking algorithms, the number of pick-and-place operations are highly reduced to simplify the handling process and improve the handling efficiency. The working concept and the typical handling and feeding process were designed and evaluated with real experiments for unattended continuous production. Experimental results provide design guidelines for future scale-up production (batch size, conveyor speed difference, food options, etc.). A multi-machine production mode shows the applicability of producing meat and vegetable kebabs and shrimp and vegetable kebabs. This research facilitates developing next-generation, more effective kabab production technologies for the U.S. food industry. It also opens up new opportunities and directions to rethink alternatives for other industries related to sorting and handling processes.

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Abstract 671 | Poster 61

Characterizing hydration kinetics in food foulants using hyperspectral imaging

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ABSTRACT

Effective cleaning of food surface foulants often begins with the absorption of aqueous cleaning solutions into the foulant layer, a process that is conventionally monitored with bulk gravimetric measurements that provide limited insight into spatial variations within the material. In this work, we developed a novel non-invasive method using Short-Wave Infrared (SWIR) Hyperspectral Imaging (HSI) and multivariate analysis to investigate the absorption kinetics of water into food foulants. Unlike conventional approaches, this method enables simultaneous acquisition of spatial, chemical, and temporal information about the hydration process. The food foulant samples, consisting of starch, protein, and fat, were exposed to aqueous cleaning solutions as a function of foulant treatment, surfactant type and concentration, and solution pH. The Peleg model was fitted to characterise the water absorption in each system, with R^2 ranging from 0.961 to 0.998, depending on system conditions. The degree of water absorption was increased by the presence of an anionic surfactant. A Partial Least Squares Regression (PLSR) model was trained on the gravimetric and hyperspectral data and showed strong predictive performance (R^2_{Val} = 0.975, $RMSE_{Val}$ = 0.032 g/g_{fouant}). Pixel-level prediction maps and spatial heterogeneity metrics showed that water uptake was spatially non-uniform, with the greatest within-sample variation occurring at intermediate soaking times. Time series predictions from HSI were fitted to the Peleg equation, which showed a satisfactory agreement with the equations fitted to the experimental data. This work demonstrates that SWIR HSI and PLSR can quantify both bulk water absorption kinetics and local moisture heterogeneity in food soils. This approach provides a broadly applicable investigative framework for investigating water transport in various food processing operations, including cleaning, soaking, rehydration, and drying, highlighting the value of non-invasive, spatially resolved water-content prediction for understanding and optimizing processes that cannot be fully characterised using bulk gravimetric measurements alone.

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Abstract 682 | Poster 62

Development and Validation of a Scaled-Down Autonomous Mobile Robot (AMR) Navigation Testbed for Ceiling-Mounted Global Vision Control in Smart Food Processing

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ABSTRACT

Food-manufacturing environments require mobile robotic systems capable of responding to changing layouts, workers, obstacles, and strict environmental and hygienic constraints. This study aimed to develop and preliminarily validate a scaled-down autonomous mobile robot (AMR) navigation testbed and a timing-based evaluation framework for future ceiling-mounted global-vision control in smart food-processing environments. A maze-type testbed was fabricated with defined start and goal zones, obstacles, and multiple guide paths. A programmable mobile robot was evaluated using a timing module comprising an infrared sensor, OLED display, XIAO ESP32-S3 microcontroller, and USB power supply. The module automatically recorded completion time when the AMR passed the sensing point. In parallel, an overhead-vision workflow was designed to acquire workspace images, identify navigable regions, obstacles, and target zones, and convert the extracted spatial information into an X–Y coordinate-based global map for subsequent path planning. Repeated navigation trials generated 55 valid records. Of these, 34 trials (61.8%) were completed in less than 1 min, 10 trials (18.2%) required 1–2 min, and 11 trials (20.0%) required at least 2 min. The fastest completion time was 20.34 s. A finer analysis using the intervals of 0–30, 30–60, 60–90, 90–120, and ≥120 s further demonstrated a broad distribution of completion times among the navigation trials. These results indicate that the developed testbed and sensing module can consistently collect quantitative completion-time data and distinguish temporal performances among repeated AMR navigation trials. Because the present validation focused solely on travel time, other important navigation performance metrics, such as positional accuracy, path deviation, collision frequency, and normalized path efficiency, will be evaluated in future work. The ceiling-mounted vision module will be integrated to enable comprehensive assessment of these metrics for autonomous material-transport applications in food-processing environments.

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Abstract 683 | Poster 63

Machine Learning for Predictive and Inverse Design of Rheological Properties in Yeast Protein–Xanthan Food Systems

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ABSTRACT

Developing food formulations with targeted rheological properties remains a major challenge because nonlinear interactions between ingredients often require extensive trial-and-error experimentation. This study presents a machine learning framework for predicting, interpreting, and inversely designing the rheological properties of yeast protein (YP)–xanthan gum (XG) systems, providing a data-driven approach for rational food formulation. A formulation space consisting of YP (0–30 wt%) and XG (0.25–1.0 wt%) was experimentally characterized using steady shear, small-amplitude oscillatory shear, and large-amplitude oscillatory shear measurements. Key rheological targets included apparent viscosity (η_{50}), storage modulus (G' at 1 Hz), breaking stress, and breaking strain. Multiple regression algorithms were benchmarked using formulation-grouped cross-validation and independent external validation to ensure robust evaluation across previously unseen formulations. Kernel-based models consistently outperformed linear and ensemble tree methods, achieving excellent external prediction accuracy for storage modulus (R^2 = 0.96), viscosity (R^2 = 0.94), and breaking stress (R^2 = 0.88). Automatic relevance determination further revealed that yeast protein concentration accounted for approximately 73–90% of model relevance, identifying protein content as the primary formulation variable governing rheological behavior. Incorporating compact rheological descriptors, including G' and η_{50}, further increased prediction accuracy for breaking stress to nearly R^2 = 0.99, demonstrating a hierarchical relationship between linear viscoelasticity and structural failure. Finally, Gaussian process regression enabled inverse formulation design by identifying multiple candidate formulations satisfying predefined viscosity and elasticity targets, which were subsequently validated experimentally. This work demonstrates how artificial intelligence can transform food formulation from empirical trial-and-error toward predictive, interpretable, and design-oriented engineering, providing a general framework for developing protein-based foods with tailored texture and functionality.

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Abstract 687 | Poster 64

Wide Field Hyperspectral Imaging for Detection, Classification, and Quantification of Microbial Contamination on Food Contact Surfaces

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ABSTRACT

The contamination of food contact surfaces by microbes is a major source of cross-contamination in food processing plants. While existing culture-based methods offer precise microbial detection, the process destroys samples and involves incubation, which means that the results cannot be obtained immediately. To overcome these challenges, this study investigates wide-field hyperspectral imaging (HSI) as a detection technique for microbial identification and quantification.

The objective of this study is to develop machine learning models for contamination detection, microorganism identification, and microbial load classification on 3 different food-contact materials: high-density polyethylene (HDPE), polytetrafluoroethylene (PTFE), and silicone. Coupon with uncontaminated (0 CFU/cm²), low (10^4 CFU/cm²), and high (10^8 CFU/cm²) contamination levels of *Listeria innocua* and *Escherichia coli*, used to develop classification models for contamination detection and microorganism identification.

Coupons inoculated with 150 µL of microbial suspension to obtain controlled surface concentrations expressed as CFU/cm². Hyperspectral (HS) images have been acquired using a Hinalea 4300 hyperspectral imaging system over the 500–1700 nm spectral range. The spectra extracted from the HS images processed using optimal preprocessing method, standard normal variate. Common wavelengths have been selected from three feature selection methods: competitive adaptive reweighted sampling, selectivity ratio, and variable importance in projection. 6 machine learning models which include logistic regression, support vector machine, decision tree, ANN, 1d-CNN and transformer have been trained on selected wavelengths to identify the microorganisms and then classify their concentration levels.

The results showed the successful identification of *E. coli* and *L. innocua* with 98.65% accuracy and the classification of their concentration levels with an overall accuracy of 87.73%. The 1d-CNN provided the best overall results, with the selected key wavelengths majorly in the range of 1212 nm to 1592 nm. These findings support the development of microbial monitoring methods for sanitation verification in food processing environments.

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Abstract 699 | Poster 65

Development of Three-Dimensional Simulation Model for Electron-Beam Pre-Sterilization of Food-Grade PET Containers

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ABSTRACT

Microbial contamination of food packaging containers significantly affects product safety and storage stability. Conventional container sterilization methods using hydrogen peroxide (H_2O_2), peracetic acid (PAA), or high-temperature treatment can provide effective microbial control; however, residue management, rinsing and thermal deformation of plastic containers increase process complexity and operational burden. Although aseptic filling systems can address some of these limitations by maintaining the filling environment under aseptic conditions, large-scale facilities and complex maintenance requirements restrict broader application. Therefore, a nonthermal and dry sterilization module that can be integrated into high-speed packaging lines is required. Electron-beam irradiation can rapidly inactivate foodborne microorganisms without chemical sterilant or high-temperature treatment, making it a promising alternative for container pre-sterilization.

This study was aimed to develop three-dimensional electron beam irradiation model incorporating the geometry, material properties, wall thickness, and movement of food-grade PET containers and to derive key design parameters for continuous processing. An absorbed-dose range of 0.1–0.7 kGy was selected. A CFD–EDM based model comprising an electron beam source, irradiation window, air domain, and PET container geometry was developed using COMSOL Multiphysics. Electron trajectories, scattering, energy attenuation, and spatial dose distributions were calculated according to beam energy, current, irradiation width, distance, position, and angle. Effective penetration depth and transmitted dose were evaluated according to PET wall thickness, while cumulative absorbed dose during transport was analyzed using conveyor speed and irradiation-zone length. Maximum and minimum absorbed doses were determined at the body, shoulder, neck, bottom, and dose uniformity was evaluated using the maximum-to-minimum dose ratio (D_{max}/D_{min}). Low-dose regions and irradiation shadow zones caused by curved and inlet geometries were analyzed under different irradiation directions and angles. The developed model is expected to identify operating conditions for uniform target-dose delivery and provide design criteria for an in-line electron-beam pre-sterilization system and microbial validation experiments.

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Abstract 700 | Poster 66

Development of the Integrated CFD Model for Evaluating the Thermal Response of Dairy Cows in Barn Environments

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ABSTRACT

Conventional CFD studies of dairy barns have mainly focused on airflow, ventilation devices, or individual environmental variables, without fully representing the coupled interactions that determine animal thermal conditions. This study was conducted to develop three-dimensional CFD model using COMSOL Multiphysics for simulating the thermal response of a dairy cow under the ambient conditions of open-sided barn. The proposed coupled model simultaneously accounts for airflow, heat and water vapor transport, radiative heat exchange, and internal heat transfer within the cow to accurately predict surface and core body temperature responses under a range of ambient environmental conditions. Cow-specific heat production at 20°C was calculated from body mass, days of pregnancy, and daily milk yield according to the CIGR method, converted to heat-producing units, and adjusted for each simulated ambient temperature using the CIGR temperature-dependent relationship for cattle. A thermally thin hair-coat layer was included, while the nose and mouth were represented as localized wet surfaces. Relative humidity produced only minor differences under the present model assumptions. Two simulation sets were conducted. Air velocity was fixed at 1 m s^{-1} to evaluate the effects of ambient temperature and relative humidity, whereas relative humidity was fixed at 50% to evaluate the effects of ambient temperature and air velocity. Predicted cow temperatures were primarily governed by ambient temperature, while relative humidity produced only minor differences under the present model assumptions. Increasing air velocity from 0.3 to 3 m s^{-1} reduced the predicted volume-averaged cow temperature by approximately 0.9°C at 20°C. However, the cooling effect declined as ambient temperature increased, decreasing to less than 0.1°C at 35°C and becoming negligible at 40°C. These results indicate that forced airflow alone may be insufficient under severe heat conditions, supporting the need for supplementary cooling strategies.

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Abstract 742 | Poster 67

Toward triaging food and coating combinations to qualify non-BPA can coatings using optical profilometry and self-supervised machine learning

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ABSTRACT

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Justification: Metal cans preserve the global food supply, and a micrometer-thin polymer coating prevents corrosion by limiting contact between the can and its contents. That coating is being reformulated as bisphenol A (BPA) is phased out of food contact materials under EU Regulation 2024/3190. Qualifying a replacement coating against each food still depends on pack tests lasting up to two years, and there are far more food and coating combinations than those tests can cover.

Objective: We asked whether images of a polymer-coated metal panel, captured by optical profilometry and analyzed by self-supervised machine learning, can recover known degradation pathways and triage which combinations warrant pack testing.

Methods: Tinplate panels coated with a BPA epoxy-phenolic benchmark or a non-BPA polyester-phenolic alternative were exposed to 17 model simulants from a definitive screening design over six ingredients (acids, protein cocktail, chloride salts, paprika oleoresin), retorted, and aged. Imaging captured co-registered height and reflectance maps. A masked autoencoder learned surface texture, and linear models predicted responses measured on the same panels by electrochemical impedance spectroscopy, X-ray fluorescence, X-ray diffraction, and differential scanning calorimetry, with strict controls separating real signals from lighting and imaging-day artifacts.

Results: The images flagged three candidate findings, each consistent with independent materials characterization: protein-driven sulfur uptake underlying sulfide staining, early acid-driven barrier loss, and paprika oleoresin uptake. Beyond individual findings, ingredient main effects and interactions predicted from the images matched laboratory measurements across several responses. Surface roughness in particular was consistent with mediating roughly half the protein cocktail's effect on sulfur uptake.

Even so, the triage tool cannot waive pack testing where failure runs through salt transport, citric acid effects, thermal transitions, or metal dissolution.

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Conclusions and Significance: Within those limits, image-based screening could prioritize pack tests, accelerating coating qualification and supporting a resilient, sustainable food supply, though the evidence is strongest for the epoxy-phenolic benchmark.

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Abstract 781 | Poster 68

An AI-Assisted Engineering Framework for Evidence-Based Food Processing Condition Recommendation

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ABSTRACT

Objectives:

Selecting appropriate processing conditions is a critical yet knowledge-intensive task in food engineering. Engineers must integrate scientific literature, engineering principles, empirical knowledge, and process models to balance product quality, process efficiency, and energy consumption. This process is often labor-intensive, difficult to standardize, and increasingly challenged by the rapid growth of published research. Although large language models offer strong capabilities in information retrieval, their application in food engineering remains limited by insufficient domain-specific reasoning, lack of traceable evidence, and inability to support quantitative decisions. This study aims to develop an AI-assisted framework that provides transparent, evidence-based recommendations for food processing conditions by combining scientific literature retrieval with quantitative process modeling and optimization.

Methods:

The proposed framework integrates retrieval-augmented generation (RAG), a domain-specific food engineering knowledge base, mechanistic process models, and optimization algorithms into a unified decision-support workflow. Given a food product, processing method, and engineering objective, the system retrieves relevant scientific evidence, identifies key process variables and constraints, performs process simulation, and generates recommended processing conditions together with quantitative analysis, literature-supported explanations, and confidence-aware outputs. A representative food drying application is used to demonstrate the complete end-to-end workflow from knowledge retrieval to engineering recommendation.

Results:

Preliminary results show that the framework can successfully retrieve and synthesize relevant scientific literature, identify critical process variables, and generate quantitatively justified recommendations for drying temperature, air velocity, and processing time. In the drying case study, the recommended conditions reduced predicted energy consumption while maintaining product quality attributes within acceptable limits, with all supporting evidence fully traceable to the retrieved literature and model calculations. These findings demonstrate the feasibility of combining retrieval-augmented AI with engineering modeling to support transparent, explainable, and evidence-based process design. The modular architecture is readily extensible to a wide range of food processing operations and provides a practical pathway toward intelligent decision-support systems for food manufacturing.

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Abstract 785 | Poster 69

Food Physics and Modeling for Engineers: Learning Material You Can Use Today

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ABSTRACT

A physics framework is just as critical for the learner as chemistry and microbiology, more so for engineers. Such framework is the basis of optimization, digital twins and other aspects of computer-aided manufacturing. However, educational material to prepare a future workforce well-versed in the physics and modeling fundamentals at an appropriate engineering level have roadblocks such as unavailability of content, missing pedagogical map, and insufficient learners at any one place to justify the effort.

We address this need by developing pedagogically rich, modularized, chunked, active learning-enabled, multistage web-based content that is synthesized from recent research. More than 25 modules have been completed and integrated into one course, freely offered under a university platform. Learners can be in any engineering undergraduate program—mechanical, chemical, biological and certainly food, engineers doing PhD/MS, and those in industry. The learning outcomes include the ability to: 1) Explain the physics of a food process using basic building blocks of a universal framework, 2) Compare and contrast between simpler and more comprehensive frameworks for understanding food processes, 3) Optimize complex food processes, and 4) Formulate, implement, compute, and communicate a food process model.

In its first formal online offering in 2026, 32 learners signed up from 7 countries, with 25+ completing it. They included undergraduates in food engineering and graduate students in food science programs. Assessments show significant improvements between pre- and post-module use with liking of the platform and the videos. Grading many text answers and motivating learners for timely completion was a challenge for the instructor.

The modular approach enables customization for three groups of learners—using some of the modules in existing courses (food engineering, food processing), using the entire material to start a course on food physics/modeling/engineering, or customized industry use. All this should propel food physics/engineering education to a level appropriate for today.

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Abstract 786 | Poster 70

Machine Learning Prediction of Ice Nucleation Timing and Supercooling Stability in Whole Fish Treated with Oscillating Magnetic Fields

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ABSTRACT

Supercooling preserves fresh fish below 0°C without freezing, but predicting or controlling nucleation onset is challenging. Despite the potential of oscillating magnetic field (OMF) treatment to delay ice nucleation, no validated machine learning framework quantifies OMF effects on supercooling stability.

This study aimed to develop and evaluate a machine learning framework to predict time to nucleation and supercooling stability in whole fish under OMF treatment.

A total of 174 fish samples were stored for up to 72 hours under six OMF-temperature combinations (0 mT as the control, 7.5 mT, and 15 mT at -4.0 or -4.5°C). Features measured before or at the start of the supercooling phase served as inputs, including OMF intensity, set temperature, fish physical dimensions (weight, length, and thickness), and early-stage thermal responses. Ice nucleation was treated as a time-to-event outcome, with fish remaining supercooled at 72 hours considered event-free. Three survival models, Cox proportional hazards, Elastic-net Cox, and Random Survival Forest (RSF), were compared using stratified nested cross-validation (outer 5-fold, inner 3-fold). A secondary 72-hour endpoint classification and an exploratory regression of nucleation temperature were also conducted.

RSF achieved the best primary performance, with a concordance index of 0.840, mean discrimination of 0.956 across 24, 48, and 70 hours, and a Brier score of 0.100. Kaplan-Meier curves and Cox hazard ratios consistently identified OMF intensity as the strongest predictor of supercooling outcomes. The secondary classification achieved an F1 score of 0.938, and the exploratory regression predicted nucleation temperature with an R^2 of 0.615. OMF intensity emerged as the strongest controllable predictor of supercooling stability across all three analyses. The validated framework developed here may support the design of OMF-assisted cold chain systems to extend the shelf life of fresh fish without freezing.

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Abstract 790 | Poster 71

Starch magnetic nanozymes for biogenic amine colorimetric detection in wine

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ABSTRACT

Justification: Iron oxide nanoparticles (IONPs) exhibit intrinsic peroxidase (POD)-like activity and have been widely explored as nanozymes for biosensing applications. However, their aggregation in aqueous environments reduces colloidal stability and accessible catalytic surface area, limiting their analytical performance.

Objective: This study aimed to develop a stable starch-based magnetic nanozyme through short-chain glucan (SCG) self-assembly and TEMPO-mediated surface functionalization and to evaluate its applicability for colorimetric detection of biogenic amines (BAs) in food matrices.

Methods: Citrate-modified IONPs (Cit@IONPs) were incorporated into spherical starch-based magnetic beads (SMBs) during spontaneous self-assembly of SCGs in aqueous media. The SMB surface was subsequently functionalized with carboxyl groups through TEMPO-mediated oxidation. POD-like catalytic activity was characterized using Michaelis–Menten kinetics. The resulting TEMPO-oxidized SMBs (TEMPO-SMBs) were applied to colorimetric detection of aliphatic BAs, including putrescine, cadaverine, spermidine, and spermine. Analytical performance was further evaluated using wine as a model food matrix.

Results: TEMPO-mediated oxidation improved the colloidal stability and catalytic performance of SMBs. The POD-like activity of TEMPO-SMBs decreased progressively with increasing BA concentrations, producing concentration-dependent colorimetric responses toward the tested aliphatic BAs. The sensing platform retained analytical functionality in the wine matrix and achieved a limit of detection of 4.7 μM.

Conclusions: SCG self-assembly enables efficient incorporation of IONPs into a starch-based microstructure, while TEMPO-mediated surface functionalization enhances the stability and catalytic properties of the resulting magnetic nanozyme.

Significance: This strategy provides a simple carbohydrate-based platform for constructing stable magnetic nanozymes and demonstrates its potential for rapid colorimetric monitoring of biogenic amines in food matrices.

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Abstract 793 | Poster 72

Deep learning-based early detection of salinity stress in sweet basil for yield and quality management

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ABSTRACT

Sweet basil is widely consumed as fresh produce and used as a food ingredient, making stable production of sweet basil with consistent quality important for both fresh consumption and food processing. Salinity stress can reduce plant growth and visual quality, ultimately affecting the yield and marketability of harvested basil. Therefore, early detection of salinity stress is important for maintaining the yield and quality of sweet basil before substantial deterioration occurs. This study developed a non-destructive approach using time-series RGB imaging and a CNN-LSTM model for early salinity stress detection in sweet basil. Plants grown in a deep water culture hydroponic system were exposed to 0, 50, 100, and 200 mM NaCl for 9 days, generating 5,100 images. Water uptake was progressively suppressed with increasing salinity, accompanied by changes in projected leaf area (PLA), a yield-related growth indicator, and normalized green-red difference index (NGRDI), a quality-related greenness indicator. On Day 0, PLA and NGRDI were comparable among treatments. By Day 9, PLA increased to 58.32 ± 0.95 cm² in the control, remained at 43.89–44.91 cm² under 50–100 mM NaCl, and decreased to 14.07 ± 0.36 cm² under 200 mM NaCl, indicating concentration-dependent growth inhibition. NGRDI also decreased under severe salinity, indicating loss of leaf greenness and visual quality. The CNN-LSTM model achieved an overall classification accuracy of 88.5% and a precision of 86.2%. Salt stress was detected as early as Day 2 at 200 mM NaCl (87.3% accuracy), Day 4 at 100 mM (86.6%), and Day 6 at 50 mM (82.2%). These findings demonstrate the potential of a deep learning-based computer vision approach for early detection of salinity-induced changes in sweet basil associated with yield, marketability, and quality, supporting quality management of sweet basil for fresh and processed food applications.

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Abstract 797 | Poster 73

Portable multimodal sensing platform integrating bioimpedance and VIS-NIR spectroscopy for non-destructive assessment of food and agricultural materials

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ABSTRACT

Quality assessment of food and agricultural materials often relies on destructive analyses or laboratory-based instruments, limiting rapid on-site evaluation. Bioimpedance and optical spectroscopy have been widely investigated as non-destructive sensing techniques because they enable rapid and relatively low-cost measurements, facilitating their use in field settings.

These techniques provide complementary information by measuring the electrical and optical properties of biological materials, respectively. Their integration into a single platform may therefore enable more comprehensive assessment of plant physiological status, food quality, and freshness. Accordingly, this study developed a portable multimodal sensing platform integrating bioimpedance and VIS–NIR transmission spectroscopy for non-destructive assessment of food and agricultural materials. The system consisted of an AD5941-based impedance module with a four-electrode configuration and an optical module using a C12880MA microspectrometer and a xenon light source. Preliminary performance was evaluated using reference electrical components, dye solutions, commercial instruments, and intact leaves. The impedance module showed mean absolute errors of 0.53% at 50 Hz–1 kHz and 0.52% at 1–20 kHz for reference resistors. In leaf measurements, the four-electrode configuration reduced electrode–tissue interface effects and provided clear frequency-dependent impedance responses. The optical module showed coefficients of variation of 0.31–1.49% for dye standards and high spectral agreement with an Ocean Optics spectrometer ($r = 0.917–0.997$). Characteristic leaf spectral features, including chlorophyll absorption near 680 nm and the red-edge region, were also reproduced. These results demonstrate reliable acquisition of complementary electrical and optical information using the developed portable platform. Further validation under controlled stress conditions and across diverse food and agricultural materials is needed to determine whether multimodal integration improves diagnostic and quality assessment performance. With such validation, the platform is expected to contribute to non-destructive crop monitoring, production management, and quality assessment of food and agricultural raw materials.

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Abstract 813 | Poster 74

Multi-Frequency Bioelectrical Impedance Analysis for Non-Destructive Evaluation of Meat Quality During Storage

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ABSTRACT

The food industry requires rapid, non-destructive technologies to facilitate meat quality monitoring, storage management, and processing decisions. Bioelectrical impedance analysis (BIA) provides a cost-effective sensing method for detecting tissue-level electrical changes related to water distribution, cell viability, and post-storage quality alterations. This study evaluated multi-frequency BIA as a sensor-based technique for assessing meat quality and storage-induced tissue changes. Meat samples were analyzed using BIA at 50, 100, and 180 kHz, with resistance, reactance, impedance magnitude, and phase angle calculated. Conventional meat quality traits, such as color parameters, pH, and cooking loss, were integrated with BIA-derived features. Technical repeatability, mixed-model analysis, principal component analysis, machine learning, animal-level bootstrapping, and Monte Carlo simulation were employed to assess sensor performance, uncertainty, and robustness.

BIA measurements demonstrated strong repeatability across technical replicates, exhibiting low within-sample variation. Storage resulted in distinct electrical shifts from fresh to 120-day samples, with animal-level bootstrap analysis confirming decreases in resistance, reactance, impedance magnitude, and phase angle. Monte Carlo simulations indicated that these storage-related changes remained stable under realistic measurement noise, supporting the robustness of the sensor response. Meat quality analysis revealed changes in lightness values during storage, whereas pH, redness, yellowness, and cooking loss exhibited weaker or less consistent trends. Machine learning models demonstrated exploratory potential for cut classification and meat quality prediction, although the limited number of biological samples constrained predictive performance.

In summary, multi-frequency BIA demonstrated significant potential as a rapid, non-destructive sensing tool for detecting storage-associated changes in meat tissue. This approach may facilitate the development of sensor-guided meat quality monitoring, processing decision support, and data-driven food engineering applications.

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Abstract 827 | Poster 75

NIR Imaging with Deep Learning for Real-Time Moisture Prediction During Microwave Vacuum Drying

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ABSTRACT

Real-time moisture monitoring remains a major challenge in microwave vacuum drying (MVD), where product quality is typically assessed using intermittent sampling and destructive offline measurements. Consequently, drying process control is usually empirical, and parameters optimization is based on trial-and-error experiments, which are time- and resource-consuming, limiting process efficiency, energy utilization, and product consistency. Existing imaging-based approaches primarily focus on post-process analysis and rarely provide continuous feedback for intelligent process monitoring and control.

This study presents a retrofit near-infrared (NIR, 720–1000 nm) imaging system for real-time, non-contact, sample-level moisture prediction during a commercial-scale MVD process. Beet slices were selected as model material, and reference moisture contents (MC) were determined using the standard thermogravimetric method. A dataset comprising 334 beet samples monitored across seven drying time points (0–27 min, 3 W/g) was collected, resulting in NIR images paired with corresponding moisture ratios (MR) ranging from approximately 0.85 to 0.10.

An automated pipeline was developed for monochrome NIR image correction and individual beet segmentation. Three deep-learning strategies were developed to investigate how NIR intensity and spatial changes contribute to moisture prediction: 1) a single-channel ResNet-18, 2) a dual-channel CNN jointly processing paired images, and 3) a Siamese ResNet-18 that explicitly learns feature-level differences. These models achieved RMSE from 5.29 to 6.54 and R^2 from 0.944 to 0.963 for MC prediction, and RMSE from 4.70 to 4.95 and R^2 from 0.966 to 0.970 for MC loss prediction. Trained models were integrated into a monitoring platform and evaluated by continuously estimating MC of new beet samples throughout the drying process.

The proposed framework provides a practical low-cost retrofit sensing solution for precise endpoint determination for the industrial food drying process for improved efficiency and product quality consistency. This work also establishes a foundation for intelligent drying systems capable of adaptive process control.

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Abstract 853 | Poster 76

Machine Learning Prediction of Papaya Quality Characteristics using Vision Transformers

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ABSTRACT

This study implemented machine learning (ML) models, including Vision Transformer (ViT) and Data Efficient Image Transformer (DeiT), to objectively assess the ripeness of papaya (Rainbow, Solo, Kapoho) by predicting texture, pH, and total soluble solids. Additionally, classify based on variety and ripeness, separately. All papaya samples were bought with an entirely green or mostly green appearance and left in 21℃ until they adopted a yellow appearance. The degree of yellow appearance was random to obtain a wide range of quality characteristics. Each papaya had four images taken by rotating it by 90 degrees, using a digital camera. The texture was evaluated by measuring pulp firmness, peel firmness, and adhesiveness. Afterward, the remaining papaya was peeled and crushed to obtain the concentrate, which was used to measure pH and total soluble solids. These characteristics and images were compiled into a single table and uploaded into the ML model to develop regression and classification models. The dataset was divided into training, validation, and test sets with a ratio of 8:1:1. The mean squared error (MSE), coefficient of determination (R^2), mean absolute error (MAE), F1-score, and root mean squared error (RMSE) were the metrics to evaluate each model's performance. ML models were trained using 5,892 papaya images obtained through image augmentation from a total of 300 papaya fruits. The regression predictions for seed weight, total weight, pH, and total soluble solids varied, with R^2 values ranging between 0.60 and 0.83, depending on the selected model (ViT or DeiT). The study emphasized a strong correlation between papaya images and their features, such as texture quality and total soluble solids. AI applications maintain strong resilience for non-invasive assessment and possibly predictions of the human sense of taste.

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Abstract 857 | Poster 77

Using Computer-Aided Design Instructional Tools and 3-D Printing to Improve Spatial Visualization Skills of Biological Engineering Students

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ABSTRACT

An important component of engineering design is 3-D spatial visualization, which is defined as the ability to mentally rotate an object in space. Spatial visualization skills (SVS) have been shown to relate to creativity and are critical for design and prototype development. This study assessed the impact of two instructional changes on student SVS over four years (2022 – 2025, 29–49 students per cohort) in the computer-aided design (CAD) component of an introductory biological engineering course. Instructional changes: (1) from 2023, discipline-relevant examples and homework were utilized, including food- and agriculture-related models; (2) in 2025, 3-D printed prototypes were provided to connect with the CAD model examples and assignments. Prior to any CAD instruction (pre-test), and in the last week of class (post-test), students took the Revised Purdue Spatial Visualization Test (PSVT:R), a validated instrument to assess SVS in first-year engineering students. Students improved significantly from pre- to post-test in three of the four years (means +2.08, +1.87, and +1.29 points, $p < 0.05$; +0.97 in 2025, not significant) with low normalized gains (Hake gain range 0.12–0.19). For example, in 2023 the bottom half of the class (median split, $n = 19$; pre-test 14.42 ± 4.53) gained +3.84 points, while the top half ($n = 19$; pre-test 25.74 ± 2.45) declined slightly (−0.11). Neither the introduction of discipline-relevant examples in 2023 nor the addition of 3-D printed prototypes in 2025 produced a significant change in gain across years (ANOVA $p \geq 0.6$). Lower-scoring students (on the pre-test) showed larger increase during the course than higher-scoring students, but this pattern was also present in the baseline year (2022), so it cannot be attributed to the instructional changes. Future work should measure additional outcomes that these changes are most likely to affect, such as engagement and CAD-model performance.

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Abstract 869 | Poster 78

Interpretable and Accelerated Colorimetric Biosensor Readout toward Food Analysis Using RGB Thresholds

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ABSTRACT

Colorimetric biosensors offer simple and visually intuitive detection, but reliable interpretation often requires prolonged reaction times to produce a clear endpoint. Subtle early color changes are difficult to distinguish by the naked eye, increasing subjectivity and inter-observer variation. To address this limitation, an interpretable RGB threshold-based method was developed for rapid and objective assessment of a gold nanoparticle-based colorimetric biosensor for protein-target detection. Reactions were performed in phosphate-buffered saline (PBS), and time-resolved images were acquired under fixed illumination and camera settings. Based on the previously established 90-min reaction time and spectral criterion, the 90-min endpoint served as the reference, with a peak wavelength ≥545 nm classified as positive. Mean RGB values from the upper reaction region were analyzed for 80 independent samples (40 endpoint-positive and 40 endpoint-negative). At 4 min, the G channel provided the strongest discrimination between endpoint classes, with a higher area under the receiver operating characteristic curve (AUC) than the B channel (0.994 vs. 0.966). This time point was the earliest at which accuracy exceeded 95%, with a single-channel threshold of G ≥6.5 yielding 97.5% accuracy. The established readout time was therefore reduced from 90 to 4 min, corresponding to a 95.6% reduction. These findings support rapid and transparent classification of the final spectral endpoint using a single G-channel threshold. This fundamental dataset supports the evaluation of matrix-induced color interference and the development of adjusted RGB thresholds for colored and turbid food samples.

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Abstract 809 | Poster 79

An Artificial Intelligence-Supported Roleplay Learning Strategy in Food Engineering Education to Train Future Food Scientists

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ABSTRACT

The use of artificial intelligence (AI) technology, such as ChatGPT, presents both challenges and opportunities for higher education across all disciplines. Misuse of AI tools in education can lead to ethical issues and stifle the development of critical thinking. However, integrating AI into pedagogy can provide students with essential skills and competencies for their future careers.

With support from the USDA Higher Education Challenge program, this study developed an AI-integrated pedagogy consisting of AI-supported role-play strategies and curricula for food engineering education. Through simulated future work environments, students assume different roles related to AI, including consultees, coworkers, and supervisors. A series of active learning activities involved AI use were developed and incorporated in students' learning process: AI prompts were provided in lecture slides to allow students interact with AI by asking questions and follow-ups to enhance learning of fundamental concepts in broader and deeper ways; lecture examples/practices were solved by AI tools to allow students learn how to solve simple engineering problems by reviewing, criticizing, and correcting the AI solutions; homework and comprehensive problems based on real-life contexts were assigned as projects to allow students use AI tools to analyze problems, develop solutions, and prepare reports.

The AI-supported teaching activity and curricula were tested with a cohort of food science students. A course survey and focus group were conducted with several key areas of impact and challenges were highlighted: Skill Development: Students reported significant gains in technical soft skills and AI prompt generation; Career Readiness: AI-assisted projects were highly valued for demonstrating real-world applications and providing structural support for professional tasks and expectations; Learning Obstacles: Despite the benefits, significant challenges remain, including technical unit errors, difficulty processing graphical data, and a 'negative affect on memory retention' caused by over-reliance on AI-generated solutions.

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Abstract 892 | Poster 80

Inverse Estimation of Effective Moisture Diffusivity in Apple Slices for Hot-Air Drying Process Control

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ABSTRACT

Hot-air drying is among the most energy-intensive food unit operations, running at 10-60% efficiency. Real-time optimal control requires a first-principles food model whose parameters are physically meaningful and transferable across equipment, scale and food-stock switchover. Its limiting unknown, effective moisture diffusivity (D_{eff}), cannot be measured directly and is seldom reported with uncertainty.

Objective: To estimate the temperature and moisture dependence of D_{eff} in apple slices by inverse modeling of drying data, with identifiability analysis, so the cyber-physical drying model carries quantified uncertainty.

Methods: Fuji apple slices (5 mm) were dried in a pilot-scale impingement oven at 65, 75, 80, 85 °C for 80 min, logging surface and center temperature, moisture and air conditions. A 1-D coupled heat and mass transfer model (Fourier and Fick, temperature-dependent thermophysical properties) was solved by weighted implicit finite differences, with D_{eff} log-linear in temperature (Bigelow form; D_r, z). Scaled sensitivity coefficients (SSC) screened identifiability before nonlinear least-squares estimation.

Results: SSCs showed weak z sensitivity and strong D_r-z correlation, so z was held constant and only D_r estimated. Reparameterizing at the optimal T_{ref} (78.9 °C) minimized that correlation, narrowing its interval. D_{eff} rose from 3.16×10^{-11} m^2/s at 65 °C to 1.22×10^{-9} m^2/s at 85 °C, with D_r = 7.61 (95% CI 5.49-9.74) × 10^{-10} m^2/s. Estimation error stayed below 10%; values agree with literature for similar products. Predictions matched moisture (RMSE 0.04-0.16 kg/kg dry basis). The food model uses diffusivity with bounded uncertainty, while improved identifiability at higher drying temperatures guides further validation.

Relevance: No sensor can directly measure moisture inside a moving slice, so processors often over-process products, wasting energy and reducing quality. A physics-based diffusivity model with known uncertainty can act as a virtual sensor, enabling real-time control of yield and energy use without new hardware.

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Abstract 927 | Poster 82

Use of Machine learning to avoid spoilage in the fresh produce industry

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ABSTRACT

Globally, food loss reaches nearly 2.5 billion tons each year, with the United States alone discarding 60 million tons annually. Because of its perishable nature, large amounts of fresh produce are wasted at an industrial scale. Recent advances in machine learning and artificial intelligence can be harnessed to solve the industrial food waste problem. This poster explores the use of AI and machine learning models to determine the shelf-life of strawberries in the food chain.

A MATLAB-based machine learning framework was constructed to assess images and classify strawberries by shelf-life based on image features. The initial research completed basic training on a first version of the model, achieving 85% accuracy after 10 epochs to classify strawberries into two groups. This study focuses on expanding the training database and improving the model overall, including increasing accuracy. Additional data (images) were added to train the model and expand its capabilities, and extensive training was completed. The image database was partitioned into three segments: 55% for the primary training set, 25% for validation, and the final 20% reserved for testing. The model accurately classified all 3 shelf-life classes with 100% accuracy. Additional training is underway to further improve the model using a larger and more complex database.

By implementing image capture and AI, strawberries (and eventually other fruits) with shorter shelf-life can move through the process at the right time, optimizing the supply chain. In the warehouse, periodic photos can be taken to analyze shelf-life, which can be used to sort the produce accordingly and inform supply chain decisions. This technology can also be implemented in grocery stores to sell ripe fruit first, rather than using a first-in, first-out approach that may not account for shelf-life variation.

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Abstract 956 | Poster 83

A Simplified Temperature Prediction Model for Frozen Foods during Post-Delivery Storage in Insulated Packaging

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ABSTRACT

Temperature increases in frozen foods after delivery can affect product quality during the final stage of the cold chain. However, practical models for estimating the warming time of frozen products often require numerous thermal and packaging parameters. This study aimed to develop a simplified temperature prediction model using a limited number of readily measurable variables. Ice samples with different thicknesses and masses were initially stored at −30 °C in expanded polystyrene (EPS) boxes and subsequently exposed to controlled ambient temperatures of 25, 30, and 35 °C. The EPS box had external dimensions of 25.8 × 25.8 × 26.7 cm and a wall thickness of 2 cm. The thermal conductivity of EPS was assumed to be 0.03 W m^{-1} K^{-1}, giving an effective heat transfer coefficient of 1.5 W m^{-2} K^{-1} based on (U=k/L). Internal and external convective resistances were neglected, and the outer surface of the EPS box was assumed to instantaneously equilibrate with the ambient temperature, corresponding to a first-kind (Dirichlet) boundary condition. Because the Biot number was sufficiently small, a lumped-capacitance model was used to estimate the theoretical warming time from −30 to −5 °C. A time-correction factor, defined as the ratio of experimentally measured warming time to the theoretical warming time, was modeled as a function of ice thickness, mass, and ambient temperature. The regression model showed strong predictive performance, with an R^2 of 0.9675. These results demonstrate that the warming time of frozen products in EPS packaging can be effectively estimated using a simplified model with a limited number of practical input variables. This study provides foundational data for subsequent development of models to predict food temperature after cold-chain interruption following delivery and to estimate the required PCM quantity for maintaining frozen-food temperatures.

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Abstract 959 | Poster 84

Non-destructive simultaneous classification of species, roast level, and geographic origin of single coffee beans using NIR hyperspectral imaging and an explainable multi-task 1D-CNN

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ABSTRACT

Accurate identification of coffee species, roast level, and geographic origin is essential for market authentication, fair pricing, and quality assurance. However, conventional analytical methods are often destructive, time-consuming, and unsuitable for rapid, individual-bean assessment. This study proposes a non-destructive approach integrating near-infrared hyperspectral imaging (NIR-HSI) with a multi-task one-dimensional convolutional neural network (1D-CNN) for simultaneous classification of these three attributes at the single-bean level. Reflectance spectra (900-1700 nm) were acquired from 7,950 individual roasted coffee beans covering two species, five roast levels, and thirteen geographic origins. After standard normal variate (SNV) preprocessing, the optimized multi-task 1D-CNN achieved test accuracies of 99.75%, 98.58%, and 97.99% for species, roast level, and geographic origin classification, respectively. To improve model interpretability and reduce spectral dimensionality, Gradient-weighted Class Activation Mapping (Grad-CAM) was employed to identify 29 wavelengths shared across the three classification tasks. These wavelengths were associated with spectral features related to key coffee constituents, including moisture, lipids, and chlorogenic acids. Using only these selected wavelengths, the model maintained test accuracies above 92% for all three tasks, demonstrating the potential for substantial spectral reduction with limited loss of predictive performance. Furthermore, Grad-CAM and SHapley Additive exPlanations (SHAP) were used to interpret model predictions by identifying influential spectral regions and assessing wavelength contributions to classification outcomes. Overall, this study demonstrates the potential of combining NIR-HSI, multi-task deep learning, and explainable artificial intelligence (XAI) for accurate and interpretable multi-attribute coffee authentication. The proposed approach provides a foundation for developing efficient, non-destructive, and potentially cost-effective solutions for individual-bean quality assessment in the coffee industry.

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Poster Presentations: Tuesday, November 10

Tuesday, November 10, 2026, 3:00 pm-4:00 pm. Kona Ballroom

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Poster Session 4: Food Safety & Microbial Control

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Abstract 610 | Poster 91

Decontamination of Foods and Processing Surfaces by Pulsed Ultraviolet Light: An Update

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ABSTRACT

Pulsed Ultraviolet (UV)-Light is an emerging technology, which has a potential to be used for decontamination food products. The light generated in pulses consists of a continuum broadband spectrum from deep UV to infrared, especially rich in UV range below 400 nm, which is germicidal. Recent studies suggest pulsed UV light inactivates microorganisms not only photochemical reactions, but also by other mechanisms associated with the use of high intensity pulses such as photo- thermal and photo-physical mechanisms, Microbial cells become inactive with conventional UV induced photochemical reactions have taken place, but the cell structures remain intact after UV treatment. However, pulsed UV light also damages the cell structures for some of the pulsed UV treated cells. Therefore, pulsed UV-light can be considered a powerful tool for inactivation of microorganisms on food surfaces or liquids. Many studies have demonstrated the effectiveness of pulsed UV-light on microbial inactivation. In this paper, various recent studies in our lab for applications of pulsed UV-light treatment including food and food processing surfaces will be presented.

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Abstract 624 | Poster 92

OSMOTIC STRESS ENHANCES ANTIBIOTIC RESISTANCE AND BIOFILM FORMATION OF *LISTERIA MONOCYTOGENES* IN DAIRY PROCESSING ENVIRONMENTS

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ABSTRACT

Listeria monocytogenes is a persistent foodborne pathogen capable of surviving multiple environmental stresses encountered during dairy processing. Exposure to sublethal stress conditions may promote physiological adaptation, increasing bacterial persistence and reducing susceptibility to antimicrobial agents. This study investigated the effects of osmotic stress induced by 4% and 6% NaCl on the survival, antibiotic resistance, and biofilm-forming ability of 10 *L. monocytogenes* isolates recovered from a dairy processing facility.

Exposure to osmotic stress resulted in significant, strain-dependent differences in bacterial survival ($P < 0.001$). At 4% NaCl, viable counts decreased by up to 1.03 $\log_{10}$ CFU, whereas exposure to 6% NaCl enhanced survival in some isolates, with increases of up to 0.24 $\log_{10}$ CFU, indicating adaptive responses to elevated salt concentrations. Osmotic stress also substantially altered antimicrobial susceptibility profiles. Minimum inhibitory concentrations increased for several clinically relevant antibiotics, including tetracycline (≤0.5 to 16 µg/mL), vancomycin (≤1 to >64 µg/mL), and lincomycin (≤4 to >256 µg/mL). In addition, biofilm formation remained strong under osmotic stress and was enhanced at higher NaCl concentrations. Biofilm densities reached 7.85 log CFU/cm², with significantly greater biomass observed on polyurethane than on stainless steel surfaces.

These findings demonstrate that osmotic stress promotes adaptive responses that enhance both antimicrobial resistance and biofilm formation in *L. monocytogenes*. Such stress-induced adaptations may facilitate the long-term persistence of this pathogen in dairy processing environments and reduce the effectiveness of sanitation procedures. The results highlight the importance of incorporating environmental stress factors into food safety risk assessments and the development of effective control strategies for dairy production facilities.

This study was funded by the Minister of Science under the **Regional Initiative of Excellence** Program.

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Abstract 625 | Poster 93

Whole-Genome Sequencing Reveals Foodborne *Staphylococcus epidermidis* as a Reservoir of Antimicrobial Resistance and Mobile Genetic Elements

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ABSTRACT

Coagulase-negative staphylococci (CoNS), particularly *Staphylococcus epidermidis*, are common inhabitants of the food processing environment and frequent contaminants of ready-to-eat (RTE) foods. Although traditionally regarded as harmless commensals, the emergence of multidrug-resistant *S. epidermidis* as an opportunistic pathogen and reservoir of antimicrobial resistance (AMR) genes has increased concern regarding its role at the food–human interface. This study aimed to investigate the antimicrobial resistance profiles and genomic characteristics of 26 *S. epidermidis* isolates recovered from RTE foods using whole-genome sequencing (WGS) and phenotypic antimicrobial susceptibility testing.

Genomic analysis identified 17 sequence types (STs), with ST329 being the most prevalent, and revealed one previously undescribed sequence type, indicating substantial genetic diversity among the isolates. Phenotypic testing demonstrated high resistance rates to erythromycin (80.77%) and clindamycin (73.08%). Whole-genome sequencing detected numerous antimicrobial resistance determinants, including *mecA, norA, norC,* and *dfrC*, together with additional genes associated with multidrug resistance. Mobile genetic elements were identified in 96.15% of isolates, indicating a high potential for horizontal gene transfer and dissemination of resistance determinants within the food chain.

The combination of extensive genetic diversity, multidrug resistance, and widespread mobile genetic elements highlights the epidemiological significance of food-associated *S. epidermidis*. These findings demonstrate that RTE foods constitute an overlooked reservoir of antimicrobial resistance genes with the potential to contribute to their dissemination through the food chain. The results emphasize the importance of including coagulase-negative staphylococci in food safety surveillance and microbial risk assessment within a **One Health** framework.

This work was funded by the Minister of Science under the **Regional Initiative of Excellence** Programme.

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Abstract 626 | Poster 94

INFLUENCE OF OSMOTIC AND HIGH HYDROSTATIC PRESSURE STRESS ON VIRULENCE FACTOR EXPRESSION IN ENTEROCOCCI ISOLATED FROM FOOD

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ABSTRACT

This study aimed to determine the prevalence of selected virulence factors—gelatinase, hemolysin, biofilm formation, and slime production—and associated genes in enterococci isolated from food of animal origin, and to assess the impact of osmotic stress and high pressure processing (HPP) on gene expression. Seventeen virulence-associated genes and corresponding phenotypic traits were analyzed. Strains showing genotype–phenotype discrepancies and carrying gelE, asa1, esp, and cylL were selected for further study. None of the isolates exhibited strong biofilm formation. Slime production was observed in 38.5% of strains, gelatinase activity in 41%, γ-hemolysis in 55%, and α-hemolysis in 45%. All isolates carried 1–13 virulence genes, with gelE (85.9%), sprE (78.2%), and asa1 (75.6%) being the most prevalent. Expression of all genes increased at 4% NaCl. At 7% NaCl, gelE, esp, and cylL were further upregulated, while asa1 expression decreased. HPP at 400 MPa had no significant effect, whereas 500 MPa significantly increased esp and cylL expression. These results indicate that foodborne enterococci may serve as reservoirs of virulence genes, and that stress conditions can modulate their expression, potentially affecting food safety and public health.

Funded by the Minister of Science under „The Regional Initiative of Excellence Program".

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Abstract 627 | Poster 95

Biofilm Survival of *Listeria monocytogenes* after High-Pressure Processing: Implications for Food Safety

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ABSTRACT

Listeria monocytogenes is a major foodborne pathogen that persists in food processing environments due to its strong biofilm-forming ability. The bacterium readily colonizes food-contact and packaging surfaces and can withstand standard sanitation. High-pressure processing (HPP) may affect not only survival but also stress adaptation and virulence.

This study evaluated the effects of sublethal HPP (200 and 400 MPa for 5 min) on biofilm formation and gene expression. Strains from serogroups IIa and IVb were tested. Biofilms were developed on stainless steel (SS304), PET, and PP. Viable cells and biomass were measured, and expression of nine virulence- and stress-related genes was analyzed by qPCR.

HPP reduced biofilm viability and biomass in a pressure-dependent manner, with stronger effects at 400 MPa (~5 $\log_{10}$ CFU/cm²). SS304 supported higher biofilm formation than PET and PP. Genes *flaA* and *sigB* were strongly affected, while most virulence genes were downregulated. IVb strains showed stronger stress responses, indicating possible serogroup-specific adaptation.

Project funded under the designated subsidy of the Minister of Science and Higher Education Republic of Poland, task entitled: The Research Network of Life Sciences Universities for the Development of the Polish Dairy Industry – Research Project.

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Abstract 661 | Poster 96

Design and Evaluation of a Hydrodynamic Vortex Nanobubble Reactor Coupled with Cold Plasma for Biofilm Control

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ABSTRACT

Cold plasma has demonstrated antimicrobial effects; however, its application through plasma-activated water (PAW) remains a challenge in large-scale applications due to the short lifetime of reactive oxygen and nitrogen species (RONS). Nanobubble water (NBW) technology is an emerging technique that produces highly stable, nanoscale bubbles with a high interfacial area, which could play an important role in reactive species lifetimes due to their electrostatic stability. However, conventional methods often require high flow rates and complex equipment, limiting applications. The objective of this study was to develop a hydrodynamic nanobubble vortex reactor integrated with cold plasma and evaluate its performance through physicochemical characterization and antibiofilm activity.

A hydrodynamic NB reactor was designed with a specialized vortex-generation system to promote gas breakup through pressure differentials, turbulence, and shear force mechanisms. The generated bubbles were characterized by bubble size and bubble concentration (particles/ml) under optimal operating conditions. The antimicrobial potential was evaluated against a mixed-species biofilm comprising *Rouxiella chamberiensis* FUA12018, *Pseudomonas gessardii* FUA12019, *Pseudomonas constantinii* FUA12020, *Pseudomonas lurida/poae* FUA12023, and *Pseudomonas weihenstephanensis* FUA12024, while the corresponding oxidation-reduction potential (ORP) and reactive oxygen and nitrogen species (RONS) concentrations were measured.

The reactor generated nanoscale bubbles with an average bubble size of 283 ± 11 nm and 10^8 particles/mL. Upon integration with cold plasma, it decreased to 165 ± 18 nm and 10^7 particles/ml. Treatment of biofilms with cold plasma nano-bubbles reduced the cell count by 3.09 ± 0.04 log CFU/cm^2 after 20 min of generation and 5 min of biofilm treatment. The antimicrobial activity corresponded to an increased ORP of 427 mV, an H_2O_2 concentration of 0.624±0 ppm, and an O_3 concentration of 0.171±0.04 ppm.

The hydrodynamic vortex nanobubble reactor provides a scalable, easily incorporated platform for enhancing gas transfer and controlling microbes, with potential applications in sustainable food processing and sanitation technologies.

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Abstract 677 | Poster 97

Development of an Atmospheric Cold Plasma-Based Post-Harvest Process for OTA Mitigation in Liberica Coffee

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ABSTRACT

Background: Liberica (Coffea liberica), an underutilized coffee species, is increasingly valued for its resilience to changing climatic variability, unique sensory traits, and potential to diversify global coffee production. However, green coffee beans remain vulnerable to contamination by ochratoxin A (OTA)-producing fungi during post-harvest handling and storage, posing significant food safety and economic risks. Conventional decontamination methods often rely on thermal treatments that can degrade key coffee quality attributes, including flavor, aroma, and bioactive compounds. Atmospheric Cold Plasma (ACP), an innovative non-thermal food processing technology, offers a promising alternative for microbial control while minimizing quality deterioration.
Objective: This study aims to develop and evaluate an ACP-based post-harvest processing approach for Liberica coffee by establishing analytical and microbiological methods to evaluate its potential for OTA mitigation and quality preservation.
Methods: Green coffee beans were conditioned to controlled moisture levels to simulate natural post-harvest processing conditions, and ACP treatment parameters were optimized for fungal inhibition studies. Analytical protocols including high-performance liquid chromatography (HPLC) were established to quantify caffeine as a quality indicator and provide a platform for future OTA analysis. Additionally, methods for isolation, cultivation, and evaluation of OTA-producing fungi were developed to support the assessment of ACP treatment effects on fungal growth.
Results: Preliminary HPLC results demonstrated average caffeine concentrations of approximately 5.44 mg g^{-1} in green coffee beans, 5.81 mg g^{-1} in roasted coffee, and 5.91 mg g^{-1} in double-roasted coffee. These baseline values will serve as reference points for detecting potential quality changes induced by ACP during future optimization studies.
Conclusion: This research provides a foundation for development of sustainable, non-thermal processing technologies that enhance coffee safety while preserving quality attributes. Integrating ACP with chromatographic and microbiological evaluation establishes a platform for future industrial applications focused on mycotoxin risk reduction, and the advancement of innovative food engineering solutions for the coffee industry.

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Abstract 704 | Poster 98

Engineering a Charge-Reversal Delivery System for Precision Antimicrobial Release to Enhance Microbial Safety of Dairy Foods

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ABSTRACT

Biofilm formation on dairy processing equipment is a major source of microbial contamination, compromising food safety and causing substantial economic losses. Although the natural cationic antimicrobial ε-polylysine (EPL) is a promising alternative to conventional chemical disinfectants, its application in dairy systems is limited by strong electrostatic interactions with negatively charged milk proteins, resulting in reduced antimicrobial efficacy. To overcome this challenge, we engineered a pH-responsive charge-reversal polymer (EPL-DA) as a precision antimicrobial delivery system that protects EPL from premature protein binding while enabling site-specific activation within the acidic biofilm microenvironment.

EPL-DA was synthesized by direct conjugation of 2,3-dimethylmaleic anhydride (DA) to ε-polylysine and characterized by 1H NMR, FTIR, UV–Vis spectroscopy, and free amino-group assays. The pH-responsive charge-reversal behavior was verified by zeta potential measurements and hydrolysis studies. Antibacterial activity against *Listeria monocytogenes* and *Salmonella Typhimurium* was evaluated using broth microdilution assays under both standard culture conditions and simulated dairy environments containing whey protein and casein. Biofilm disruption was assessed using crystal violet staining.

EPL-DA maintained a negatively charged surface under neutral conditions and restored its cationic antimicrobial activity under acidic conditions. Compared with native EPL, EPL-DA exhibited reduced interference from milk proteins while retaining effective antibacterial activity and enhanced biofilm disruption under dairy-relevant conditions. These findings demonstrate that charge-reversal engineering provides an effective strategy for precision antimicrobial activation in complex dairy matrices and represents a promising approach for improving biofilm control and food safety in dairy production.

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Abstract 720 | Poster 99

Title: Synergistic pasteurization and sanitation using food-grade antimicrobials and mild physical stress

Synergistic pasteurization and sanitation using food-grade antimicrobials and mild physical stress

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ABSTRACT

Thermal processing is the primary approach for inactivating pathogenic and spoilage organisms and ensuring safety of food and processing equipment. However, high temperatures and intensive chemical sanitation reduce product quality and increase energy use. Synergistic processing combining food-grade antimicrobial compounds with mild physical treatments is an emerging approach to lower processing intensity while preserving safety.

Objective: To evaluate the synergistic antimicrobial efficacy of GRAS compounds, olive pomace extract (OPE), propyl gallate (PG), and ethyl lauroyl arginate (LAE), combined with mild heat (55-65°C), for surface sanitation and beverage pasteurization.

Methods: Biofilms of E. coli and L. innocua on stainless steel and polystyrene were treated with OPE or LAE plus mild heat (55°C) and benchmarked against heat alone and chlorine. PG (1-10 mM) with mild heat (55-65°C) was evaluated against E. coli O157:H7 in apple juice, carrot juice, and coconut water. LAE with mild heat (55°C) was tested for pasteurization of coconut water and almond milk against E. faecium. Inactivation kinetics, mechanism, and energy use were assessed.

Results: OPE/LAE plus mild heat achieved 3–5 log reductions of biofilms at 55°C versus 75°C with heat alone, lowering D-values from over 10 minutes to under 0.5 minutes. In juices, 5 mM PG with mild heat achieved ≥5-log reduction of E. coli O157 at 55°C for 2.5 min or 60°C for 1 min, versus 75°C for 2 min with heat alone, with no significant color change and estimated U.S. juice-processing energy savings of 1.13 TBTU/year. LAE-assisted mild heat achieved 5-log reduction of E. faecium in coconut water and almond milk at 55°C, versus 75°C for heat alone. Membrane damage and metabolic suppression were shared inactivation mechanisms.

Relevance: This research offers an alternative to traditional thermal processing, reducing energy, water, and chemical sanitizer use while enabling production of minimally processed food.

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Abstract 722 | Poster 100

Health impacts of dietary polystyrene nanoplastics: absorption,tissue accumulation, and chronic immune and metabolic effects in mice

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ABSTRACT

Microplastics—plastic particles smaller than 5 mm—are an emerging contaminant in the human food supply. Polystyrene (PS) is among the most widely used polymers in food-contact materials such as disposable cups, foam takeout containers, and packaging films, from which micro- and nanoplastics can migrate into food, particularly under heating and contact with fatty or acidic matrices. While microplastics have now been detected in drinking water and a range of processed foods, the health consequences of dietary nanoplastics—particles under 1 μm, small enough to cross biological barriers and enter the bloodstream—remain poorly characterized in mammals. Here we examined the cellular uptake, biodistribution, and chronic effects of PS nanoplastics. In vitro, uptake occurred within 24 hours of treatment in both 3T3-L1 adipocytes and Caco-2 colon carcinoma cells, indicating absorption across intestinal and adipose cell models. In mice, orally administered nanoplastics were rapidly absorbed into the blood within one hour and accumulated in the kidney and epididymal adipose tissue by 24 hours. Following 16 weeks of repeated exposure, mice showed a significant decrease in leukocyte counts, elevated fasting glucose, and altered fecal microbiota composition. Together, these findings demonstrate that PS nanoplastics present in food are readily absorbed and accumulate in mammalian tissues, and that long-term dietary exposure can disrupt immune function, glucose metabolism, and the gut microbiome. Because PS is a dominant material in processed-food packaging, these results highlight a plausible route by which habitual consumption of packaged and processed foods may contribute to immune abnormalities and chronic metabolic disease, underscoring the need to evaluate nanoplastics as a dietary health risk across the processed-food supply.

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Abstract 723 | Poster 101

Comprehensive Kinetic Modeling of Aflatoxin B1 Photodegradation under UV Irradiation for Process Design and Optimization

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ABSTRACT

Aflatoxin B1(AFB_1) is among the most toxic and carcinogenic mycotoxins, posing significant challenges to food safety, product quality and global food security. Ultraviolet (UV) processing is a promising non-thermal, chemical free intervention for AFB_1 mitigation. However, its industrial implementation requires reliable kinetic models to support process optimization, reactor design, and scale-up. The objective of this study was to characterize the degradation kinetics of AFB_1 and identify the mathematical model that best describes its degradation behavior under different UV processing conditions. AFB_1 standard solutions were exposed to UVB and UVC irradiation at lamp powers of 3, 6, and 9W under continuous stirring. Residual AFB1 concentrations were quantified using ELISA and LC-MS. Experimental data were fitted to six kinetic models: zero-order, first-order, second-order, Weibull, first-order with plateau, and biphasic formulations. Model performance was evaluated using the residual sum of squares(RSS), root mean square error(RMSE), coefficient of determination(R^2), Akaike Information Criterion corrected for small sample size(AICc), Bayesian Information Criterion(BIC), and residual analysis. Increasing lamp power significantly accelerated AFB_1 photodegradation. Mean first-order degradation rate constants increased from 0.0071 ±0.0013 min^{-1} at 3 W, to 0.0081 ±0.0006 min^{-1} at 6 W, and 0.0138 ±0.0010 min^{-1} at 9 W, representing an approximately 70% increase from 6 to 9 W. No significant differences ($p>0.05$) were observed between UVB and UVC irradiation at equivalent power levels or between ELISA and LC-MS, indicating that degradation was governed primarily by UV dose rather than wavelength or analytical method. Across all processing conditions, First-order and Weibull models consistently provided the best fits, with R^2 values of approximately 0.97 and 0.999, respectively. Zero- and second-order models showed inferior performance, while the additional parameters of plateau and biphasic models did not improve model quality. These findings provide kinetic parameters to support the design, optimization, and scale-up of UV-based AFB_1 mitigation processes.

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Abstract 735 | Poster 102

A Predictive Risk-Based Framework for Adaptive Environmental Monitoring in Low-Moisture Food Facilities

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ABSTRACT

Environmental monitoring programs (EMPs) in low-moisture food (LMF) facilities commonly rely on fixed, zone-based sampling, limiting detection of emerging contamination hotspots when sampling resources are constrained. This study developed and evaluated a predictive risk-based framework for adaptive EMP sampling in LMF processing facilities. A literature-informed synthetic facility comprising 100 environmental monitoring sites across four hygiene zones was simulated for 520 weeks, generating 52,000 site-weeks. The latent contamination process incorporated site risk, residue, dust, traffic, sanitation, moisture, maintenance, spatial transfer, and temporal persistence. *Salmonella* spp. was used as the target environmental pathogen. The predictive task used 14 site-week features to identify sites likely to become contaminated during the subsequent 8 weeks. Six models—Logistic Regression, Random Forest, Multilayer Perceptron, Gated Recurrent Unit, Graph Convolutional Network, and Graph Convolutional Network–Gated Recurrent Unit—were compared using chronological train-test splits across five random seeds. At the 15-site/week sampling budget, Random Forest achieved the highest mean PR-AUC (0.233), ROC-AUC (0.647), Precision@15 (0.257), and Recall@15 (0.255). Random Forest-guided sampling detected 63.6 ± 4.9 contaminated site-weeks compared with 31.2 ± 7.3 for the standard EMP strategy, defined as fixed sampling of 15 sites/week according to the zone-based sampling plan, and increased detections per sample from 0.0135 ± 0.0032 to 0.0275 ± 0.0021 (2.04-fold). Hotspot capture increased from 13.55% to 26.45%. All model-informed strategies significantly outperformed the standard plan ($p < 0.006$). Across sampling budgets of 10–70 sites/week, the best learned strategy provided 1.54–2.52-fold higher detection efficiency than the standard plan. Predicted hotspots were converted into a proof-of-concept robotic sampling route. These findings from simulated data suggest that the proposed framework can improve EMP sampling efficiency and enable more targeted, risk-based monitoring in LMF facilities. Future work should validate its performance using historical EMP data from one or, preferably, multiple LMF facilities.

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Abstract 765 | Poster 103

Comparative Evaluation of Light Sources for Bacterial Inactivation: Process Efficiency and Cellular Damage Responses

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ABSTRACT

Although light-based technologies have been widely investigated for microbial control, systematic comparisons among light sources remain limited. This study aimed to characterize the energy emission properties of 12 light sources, quantitatively compare their microbial inactivation efficiencies, and determine cellular damage patterns associated with each wavelength region. Twelve light sources representing low-pressure UV lamps, light-emitting diodes (LEDs), intense pulsed light (IPL), and UV discharge lamps were evaluated against *Escherichia coli* (ATCC 25922), *Bacillus subtilis* (ATCC 6051), and *Shigella sonnei* (ATCC 29930). Survival curves were fitted to log-linear, Weibull, and double Weibull models to characterize bacterial inactivation kinetics. The fluence required for a 4-log reduction (F_{4D}) and electrical energy per order (E_{EO}) were calculated as process-efficiency parameters. Cellular damage indicators were further assessed in *E. coli* after treatments producing equivalent log reductions. Microbial inactivation performance was strongly dependent on wavelength region, with UV-C-emitting sources requiring the lowest total fluence (0.007–0.029 J/cm²) to achieve a 6-log reduction. The most efficient sources by wavelength region were the UVC lamp (F_{4D}, 0.004–0.006 J/cm²; E_{EO}, 0.015–0.024 kWh/m³), broadband UVB (UVB-BB) lamp (0.081–0.175 J/cm²; 0.83–1.80 kWh/m³), 365 nm LED (27.46–323.46 J/cm²; 50.83–767.50 kWh/m³), and xenon flashlamp (0.105–0.256 J/cm²; not determined), respectively. The UVC and UVB-BB lamp treatments significantly decreased relative dsDNA content to 57.8 ± 11.5% and 49.5 ± 13.6%, respectively ($p < 0.05$), and resulted in greater photoreactivation percentages (24.6 ± 9.5% and 55.7 ± 2.2%, respectively) than the other treatments ($p < 0.05$). In contrast, *E. coli* cells treated with the 365 nm LED exhibited the highest relative ROS level (3.28 ± 0.18; $p < 0.05$) and the lowest total ATP content (6.26 ± 1.96 nM; $p < 0.05$). Membrane permeabilization and morphological deformation were also observed following both IPL and 365 nm LED treatments.

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Abstract 768 | Poster 104

Investigation of Food Removal by Dissolution through Hydrodynamic Removal using Microscale Modelling

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ABSTRACT

Removal of food residues (also termed food foulants) from surfaces is of significance to a wide range of areas and industries. The process of surface cleaning is essential for maintaining food quality and safety through reducing the build-up of food fouling and preventing potential contamination. Despite extensive research, some knowledge gaps remain; particularly, the understanding of microscale interactions between cleaning agents and foulants. Hence, a computational framework is being developed for modelling the physico-chemical cleaning processes and interactions between cleaning agents and foulants on a surface, with a particular focus on simulating the dissolution of foulants at the microscale.

The computational models being developed to simulate surface cleaning are a combination of several mathematical particle-based methods with the current focus being on Smoothed Dissipative Particle Hydrodynamics (SDPD). SDPD solves the Navier-Stokes equations over particles with the addition of thermal fluctuations. Using this, the dissolution of a model homogeneous foulant by hydrodynamic removal using shear application has been investigated. Several scenarios are simulated, including increasing the water to foulant ratio and applying shear periodically allowing for intervals of soaking. In the variable water simulations, a significant decrease in the time taken for complete dissolution is seen as the amount increases, with increasing shear rate further enhancing this. For the intervals of shear simulations, removal time is seen to increase when compared with constant shear, however the soaking periods result in an increased removal following reapplication of shear.

Building on these simulations, the complex physical structure of real foulants on substrates will be modelled through extracting data for various parameters (such as adhesive and cohesive properties) from available experimental and in-house data. Additionally, the model foulant structure will be redesigned based on confocal images of microstructures from literature to create more realistic heterogeneous foulants.

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Abstract 774 | Poster 105

Thermal Inactivation Kinetics of *Listeria monocytogenes* in Low-Acid Canned Pâté-Style Pet Food

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ABSTRACT

Background: Pet food safety extends beyond animal welfare to public health. While *Clostridium botulinum*, is the target microorganism for establishing thermal processes in low-acid canned foods (LACF), *Listeria monocytogenes* still remains a significant public health concern. *L. monocytogenes* is a vegetative pathogen with lower heat resistance. However, post-opening recontamination poses critical risk, making thermal inactivation data essential for risk assessment..

Objectives: To design the thermal processing intensity for a chicken-based pate style pet food while evaluating the thermal inactivation kinetics of *L. monocytogenes* .

Methods: A full factorial design was employed to evaluate the thermal inactivation across temperatures of 60, 65, and 70°C, holding times of 5, 10, and 15 min and pH levels of 5.0, 5.5 and 6.0 (N = 3×3×3 = 27 combinations). A first-order kinetic modeling was applied to determine D and z-values. Global kinetic model incorporating temperature and pH effects were assessed using R^2 analysis and ANOVA (α=0.05).

Results: Thermal processing achieved > 5 log reduction of *Listeria* population across all temperature and pH combinations. At 70°C for 15 min (pH 5.0), populations reduced from 8.0 log CFU/g to < 1 log CFU/g. D-values demonstrated strong temperature and pH dependence, with heat resistance decreasing significantly at higher temperatures and lower pH. Temperature showed a more pronounced effect on inactivation kinetics compared to pH. The global kinetic model demonstrated excellent predictive capability for *Listeria* inactivation at 70°C for 15 min (pH 5.0), achieving > 5 log reduction in this matrix ($p < 0.05$).

Significance: LACF thermal sterilization completely eliminates *L. monocytogenes*, supporting FDA zero-tolerance policy compliance and 21 CFR Part 113 requirements. These kinetic data advance food safety through robust process design validation and post-consumer storage guidance to prevent *L. monocytogenes* multiplication.

Keywords: *Listeria monocytogenes*, Low-acid canned pet food, Thermal process validation, Kinetic modeling

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Abstract 775 | Poster 106

Beyond Thermal Inactivation: Electroporation-Driven Microbial Reduction During Ohmic Heating of Soy Milk

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ABSTRACT

Ohmic heating (OH) is an electro-thermal technology that generates volumetric Joule heat, enabling rapid and energy-efficient food processing. While thermal inactivation by OH is well documented, the phenomenon of non-thermal electroporation by OH is not well understood, which restricts the rational design of OH processes, especially for plant-based beverages such as soy milk.

This study aimed to quantify microbial inactivation in soy milk under thermal and non-thermal OH conditions, and develop a 3D computational model to confirm electroporation occurrence at the cellular scale.

Soy milk was inoculated with ~7 $\log_{10}$ CFU/mL of *Enterococcus hirae* and *Enterococcus durans*. Thermal OH treatment was applied at 50 Hz (50 V/cm for 15 s, then 16.7 V/cm for 435 s; endpoint temperature: 75°C). The contribution of electroporation was isolated by using 40 rectangular pulses (50 V/cm; 1 ms duration; 1 ms interval) that kept the sample below 50°C. A 3D mathematical model coupled the electric potential and energy equations; after validation against experimental temperature profiles, the model was extended to the sub-cellular scale to compute the transmembrane potential (TMP) for *Enterococcus* cells (diameter: 0.5–1 μm; membrane conductivity: 10^{-5} S/m).

Thermal OH treatment achieved 4.46 ± 0.44 and 4.09 ± 0.34 $\log_{10}$ CFU/mL reductions for *E. hirae* and *E. durans*, respectively. Non-thermal pulsed OH treatment yielded reductions of 1.28 ± 0.17 and 1.34 ± 0.19 $\log_{10}$, providing evidence of electroporation. The calculated TMP using mathematical model was 13.21 V, which was well above the electroporation threshold of 1 V, thus verifying electroporation.

These findings establish that OH operates through a dual thermal–non-thermal mechanism, supporting its use as an energy-efficient pasteurization strategy for plant-based beverages. The experimental-computational framework provides quantitative tools for process design and electric field optimization, with future work directed at integrating electroporation kinetics with inactivation modeling toward fully predictive process control.

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Abstract 783 | Poster 107

Atmospheric Cold Plasma for *E. coli* and *Salmonella* Inactivation in Chickpea Grains

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ABSTRACT

Justification: Chickpea is a nutritionally important pulse increasingly consumed as a whole grain and flour ingredient. Like other low-moisture foods, chickpea may become contaminated with enteric pathogens before processing, creating a need for effective non-thermal decontamination methods.

Objective: To evaluate atmospheric cold plasma (ACP) for inactivating Shiga toxin-producing *Escherichia coli* (STEC) and *Salmonella enterica* on chickpea grains, and to determine its effect on flour quality under the optimized treatment conditions.

Methods: Chickpea grains were inoculated with STEC O121, STEC O26, or a four-serovar *S. enterica* cocktail and allowed to attach for 2 h. Samples were treated in an ambient-air multipin-to-plate ACP system at three voltages (150-250 V) for 0-20 min, 5-time variations. Survivors were enumerated using thin-agar-layer recovery. Grains treated under the optimized condition were milled and evaluated for quality.

Results: Initial populations were 7.48 ± 0.13, 7.34 ± 0.06, and 7.69 ± 0.13 log CFU/g for STEC O121, STEC O26, and *Salmonella*, respectively. Reductions increased with voltage and exposure time. At 250 V for 15 min, STEC O121 and O26 were reduced by 3.09 and 3.30 log CFU/g, respectively. At 250 V, *Salmonella* reductions were 1.90, 2.29, 2.63, and 3.01 log CFU/g after 5, 10, 15, and 20 min, respectively. The optimized condition, 250 V for 20 min, achieved more than a 3-log reduction in all pathogens. It did not significantly affect seed quality attributes, including color, density, moisture, free fatty acid content, and water activity, compared with untreated grains ($p > 0.05$).

Conclusions: ACP effectively reduced STEC and *Salmonella* on chickpea grains while maintaining product quality. *Salmonella* was more resistant and may serve as a target organism for process validation.

Significance: ACP shows potential as a residue-free, non-thermal intervention for improving the microbial safety of chickpea grains without adversely affecting flour quality.

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Abstract 803 | Poster 108

Effect of discharge voltage on pilot-scale IPL inactivation of *Bacillus subtilis* vegetative cells and endospores under equivalent fluence conditions

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ABSTRACT

Intense pulsed light (IPL) is a non-thermal sterilization technology that delivers high-intensity, broad-spectrum light in short pulses for rapid microbial inactivation. *Bacillus subtilis* was selected as a model microorganism because it exists as both vegetative cells and highly resistant endospores, allowing comparison of IPL susceptibility between the two states. This study compared their IPL resistance using a pilot-scale system. Samples were treated at 1000, 1200, 1400, 1600, and 1800 V at a fixed 14-cm sample-to-lamp distance, with treatment duration adjusted to achieve equivalent total fluence. Microbial inactivation was determined by viable cell enumeration and expressed as log reduction. Survival data were fitted to multiple inactivation models (e.g., log-linear and Weibull-based), and the best-fitting model was used to estimate the fluence required to achieve a 4-log reduction (4D value). Live/Dead staining evaluated membrane integrity in vegetative cells, while dipicolinic acid (DPA) content in endospores was measured to assess DPA retention in endospores. At 0.7 J/cm², vegetative cells showed 4.7–6.2 log reductions, while endospores showed only 1.0–1.5 log reductions across all voltages. Due to their greater resistance, endospores were treated up to 10 J/cm², achieving approximately a 6-log reduction. The estimated 4D values were 0.24–0.37 J/cm² for vegetative cells and 5.08–7.31 J/cm² for endospores, indicating an approximately 20-fold higher fluence requirement for endospores. Live/Dead staining indicated increased membrane permeability in vegetative cells following IPL treatment. In endospores, the extent of DPA reduction decreased with increasing discharge voltage, from 16.0% at 1000 V to 6.9% at 1800 V. Overall, these findings indicate that IPL inactivation is influenced not only by total fluence but also by discharge voltage and microbial physiological state. This insight may contribute to optimizing IPL processing conditions for effective and energy-efficient microbial control in food applications.

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Abstract 806 | Poster 109

Wavelength-Dependent Mechanisms of LED-Induced Microbial Inactivation

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ABSTRACT

Light-based microbial inactivation has emerged as an alternative to thermal sterilization; however, the wavelength-dependent mechanisms underlying microbial inactivation remain poorly understood. This study investigated the responses of Gram-negative *Escherichia coli* (*E. coli*) and Gram-positive *Listeria innocua* (*L. innocua*) to LED irradiation at different wavelengths. Microbial suspensions were exposed to ultraviolet (UV; 265, 308, and 365 nm), visible (VIS; 405, 530, and 660 nm), and near-infrared (NIR; 850 and 940 nm) LEDs. Microbial inactivation and mechanistic responses, including DNA damage, reactive oxygen species (ROS) generation, membrane permeability, intracellular leakage, and structural changes, were evaluated. *E. coli* was completely inactivated at wavelengths ≤405 nm, whereas wavelengths ≥530 nm resulted in negligible reductions. In contrast, *L. innocua* achieved complete inactivation even at 530 and 660 nm, suggesting a greater sensitivity to longer-wavelength VIS irradiation, possibly due to endogenous photosensitizers capable of absorbing visible light. Mechanistic analysis revealed substantial DNA damage at 265 and 308 nm, while limited DNA damage was observed at longer wavelengths. Pronounced ROS generation was detected at 365 and 405 nm. At wavelengths that caused substantial microbial inactivation in the visible region, increased membrane permeability, intracellular leakage, and structural alterations were also observed. These findings suggest that microbial inactivation was primarily associated with photochemical mechanisms at shorter UV wavelengths (265–308 nm), whereas photodynamic and photophysical mechanisms contributed to inactivation at longer UV and shorter VIS wavelengths (365–405 nm). At longer VIS wavelengths, inactivation appeared to be predominantly associated with photophysical effects. Overall, the results demonstrate that the dominant inactivation mechanism varies with irradiation wavelength and microorganism, providing mechanistic guidance for selecting appropriate wavelengths for microbial control.

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Abstract 807 | Poster 110

Action Spectrum of LED Inactivation of *Escherichia coli* and Effects of Pulsed Irradiation at 305 nm

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ABSTRACT

Light-emitting diodes (LEDs) provide wavelength selectivity and rapid switching, enabling continuous and pulsed irradiation for microbial inactivation. However, comparison among wavelengths is complicated by differences in irradiance and delivered fluence. This study characterized wavelength-dependent inactivation of *Escherichia coli* ATCC 25922, constructed an action spectrum using a 4-log reduction endpoint, and investigated the effects of pulse frequency and duty cycle at 305 nm. *E. coli* suspensions were exposed to continuous LED irradiation at 11 wavelengths from 255 to 415 nm. Irradiance measured using an ILT960 spectroradiometer was corrected using petri, reflection, divergence, and water factors, and energy fluence was calculated from corrected fluence rate and irradiation time. Fluence-response curves were fitted using log-linear, Weibull, and double-Weibull models, with model selection based on adjusted R^2 and RMSE. The fluence required for a 4-log reduction (4D) was determined at each wavelength. Relative inactivation effectiveness was calculated as the reciprocal of 4D fluence and normalized to 265 nm (265 nm = 1) to construct the action spectrum. For four representative wavelengths (265, 305, 365, and 415 nm), the double-Weibull model provided the best fit, with adjusted $R^2 \geq 0.97$ and RMSE ≤ 0.39. Corresponding 4D values were 4.14 mJ/cm², 116.73 mJ/cm², 27.14 J/cm², and 159.62 J/cm², respectively. Relative inactivation effectiveness generally decreased with increasing wavelength. At 305 nm and 173.1 mJ/cm², continuous irradiation produced a 6.43-log reduction, whereas pulsed irradiation at 50% duty cycle produced 6.50, 6.43, and 6.61 log reductions at 10, 50, and 100 Hz, respectively. At 10 Hz and 154.0 mJ/cm², increasing duty cycle from 50% to 75% increased inactivation from 5.39 to 6.55 log. These findings indicate limited effects of pulse frequency, whereas duty cycle may influence inactivation. This study provides a quantitative basis for wavelength selection and pulse-condition optimization, supporting nonthermal LED-based microbial control strategies for food engineering applications.

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Abstract 811 | Poster 111

Effects of Thermal and LED Treatments on Microbial Reduction in Fruit Juices

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ABSTRACT

Limitations associated with thermal processing have increased interest in non-thermal technologies for microbial control in fruit juices. This study evaluated microbial inactivation efficiency in apple, muscat grape, and pear juices subjected to conventional thermal treatment and LED irradiation. The three juices were inoculated with *Escherichia coli* ATCC 11775 at approximately 6–7 log CFU/mL and exposed to thermal treatment at 90°C or LED irradiation at 265, 405, and 850 nm. For thermal treatment, complete inactivation was achieved after 105, 120, and 120 s in apple, muscat grape, and pear juices, respectively. For 265 nm LED irradiation, fluences of 1.66, 0.51, and 0.59 J/cm² produced 6–7 log reductions in the respective juices. At 405 nm, substantially higher fluences of 28.85, 37.0, and 58.82 J/cm² were required to obtain comparable reductions across the three juices. At 850 nm, only 1–2 log reductions were observed at 144.8 J/cm² in apple and muscat grape juices and 148.2 J/cm² in pear juice. Thermal treatment provided rapid and high-level microbial inactivation in all three juices. The inactivation efficiency of LED irradiation varied with both wavelength and juice type. Among the three juices, inactivation efficiency at 265 nm followed the order muscat grape > pear > apple, whereas at 405 nm, the order shifted to apple > muscat grape > pear. Overall, 265 nm showed higher inactivation efficiency than 405 nm, whereas 850 nm exhibited only limited microbial reduction. These findings highlight the importance of establishing juice-specific treatment conditions for effective microbial control in fruit juice processing.

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Abstract 818 | Poster 112

Comparison of inactivation and damage mechanisms in *Shigella sonnei* at various LED wavelengths

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ABSTRACT

Light-emitting diode (LED) irradiation has emerged as a promising non-thermal technology for microbial control in the food industry. Understanding wavelength-dependent microbial inactivation and cellular damage is important for establishing effective disinfection conditions. This study investigated the inactivation behavior and cellular damage of *Shigella sonnei* ATCC 29930 (*S. sonnei*) under LED irradiation at 265, 308, 365, and 405 nm. *S. sonnei* cell suspensions (initial population of 10^6–10^7 CFU/mL) were irradiated at each wavelength, and viable cell counts were enumerated by the plate count method on tryptic soy agar following incubation at 37°C for 18 h. DNA damage was assessed using the neutral comet assay, and relative intracellular H_2O_2 levels and dsDNA/protein release were measured. Transmission electron microscopy (TEM) was used to observe changes in cellular ultrastructure. A 6–7 log reduction was achieved at fluences of 0.10, 0.90, 177.61, and 375.11 J/cm² at 265, 308, 365, and 405 nm, respectively. A rapid initial reduction was observed at 265 and 308 nm. In contrast, 365 nm showed a linear reduction, and 405 nm exhibited an initial shoulder. Comet assay results showed greater DNA damage at 265 and 308 nm. Intracellular H_2O_2 levels were higher at 365 and 405 nm, and dsDNA and protein release tended to increase with wavelength. TEM observations showed that cells treated at 265 nm were similar to the untreated control, whereas 308 nm induced localized cytoplasmic damage. At 365 nm, damage was observed throughout the cytoplasm, and at 405 nm, cytoplasmic damage was accompanied by changes in cell morphology. These findings demonstrate wavelength-dependent differences in *S. sonnei* inactivation and cellular damage. This suggests that the mechanisms contributing to inactivation may also vary with wavelength. Such insights can inform food engineers in designing wavelength-specific LED disinfection strategies for the food industry.

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Abstract 822 | Poster 113

Synergistic inactivation of *Clostridium sporogenes* PA 3679 spores by pressure-assisted thermal processing and cationic antimicrobials in a low-acid food matrix

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ABSTRACT

Bacterial spores present a major challenge to the safety and shelf stability of low-acid foods because of their high resistance to processing. Pressure-assisted thermal processing (PATP) offers an alternative to conventional thermal sterilization; however, surviving or injured spores may recover during storage. This study investigated the effectiveness of PATP combined with cationic antimicrobials as a hurdle strategy for inactivating Clostridium sporogenes PA 3679 spores and preventing their post-processing recovery. Spores inoculated into carrot puree were treated by PATP (600 MPa, 105°C, 10 min) alone or in combination with chitosan (10 mg/mL), epsilon-polylysine (0.2 mg/mL), and lauric arginate (0.2 mg/mL), followed by storage at 23 °C for 35 days. Spore survivors were enumerated using the three-tube most probable number method. PATP alone produced a 4.2-log reduction in an initial population of approximately 7 Log MPN/mL, followed by a significant 1-log increase during storage, indicating potential recovery of injured spores. PATP combined with chitosan achieved a 6.5-log reduction, while combinations incorporating epsilon-polylysine or lauric arginate reduced spores below the detection limit (<0.48 Log MPN/mL) and prevented detectable recovery throughout storage. In HEPES buffer, PATP produced up to a 5.7-log reduction, whereas pressure treatment at ambient temperature was ineffective. These findings demonstrate that integrating pressure, temperature, and cationic antimicrobials can provide complementary sporicidal effects during processing and sporostatic effects during subsequent storage. This hurdle-processing approach provides an engineering strategy for improving microbial safety and shelf stability of low-acid foods while supporting the development of alternative sterilization processes.

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Abstract 829 | Poster 114

Ultrasound-assisted cleaning of simulated dairy fouling on stainless-steel surfaces

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ABSTRACT

Clean-in-place (CIP) process for dairy pasteurization systems require substantial water and energy, resulting in high operating costs. Therefore, innovative technologies are needed to enhance cleaning efficiency while reducing resource demands of conventional CIP. Ultrasound (US) treatment has potential to enhance fouling removal during CIP through acoustic cavitation. The study aims to investigate the effects of US and associated treatment factors on removing simulated dairy fouling on stainless-steel surface.

Simulated dairy fouling was generated on the bottom of stainless-steel (SS304) beakers by recirculating 10% whey protein solution supplemented with 2% $CaCl_2$ at 97°C for 1h. The cleaning process was conducted by treating fouled beakers with NaOH solutions (0–0.5%) at different temperatures (30 and 45°C) under constant stirring. US-assisted cleaning treatment was carried out by fixing beakers onto the bottom of a sonication bath (40kHz, 110W). Fouling removal percentages were quantified gravimetrically using periodic weight measurements taken periodically throughout the 28-min cleaning period.

Results showed that all US-assisted treatments achieved greater fouling removal than their controls before treatment completion. At 45°C with DI water, US increased fouling removal from 9.4% without US to 36.7% within the first 4 min and remained higher throughout treatment ($p<0.05$). Increasing cleaning temperature from 30 to 45°C also enhanced US-assisted fouling removal with DI-water throughout the treatment ($p<0.05$), whereas the same temperature increase without US did not affect fouling removal ($p>0.05$). The effect of NaOH became more pronounced at later stages, with US-assisted 0.25% NaOH increasing fouling removal to 61.7% after 20min compared with DI water ($p<0.05$). Increasing NaOH concentration from 0.25% to 0.5% provided no significant additional benefit ($p>0.05$).

The study demonstrates that US can enhance fouling removal under milder cleaning conditions, with elevated temperature and low-concentration NaOH further improving performance and offering potential to reduce cleaning time and resource consumption in future CIP designs.

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Abstract 833 | Poster 115

Aflatoxin Degradation in Corn Using Atmospheric Cold Plasma Treatment

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ABSTRACT

Aflatoxin contamination in corn is a food safety concern due to its toxicological risks to humans and animals and its associated economic losses. Atmospheric cold plasma (ACP) has emerged as a non-thermal technology for mycotoxin degradation; however, its effectiveness depends on the treatment conditions. This study evaluated the effectiveness of ACP treatment for aflatoxin detoxification in corn kernels. A full factorial design was performed with five ACP voltage levels (50, 100, 150, 200, and 250 V) and five exposure times (5, 10, 15, 20, and 25 min), with untreated samples included as controls. Corn kernels were inoculated with 50 ppb of aflatoxin and exposed to 25 (5×5) different combinations of voltage and treatment time. Residual aflatoxin concentration was measured using the Reveal Q+ MAX for aflatoxin immunochromatographic assay. The highest aflatoxin detoxification was achieved at 250 V for 25 min, resulting in 83% reduction in the initial aflatoxin concentration. Increasing ACP voltage increased aflatoxin detoxification, whereas treatment time had a less pronounced effect. Kinetic analysis indicated that aflatoxin degradation followed first-order kinetics at each applied voltage. Under the optimal treatment condition (250 V/25 min), cold plasma had minimal effects on color, quality, and nutritional properties of corn kernels. These results demonstrate the potential of atmospheric cold plasma for reducing aflatoxin contamination in corn and support its potential application as a non-thermal technology for improving grain safety.

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Abstract 847 | Poster 116

Surrogate and spoilage bacteria inactivation in kale juice by Pulsed Electric Field (PEF)

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ABSTRACT

Green juices gained prominence in health-oriented diets, and kale is a rich source of bioactive compounds. Thermal processing can effectively control microorganisms; however, it may degrade antioxidant compounds in green juices. Pulsed Electric Field (PEF) is a non-thermal technology that can operate continuously using ultrashort pulses, facilitating its integration into industrial processing lines with lower energy requirements than thermal processing. However, juice characteristics and PEF parameters may affect treatment efficacy. Therefore, this study evaluated the effects of PEF treatment time, pH, and pulse polarity on the inactivation of bacterial surrogates and spoilage bacteria in kale juice and assessed microbial stability during storage.

Kale juice was prepared at 20% (w/v) and adjusted to pH 4 or 6. Samples inoculated with *Listeria innocua* and *Escherichia coli* as bacterial surrogates, or *Leuconostoc* spp. as spoilage bacteria, were treated with PEF at 26.7 kV/cm for up to 25 min, at 3.4 mL/s. Monopolar and bipolar pulses resulted in similar inactivation levels of the bacterial surrogates ($p > 0.05$). For industrial applications bipolar pulses reduce electrode fouling and corrosion. Treatment time and pH significantly influenced inactivation. E. coli showed greater resistance at pH 4, whereas L. innocua showed greater resistance at pH 6. E. coli achieved the 5-log reduction target at both pH, whereas L. innocua reached this target only at pH 4 after 25 min of treatment. At this time point and pH 4, reductions of 5.86 ± 0.8 and 5.43 ± 0.7 log CFU/mL were achieved for E. coli and L. innocua, respectively. *Leuconostoc* was more resistant compared to the surrogates, with a 3.58 ± 0.30 log CFU/mL reduction under the same conditions. During storage, no growth of *Leuconostoc* was observed following PEF treatment, whereas growth occurred in the untreated control, demonstrating the potential of PEF for microbial control in kale juice.

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Abstract 849 | Poster 117

Development of light-activated zein-based coating for food-contact surfaces in food processing environment

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ABSTRACT

Microbial cross-contamination of food-contact surfaces remain persistent challenges in food processing. This study aimed to develop a light-activated zein-based antimicrobial coating for polypropylene (PP) surfaces and evaluate its antimicrobial efficacy, reusability, photostability, underlying antimicrobial mechanisms, and potential to mitigate cross-contamination. Food-grade photosensitizers, including curcumin, ferulic acid (FA), sinapinic acid, vitamin K1 and K3, and trans-cinnamaldehyde, were incorporated into zein-based coatings and screened for antimicrobial activity under UV-A irradiation. Among the tested compounds, incorporation of 0.5% ferulic acid into zein-based coatings on PP surface resulted in over 5-log CFU/cm^2 reductions of both *E. coli* O157:H7 and *Listeria innocua* within 10 min of UV-A treatment. Reusability was evaluated through repeated bacterial inoculation and UV-A treatment cycles. The coating maintained strong antimicrobial activity against *E. coli* O157:H7 through five cycles, whereas its efficacy against *L. innocua* gradually decreased with repeated use. Photostability evaluation after 24 h of dark or light exposure showed that antimicrobial activity was better retained against *E. coli* O157:H7 than against *L. innocua*. Scavenger-based experiments showed that reactive oxygen species generated during UV-A treatment contributed to bacterial inactivation, with species-dependent responses to different scavengers. Furthermore, a simulated cross-contamination test was conducted by bringing romaine lettuce inoculated with either bacterium into contact with coated PP surfaces, followed by UV-A treatment. The results demonstrated that the UV-A activated FA-zein coating substantially reduced both *E. coli* O157:H7 and *L. innocua* transferred to and recovered from the PP surface compared to uncoated PP and zein coated PP surfaces. These findings demonstrate that light-activated FA- zein coatings represent an effective, reusable antimicrobial strategy for reducing pathogen contamination and cross-contamination risk on food-contact surfaces in food processing environments.

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Abstract 856 | Poster 118

Effects of High-Moisture Extrusion and Storage Conditions on the Microbial Stability of Pea Protein-Based Meat Analogs

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ABSTRACT

High-moisture extrusion (HME) is widely used to produce plant-based meat analogs with fibrous structures resembling animal meat; however, limited information is available on how extrusion parameters and subsequent storage conditions influence their microbial stability and shelf life. This study investigates the effects of formulation moisture content, extrusion screw speed, and storage temperature on the microbial stability of pea protein-based HME meat analogs. Samples were produced at two formulation moisture contents (60% and 65%) and two screw speeds (200 and 300 rpm). Products from independent extrusion batches were stored at 4°C or −20°C and periodically analyzed for aerobic plate counts (APC) and yeast and mold populations during storage.

Preliminary results from the first 14 days demonstrated substantial differences in microbial growth between refrigerated and frozen storage. For samples produced at 60% moisture and stored at 4°C, APC remained below the detection limit through Day 7 but increased to approximately 3.9–4.9 log CFU/g by Day 14 across independent extrusion runs at both 200 and 300 rpm. In contrast, APC remained below the detection limit through Day 14 in corresponding samples stored at −20°C, demonstrating effective suppression of aerobic microbial growth under frozen storage. Yeast and mold populations were more variable, with colonies detected in some refrigerated samples at Day 14 but not consistently across replicates or extrusion runs. Continued monitoring will determine whether these microbial trends persist during extended storage and clarify the effects of formulation moisture content and extrusion screw speed on microbial stability. These findings provide preliminary evidence that post-extrusion storage temperature is a critical factor governing microbial stability and highlight the importance of integrating extrusion processing and storage conditions when establishing shelf-life strategies for high-moisture plant-based meat analogs.

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Abstract 872 | Poster 119

Microbial decontamination of brewer's spent grain using in situ plasma-activated water

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ABSTRACT

Brewer's spent grain (BSG), a major brewing by-product, has high moisture content and is susceptible to microbial deterioration, limiting direct utilization. The objectives were to explore in situ plasma-activated water (iPAW) treatment for microbial decontamination of BSG, optimize iPAW treatment conditions, and evaluate changes in the volatile profile, color, and moisture content. Unlike treatment with pre-generated plasma-activated water (PAW), iPAW treatment activated the water during BSG treatment by directly introducing plasma gas generated by a dielectric barrier discharge (DBD) system into a BSG–distilled water mixture. BSG and treatment liquid were mixed at 1:9 (w/v; 20 g/180 mL) and agitated at 200 rpm. iPAW treatment conditions were optimized using response surface methodology (RSM) based on a central composite design with discharge power (600–1400 W) and treatment time (5–20 min) in 13 runs. iPAW treatment at 600 W for 20 min achieved a ≥0.5 log CFU/g greater reduction in indigenous aerobic bacteria than PAW treatment. The RSM model showed an R^2 of 0.89, and optimal conditions were 1400 W and 20 min. Under the optimized conditions, the observed bacterial reduction was 4.3 log CFU/g, matching the predicted 4.4 log CFU/g. Gas chromatography with flame ionization detection (GC-FID) analysis showed that peak areas in the volatile profile decreased by ≥40% after iPAW treatment under the optimized conditions. iPAW-treated BSG showed an increase in moisture content from 71.5% to 85.6%; however, the increase was not significantly different from that observed in the distilled-water-treated control ($p > 0.05$). iPAW treatment did not significantly affect L^*, a^*, or b^* values ($p > 0.05$). These results support iPAW as a decontamination approach for wet BSG without a separate drying pretreatment, with potential applications in food processing and high-value upcycling of brewing by-products.

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Abstract 885 | Poster 120

Degradation of Aflatoxin B1 in Aqueous Solution by Surface Dielectric Barrier Discharge Cold Plasma

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ABSTRACT

Introduction: Aflatoxin B1 (AFB1), a Group 1 carcinogen produced by *Aspergillus* spp., is a leading dietary cause of liver cancer and contaminates cereals, grains, and nuts. Conventional treatments achieve only partial degradation and often compromise product quality or require hazardous reagents. Surface dielectric barrier discharge (SDBD), a planar cold plasma source, generates reactive oxygen and nitrogen species (RONS) with demonstrated bactericidal efficacy on foods, but its application to AFB1 remains limited.

Objective: This study evaluated SDBD for AFB1 degradation in aqueous solution as a first step toward application in food matrices.

Methods: AFB1 solutions (30 ppb, 25 mL) were treated with an SDBD Kapton electrode in ambient air for 0, 1, 2, 5, 10, 15, and 20 min. Sinusoidal excitation was amplified 1000-fold to deliver 5 kV peak-to-peak at 3 kHz. Residual AFB1 was quantified by competitive ELISA against a six-point standard curve (0–81 ppb), with three independent replicates per time point. Degradation was compared by one-way ANOVA with Tukey's HSD, and first-order kinetics fitted over the active phase.

Results: Degradation increased significantly with treatment time ($p < 0.001$), reaching 27.7 ± 13.9% at 1 min, 61.5 ± 14.8% at 2 min, and 93.2 ± 1.6% at 5 min, with residual AFB1 declining from 30 to 2.06 ± 0.47 ppb. The active phase followed first-order kinetics ($k = 0.554$ min^{-1}, $R^2 = 0.954$). The 1, 2, and 5 min points differed significantly from one another and from the control, whereas the 5, 10, 15, and 20 min groups did not differ significantly ($p > 0.92$), with residual AFB1 between 2.06 and 4.18 ppb, identifying 5 min as the effective treatment time. Cytotoxicity assessment, HPLC analysis, and peanut kernel trials are underway.

Significance: SDBD is a promising non-thermal intervention for AFB1 degradation, with short treatment times supporting its potential for mycotoxin control in foods.

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Abstract 901 | Poster 121

Evaluating Powdered Food Matrix Interference on the Inactivation Efficacy of Surface Dielectric Barrier Discharge (SDBD) Cold Plasma Against *Salmonella* Typhimurium

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ABSTRACT

Introduction: Cold atmospheric plasma (CAP) has demonstrated high efficacy for surface decontamination of fresh produce, such as tomatoes and spinach. However, scaling this technology to dry, powdered food matrices like infant formula has proven substantially more challenging because of complex physical and chemical interactions. Understanding these matrix-dependent protective mechanisms is essential for adapting non-thermal plasma technologies to low-moisture powder foods.

Objective: This study evaluates SDBD-generated plasma for inactivation on smooth surfaces, inert-powder, and infant-formula to distinguish between physical substrate geometry and organic matrix protection.

Methods: *Salmonella* Typhimurium was inoculated across three systems: Petri dishes (spread-plated and air-dried for 1 hour), inert matrix (sand), and powdered infant formula (PIF). After lawn inoculation with 1mL overnight culture, sand was dried for 1 hour (to compare with Petri dishes) or 48 hours (to compare with PIF), while PIF was desiccated for 48 hours (25% ± 2 RH) to achieve the original water activity. Plasma (3kHz, 5 Vpp) was applied for 0,2,5,8,10,12, and 15 minutes (70% RH, room temperature). Surviving populations were enumerated on Tryptic Soy Yeast Extract Agar (TSAYE) in triplicate.

Results: Inactivation efficacy varied significantly across matrix types ($p < 0.05$). Petri dishes exhibited rapid inactivation (>3.5 log reduction within 8 minutes). On inert sand, treatment resulted in a >3.5 log reduction at 15 minutes. Conversely, inactivation in PIF (same particle size as sand) yielded a maximum reduction of only 0.5 log, suggesting matrix shielding and scavenging of reactive species by proteins, fats, and carbohydrates.

Significance: Plasma as a waterless technology can be applied to powdered food safety. Understanding how matrix and food-product composition affect inactivation will help optimize treatment for better inactivation and support realistic industrial interventions in dry food safety.

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Abstract 910 | Poster 122

Continuous Plasma Nanobubble (PNB) Treatment for *Salmonella* and *Listeria* Inactivation and Quality Preservation in Fresh Produce

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ABSTRACT

Plasma nanobubble (PNB) technology provides a continuous delivery platform for plasma-generated reactive species and represents a promising alternative to conventional chemical sanitizers for fresh produce washing. This study developed and evaluated a continuous PNB treatment system for pathogen inactivation and cross-contamination control, assessed its efficacy under organic loading, and determined its effects on produce quality. PNB was generated using a rod-to-mesh dielectric barrier discharge plasma reactor coupled with a nanobubble generator using compressed air (5.78 kV, 1000 Hz, 5 SCFH). Cherry tomatoes and mini cucumbers (n = 189 each) inoculated with Salmonella Newport or Listeria innocua were washed in 3 L of PNB water, nanobubble water (NBW), or tap water (TW) for 1, 3, or 5 min. Uninoculated produce was included to evaluate cross-contamination. Wash water containing 4% or 7.5% produce extract and 0.1% SiO_2 was used to simulate low- and high-organic-load conditions (~32 and 60 NTU) representative of industrial produce washing. After 5 min, PNB reduced Salmonella by 5.6 ± 0.3 and 3.0 ± 0.3 log CFU/produce on tomatoes and cucumbers, respectively, and Listeria by 4.2 ± 0.1 and 4.3 ± 0.2 log CFU/produce. Under high organic loading, PNB maintained reductions of 3.6 ± 0.2 and 3.7 ± 0.3 log for Salmonella and 3.4 ± 0.2 and 3.3 ± 0.1 log for Listeria on tomatoes and cucumbers, respectively. Both microorganisms remained below the detection limit on uninoculated produce exposed to PNB wash water, demonstrating effective cross-contamination control. No significant changes in produce color or texture were observed. Scanning electron microscopy revealed membrane shrinkage and surface distortion in microbial cells following PNB treatment. Overall, continuous PNB treatment achieved substantial microbial inactivation while limiting cross-contamination and maintaining produce quality, even under high organic loading, demonstrating its potential as a scalable, chemical-free intervention for fresh produce washing.

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Abstract 922 | Poster 123

Continuous Dean-Flow UV-C Pasteurization of Whole Bovine Milk

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ABSTRACT

Objective: Thermal pasteurization reliably ensures microbial safety in milk, but it comes at a significant cost where heat-labile bioactive proteins such as lactoferrin (Lf), immunoglobulins (Igs), and native enzymes are degraded in the process, diminishing the nutritional and immunological quality of the final product. This study evaluated a continuous Dean-flow ultraviolet-C (UV-C) system as a non-thermal alternative for whole bovine milk (BM) processing, with the goal of achieving regulatory-level microbial inactivation while retaining these health-relevant bioactive components.

Methods: BM was processed through a continuous Dean-flow UV-C reactor designed to enhance fluid turbulence and improve UV fluence uniformity. Salmonella Muenchen, a validated surrogate for Coxiella burnetii, was used to characterize inactivation kinetics, fit with a log-linear-with-tail (Geeraerd) model. Retention of Lf, IgG, IgM, and IgA, along with residual enzymatic activity, was measured using sandwich ELISA, SDS-PAGE, and functional enzyme assays, and benchmarked against conventional high-temperature short-time (HTST) pasteurization. Group differences were assessed by one-way ANOVA with Tukey's HSD post-hoc test ($\alpha = 0.05$).

Results: A 5-log reduction of S. Muenchen was achieved after 6.3 passes through the reactor, corresponding to a UV-C fluence of approximately 20.5 mJ/cm². At this validated inactivation dose, continuous Dean-flow UV-C processing preserved significantly higher levels of Lf, IgM, and IgA than HTST-treated milk ($p < 0.05$), while enzymatic activity remained largely intact.

Conclusion: Continuous Dean-flow UV-C processing matches the microbial safety of thermal pasteurization while markedly better preserving milk's bioactive proteins and enzymes. These results position UV-C as a scalable, non-thermal technology capable of improving the nutritional and immunological quality of processed dairy products.

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Abstract 925 | Poster 124

Temperature dynamics predict *Salmonella* survival kinetics in chili pepper during microwave drying

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ABSTRACT

Background: While the World Health Organization listed chili pepper as the spice most susceptible to *Salmonella* contamination, little is known about the kinetics of *Salmonella* inactivation during the drying process.

Objective: To estimate D-values and z-values for *Salmonella* during microwave drying of chili peppers under dynamic temperature and water activity (a_w) conditions.

Methods: After being lengthwise sliced and inoculated with *Salmonella*, fresh red chili peppers were dried in a microwave oven for 45 min at 120W and 18 min at 240W. Using an infrared camera, a thermal image was taken rapidly at each sampling point, and the a_w was recorded. Samples were serially diluted in peptone water and plated onto modified tryptic soy agar to determine the log CFU/g of surviving *Salmonella*. To consider the influences of temperature and a_w, we incorporated a modified Bigelow mechanistic secondary model into four primary models (Weibull, log-linear, Geeraerd, and Cerf). Root mean square errors (RMSE) and corrected Akaike information criterion (AICc) were used to assess each model.

Results: Over time, *Salmonella* survival decreased with higher microwave power levels ($p<0.05$). The Geeraerd and log-linear models were found to be the preferred primary models through statistical analyzes. Similar RMSE (0.501-0.504) and AICc (12-18) were obtained when the modified-Bigelow model was incorporated into both primary models. However, the Geeraerd/modified-Bigelow displayed small scaled sensitivity coefficients, which increased the estimate errors (2.46-139.43%). The tailing effect seen in *Salmonella* inactivation during chili microwave drying was better explained by the log-linear/modified-Bigelow model with a D77°C-value of 4.24 min and a zT-value of 9.15°C.

Relevance: These findings serve as a basis for the food industry to improve drying conditions for enhanced *Salmonella* control. Temperature dynamics impact *Salmonella* inactivation rate during microwave drying. In comparison to our previous study, thermal inactivation parameters estimated using isothermal conditions overpredict *Salmonella* lethality during actual chili drying.

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Abstract 933 | Poster 125

Aqueous chlorine dioxide tempering of wheat kernels: Evaluation of STEC *E.coli* inactivation kinetics, enzyme activity, flour functionality, and baking properties

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ABSTRACT

Reoccurring outbreaks show that pathogen persistence in low-moisture foods like wheat flour is an ongoing challenge rather than an isolated event. This study evaluated the efficacy of aqueous ClO_2 incorporated into the existing tempering step for *E. coli* reduction and assessed its effects on polyphenol oxidase (PPO), lipase, lipoxygenase (LOX), downstream flour functionality, and bread quality. Wheat kernels inoculated with *E. coli* O121 and O26 were tempered to 17% moisture with aqueous ClO_2 at 20.6–102.8 mg kg^{-1} for 0.5–24 h. The highest microbial reduction of 4.3 $\log_{10}$ CFU/g was obtained at 102.8 mg kg^{-1} after 24 h, while all exposures ≥12 h at 82.2 mg kg^{-1} achieved >3-log reduction. Log-linear, Weibull, and biphasic models were used to describe ClO_2-induced *E. coli* inactivation, providing predictive kinetics for process validation. Enzyme activity decreased with increasing ClO_2concentration and tempering time. At 102.8 mg kg^{-1} for 24 h, PPO, lipase, and LOX activities decreased by 35.3%, 47.4%, and 69.3%, respectively. Weibull kinetics best described enzyme inactivation, with β values of 0.61, 0.34, and 0.59, indicating rapid initial inactivation followed by tailing. Selected CDXT treatments of 82.2 and 102.8 mg kg^{-1} were evaluated for downstream quality. CDXT significantly reduced peak viscosity from 2643.33 to 2260.33 cP and final viscosity from 2748.33 to 2397.67 cP at 102.8 mg kg^{-1} . Mixolab analysis showed modest changes in protein-related parameters (C1 and C2), while starch-related thermo-mechanical parameters were not significantly affected. Baking evaluation showed 5.66% and 6.42% higher loaf volume at 82.2 and 102.8 mg kg^{-1}, respectively, while crumb structure and texture remained comparable to the control. Overall, CDXT provides an in-process microbial intervention compatible with standard milling while maintaining flour functionality and baking quality.

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Abstract 940 | Poster 126

Pulse Light Treatment of Pinto Bean Grains to Improve Food Safety and Functional Performance

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ABSTRACT

Low-moisture foods such as grains and flours harbor foodborne pathogens. They have also been showing up with mycotoxins in recent times, which are more commonly associated with higher moisture commodities. This highlights the need for effective decontamination strategies tailored to dry food matrices since their low water activity increases microbial resistance. Emerging non-thermal technologies such as pulsed light (PL) offer rapid, chemical-free processing. Thus, attractive for dry food safety applications while reducing the risk of quality deterioration associated with other interventions such as chemical, thermal, and biological processes. The objective of the study is to evaluate the PL treatment of pinto beans for the reduction of food-safety hazards, including aflatoxin B1 (AFB1), ochratoxin A (OTA), Escherichia coli, and Salmonella. It further compares the effects of PL and benchmark heat treatment on the functional properties. Artificially contaminated pinto beans were subjected to PL treatment at applied fluences of 1, 2, 3, 4, 5, and 6 J/cm^2. Mycotoxin and pathogen reductions were evaluated following the treatment using lateral flow assay and viable plate counting, respectively. Flour functionality was assessed based on emulsification, foaming capacity, and foam stability. The reduction was maximized at a fluence of 6 J/cm2. PL treatment achieved 50% and 32% reduction in AFB1 and OTA, respectively. The populations of E. coli and Salmonella were mitigated up to 1.36 log CFU/g and 2.48 log CFU/g, respectively. PL improved emulsifying capacity at higher treatment intensity (fluence of 6 J/cm^2). Similarly, PL-treated pulse proteins demonstrated improved foam stability compared to thermal treatment. In contrast, thermal processing altered protein structure and reduced the emulsification and foaming properties. PL offers a promising dry processing intervention for reducing microbial and mycotoxin hazards while preserving or enhancing key flour functionalities. Maintaining emulsification and foaming performance is critical for applications in beverages, bakery products, and other functional foods.

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Abstract 942 | Poster 127

Use of UV-C and acidic water tempering as a hurdle approach for mitigating pathogenic *E. coli* contamination in hard red winter (HRW) wheat grains

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ABSTRACT

The use of hurdle approaches for food decontamination could improve pathogen reduction without compromising quality. This study evaluated the use of UV-C and acidic water tempering in reducing pathogenic *E. coli* contamination in raw wheat grains and their effects on whole wheat flour quality. Hard red winter (HRW) wheat grains were inoculated (high: 6.4 ± 0.1 log CFU/g and low: 3.3 ± 0.1 log CFU/g) with STEC O121 / O26 and treated with UV-C (255 to 280 nm; 0 to 80 mins exposure time) alone or in combination with acidic water (5% lactic acid - LA) tempering (18 h). The effective treatments were selected and evaluated for their impact on the physical properties & functional properties of whole wheat flour. UV-C exposure (at 280 nm) resulted in reductions ranging from 1.4 - 2.3 logs (high) and 0.4 – 1.3 logs (low). Combining both UV-C and LA showed synergistic effects (O/E > 1; 1.1 – 1.3), which resulted in higher reductions (2.3 – 3.3 logs) and shorter time required for a 3-log reduction (6 h) relative to the individual treatments. The fitted inactivation model (Weibull) also supported these findings as shorter predicted times (9.4 – 13.0 h) for a 3-log reduction were calculated for the hurdle approach compared to individual treatments (> 28.9 h). Wheat grains produced from the hurdle approach produce whole wheat flours with comparable ($P > 0.05$) color profile, particle morphology, solvent retention capacity, and pasting properties to whole wheat flours produced from the control (water), LA, and UV-C treatments. The study demonstrated the potential of UV-C alone or combined with acidic water tempering as decontamination step for wheat grains without compromising quality. The results from this study can be used as basis for improving the food safety of wheat-based foods against foodborne pathogens.

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Poster Session 5: Food Processing Technologies (Thermal, Nonthermal & Drying)

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Abstract 629 | Poster 128

Effect of technological processes on orotic acid content in milk and dairy products

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ABSTRACT

The study determined the content of orotic acid in selected dairy products using liquid chromatography coupled with mass spectrometry (LC-MS). Samples were pretreated by heating to 37°C, sonication, intensive mixing, and centrifugation, which enabled effective extraction of the analyte and removal of interfering components. The obtained results revealed significant variation in orotic acid content depending on the type of product and the degree of technological processing. In milk, the orotic acid content was approximatly 80 µg/mL and served as a reference point for further analyses. The highest levels were observed in whey, where the content was approximately 6.7% higher than in milk. In kefir, a decrease of about 54.1% relative to milk was noted, indicating a significant impact of fermentation processes leading to partial utilization or degradation of this compound by microorganisms. The greatest reduction was observed in butter, where the orotic acid content was approximately 80.0% lower compared to milk, which is related to its fat-rich nature and the removal of hydrophilic components during production. The results highlight the importance of technological processes and raw material fractionation in shaping the bioactive composition of dairy products and indicate milk and whey as important dietary sources of orotic acid.

Acknowledgements: Funded by the project SUP-RIM funded under the designated subsidy of the Minister of Science Republic of Poland, task entitled ‘The Research Network of Life Sciences Universities for the Development of the Polish Dairy Industry - Research Project’ (MEiN/2023/DPI/2862)

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Abstract 636 | Poster 129

Radio frequency thawing of frozen eggs: Industrial scale design and effects on the quality

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ABSTRACT

Due to the large-scale egg production in poultry industry, these shell eggs are commonly processed into whole liquid eggs (WLEs) and frozen for long-term storage. For thawing, conventional approaches take longer times and adversely affect the quality. Radio frequency (RF) heating with its volumetric heating ability has the potential to overcome these limitations while the non-uniform temperature distribution is a significant challenge. Therefore, the objective of this study was to develop a computational model for RF thawing of frozen WLEs, determine the effects on quality and use this model for designing industrial-scale processes.

Following the determination of dielectric and thermophysical properties, an enthalpy-based computational model was developed using COMSOL Multiphysics (V6.2) and validated with experimental data. Experiments were conducted in a 27.12 MHz, 10 kW staggered through electrode system. Rectangular and cylindrical poly-propylene cups were used in experiments, and samples were processed at electrode gaps of 12 and 15 cm (4500 and 5000 V). Quality changes were also determined for RF and air thawing effects.

The computational model showed good agreement with the experimental temperature data and accurately predicted the RF thawing behavior. Product geometry, sample dimension, and applied potential influenced the temperature distribution and thawing performance. Compared to conventional air thawing, RF process was 8 times shorter with improved quality attributes: enhanced foam capacity, stability and color. Then, industrial scale process design studies to determine the process parameters (electrode gap and potentials) for samples up to 10 kg were carried out.

The results of this study demonstrated that RF processing represented a promising alternative for thawing frozen WLEs. The computational model provided a reliable tool for optimizing process conditions and designing industrial scale processes. Use of RF thawing also aligned with the United Nations 2030 Sustainable Development Goals for energy efficiency and sustainable food processing technologies.

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Abstract 652 | Poster 130

Effects of Intense Pulsed Light and Clove Essential Oil Treatments on the Quality and Oxidative Stability of Pecan Kernels

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ABSTRACT

This study evaluated the effects of intense pulsed light (IPL) and clove essential oil (CEO), applied under previously optimized antimicrobial conditions, on the quality characteristics and oxidative stability of pecan kernels. Three commercial lots of pecans were divided into untreated controls or treated with IPL (190–290 nm, 12 s) or CEO (2%, v/v, 5 min). Following treatment, samples were analyzed for instrumental color (CIE L*a*b*), water activity, proximate composition, fatty acid profile, total phenolic compounds (TPC), peroxide value (PV), and oxidative stability using the RapidOxy oxygen absorption method.

Both IPL and CEO treatments had minimal effects on the nutritional composition of pecan kernels. Compared with the control, treated samples exhibited lower lightness (L*) values, while CEO-treated kernels also showed reduced yellowness (b*) ($P < 0.05$). Neither treatment significantly affected water activity (0.64–0.65), fat content (66.70–68.17%), protein content (7.48–7.64%), or peroxide value (3.11–3.37 meq O_2/kg fat). The CEO treatment significantly increased TPC compared with the control and IPL treatment (22.78 vs. 13.02 and 11.92 ± 0.702 mg GAE/g, respectively). Likewise, CEO-treated pecans exhibited a significantly longer oxidative induction time than untreated and IPL-treated samples (25.25 vs. 15.31 and 17.05 ± 0.604 h, respectively; $P < 0.05$). Minor changes in fatty acid composition were observed following CEO treatment, including increased concentrations of decanoic (C10:0) and stearic (C18:0) acids and a slight reduction in eicosanoic (C20:0) acid ($P < 0.05$).

Overall, IPL preserved the physicochemical quality of pecan kernels without adversely affecting nutrient composition or oxidative stability. CEO treatment enhanced oxidative stability by increasing phenolic content, although it produced slight changes in kernel color and fatty acid composition. These findings suggest that both IPL and CEO are promising interventions for improving the microbial safety of low-moisture foods while maintaining desirable quality attributes.

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Abstract 690 | Poster 131

Study on the Design of Rice Cooker Utilizing the Radiant Heat of Thin Film Graphene

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ABSTRACT

Graphene is an advanced material with excellent thermal and electrical conductivity. Its uniform far-infrared radiant heat emission makes it a promising material for heating applications requiring precise temperature control and efficient heat transfer. The primary objective of this study is to develop a novel rice cooker utilizing thin film graphene based radiant heating, replacing standard heating methods that rely solely on conduction and convection. By utilizing the far-infrared radiant heat of thin film graphene, the proposed design addresses the limitations of standard rice cookers, including uneven heat distribution and energy loss. 3D thermal-fluid simulations were performed using COMSOL Multiphysics. To simulate the heat generation of graphene, Joule heating was implemented using the heat transfer and electric currents modules, and a complex heat transfer analysis model was constructed using the surface-to-surface radiation module to simulate the radiant heat emission. The temperature distribution changes inside the rice cooking pot under various operational and boundary conditions were numerically analyzed. Simulation results showed that the radiant heat generated from the graphene diffuses rapidly and uniformly throughout the internal space without being localized in specific areas. In particular, the overall temperature increased stably, and based on this, conditions for optimizing thermal efficiency according to the structure and arrangement of the heating element were derived. This study theoretically verified the thermal stability and efficiency of this rice cooking system applying thin film graphene through simulation modeling, and it is expected to serve as core basic data for the future design and development of high efficiency radiant heat based cooking appliances that can ultimately enhance food quality and minimize energy consumption.

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Abstract 733 | Poster 132

Optimization of Vitamins B6, B9, and B12 Production in Mazzaella splendens Fermentation

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ABSTRACT

Red seaweed hydrolysates offer a renewable substrate for fermentation-based micronutrient production, but the interacting effects of culture conditions and nutrient supplementation remain poorly resolved. This study evaluated Mazzaella splendens hydrolysate for B-vitamin production through two complementary fermentation strategies. First, vitamin B12 production by Propionibacterium freudenreichii monoculture was optimized using response surface methodology. The effects of pH and cobalt, 5,6-dimethylbenzimidazole, and seaweed concentrations were fitted to a quadratic model. Significant quadratic effects for all four factors showed that production was maximized at intermediate levels. The predicted optimum was pH 6.78, 11.72 mg/L cobalt, 19.70 mg/L 5,6-dimethylbenzimidazole, and 16.11 g/L M. splendens, yielding a predicted B12 concentration of 9.08 mg/L and composite desirability of 0.64. Second, P. freudenreichii and Lactiplantibacillus plantarum were co-fermented to evaluate simultaneous production of vitamins B6, B9, and B12. A designed experiment assessed cobalt, para-aminobenzoic acid, pyruvate, and L-glutamate concentrations, and vitamins were quantified by ultra-high-performance liquid chromatography. The B12 model was significant ($p=0.001$); both linear and quadratic cobalt effects were significant, whereas the other supplements did not significantly affect B12 production. Relationships among B6, B9, and B12 were weakly to moderately positive, indicating that conditions favoring one vitamin did not necessarily maximize the others. Co-fermentation produced more B12 than the monoculture system. These findings establish M. splendens as a promising fermentation substrate and demonstrate the need for multi-response optimization when engineering processes for simultaneous vitamin production. Validation, vitamers' bioactivity confirmation, reproducibility testing, and scale-up assessment are required before food application.

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Abstract 736 | Poster 133

Cold Plasma-Induced Molecular Modifications of Guar Gum Enhance Its Engineering Properties

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ABSTRACT

Plasma, the fourth state of matter, contains highly reactive ionic particles capable of modifying the molecular structure of food ingredients. Cold plasma applies this chemistry at near-ambient temperature, offering a unique opportunity to alter functional properties without heat. Guar gum (GG), a widely used natural, non-ionic polysaccharide with high thickening and stabilizing ability, offers limited control over its functional behavior in its native form, and conventional modification depends on chemical reagents or ionizing radiation. This study evaluated how helium cold plasma exposure alters the rheological and physicochemical properties of GG. Samples were treated for 0 (control), 10 (P10), 15 (P15), and 20 (P20) min, then studied for rheological behavior (0.2%, 0.5%, and 1% w/v water) at 25°C, along with electrochemical and physical properties. Data were analyzed by one-way ANOVA and Tukey's HSD ($p < 0.05$). At 0.2%, P20 gave the highest apparent viscosity (1812 cP at 0.025 s^{-1}); P10 was lowest (325 cP). At 0.5%, P15 was highest (1402 cP), exceeding the control (1117 cP). At 1.0%, P10 was highest (15655 cP), exceeding the control (11563 cP), all near 0.025–0.040 s^{-1}. Peak viscosity shifted with concentration, from P20 at 0.2% to P15 at 0.5% to P10 at 1.0%. At 0.5%, storage modulus (G′) and loss modulus (G″) increased with frequency, with P20 showing higher G′ (9.8 Pa) and G″ (5.4 Pa) at 100 rad/s. P10 showed an earlier tan δ crossover (21 rad/s) than the control (32 rad/s). Plasma did not affect pH (6.2–6.8) while conductivity rose with concentration. Porosity increased significantly ($p < 0.05$) with exposure, from 65.50% (control) to 74.27% (P20), while Hausner ratio was unchanged. Overall, helium cold plasma alters the rheological and physicochemical properties of GG in a concentration-dependent manner, offering food engineers a non-thermal, solvent-free approach to tailor hydrocolloid functionality.

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Abstract 743 | Poster 134

Effects of Oscillating Magnetic Field-Assisted Supercooling on the Physicochemical Stability and Bioaccessibility of β-Carotene-Loaded Solid Lipid Nanoparticles

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ABSTRACT

Justification: Solid lipid nanoparticles (SLNs) are promising delivery systems for lipophilic bioactive compounds, but their storage stability can be compromised by particle aggregation, lipid polymorphic rearrangement, and chemical degradation. Both storage conditions and SLN composition are critical factors affecting SLN stability.

Objective: This study investigated how storage conditions, particularly oscillating magnetic field (OMF)-assisted supercooling, and SLN composition affect the physicochemical stability, lipid digestion, and β-carotene bioaccessibility of β-carotene-loaded SLNs.

Methods: Three SLN formulations were prepared: cocoa butter and soy lecithin (F1); cocoa butter, soy lecithin, and hydrogenated soybean phosphatidylcholine (HSPC) (F2); and a cocoa butter-beeswax blend with soy lecithin (F3). Samples were stored for 30 days under refrigeration at 4 °C or OMF-assisted supercooling at −5 °C and evaluated for particle characteristics, lipid crystalline structure, β-carotene retention, encapsulation efficiency, *in vitro* lipid digestion, and β-carotene bioaccessibility.

Results: All supercooled samples remained non-frozen at −5.0 ± 0.8 °C throughout storage. Initial particle sizes were 196–229 nm with polydispersity index ≤ 0.25. Refrigerated samples showed progressive particle growth and broader size distributions, whereas supercooled samples showed minimal changes during storage. Similar XRD patterns under both conditions indicated no major differences in lipid crystalline structure. After 30 days, F1 and F2 retained 70–72% β-carotene under refrigeration but >92% under supercooling, while F3 retained approximately 95% and nearly 100%, respectively. F2 showed the highest encapsulation efficiency (69.4–70.1%) and β-carotene bioaccessibility (43.0 ± 2.8%). Final free fatty acid release was approximately 50%, 40%, and 38% for F1, F2, and F3, respectively.

Conclusions: OMF-assisted supercooling preserved SLN colloidal stability and β-carotene content during 30 days of subzero storage, while formulation composition strongly influenced encapsulation, lipid digestion, and bioaccessibility.

Significance: OMF-assisted supercooling offers a promising approach for improving the storage stability of SLN-based delivery systems without freezing, while appropriate formulation design remains essential for optimizing functional performance.

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Abstract 747 | Poster 135

Pulsed Electric Field Inactivation of *Lacticaseibacillus rhamnosus* for Enhanced Preservation of Cellular Functionality

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ABSTRACT

Justification: Paraprobiotics have gained increasing attention as stable and safe alternatives to live probiotics. However, conventional thermal processing may damage cell-associated functional components, highlighting the need for non-thermal approaches that achieve microbial inactivation while preserving cellular functionality.

Objective: The objective of this study was to compare the effects of PEF and thermal treatment on the viability, cell-envelope proteinase (CEP) activity, and exopolysaccharide (EPS) release of *Lacticaseibacillus rhamnosus*.

Methods: The cell suspensions were treated with PEF at specific energy inputs of 50, 100, and 150 kJ/L or heated at 121°C for 15 min. Viable cell counts were determined before and after freeze-drying. CEP activity was measured using succinyl-Ala-Ala-Pro-Phe-*p*-nitroanilide as a substrate, and EPS released into the cell-free supernatant was quantified by the phenol–sulfuric acid method.

Results: PEF treatment reduced viable cell counts in an energy-dependent manner by 3.32, 4.30, and 5.20 log CFU/mL at 50, 100, and 150 kJ/L, respectively. Freeze-drying further decreased viability, and no viable cells were detected after treatment at 150 kJ/L. CEP activity was largely preserved after PEF treatment at all energy inputs, whereas thermal treatment resulted in an almost complete loss of activity. EPS release increased with PEF energy input, while the amount released remained substantially lower than that following thermal treatment.

Conclusions: PEF treatment effectively reduced the viability of *L. rhamnosus* while preserving CEP activity and limiting EPS release compared with thermal treatment. The lower EPS release suggests reduced disruption of cell-associated polysaccharide structures, supporting the ability of PEF to achieve substantial microbial inactivation with less damage to cell-associated functional components.

Significance: These findings support the potential of PEF as a non-thermal processing technology for producing function-preserved paraprobiotic ingredients.

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Abstract 749 | Poster 136

Fractionation of Antioxidant Peptides from *Chlorella vulgaris* Protein Hydrolysates using Electrodialysis

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ABSTRACT

Justification: The increasing demand for sustainable protein-derived ingredients has created a need for exploring alternative biomass sources. Microalgae have a very high protein content and are an emerging source of various bioactive peptides. However, efficient selective recovery of target peptide fractions remains a key processing challenge for practical applications.

Objective: This study evaluated electrodialysis (ED) as a solvent-minimized approach for the fractionation and recovery of antioxidant peptides derived from the protein isolate of microalga *Chlorella vulgaris*.

Methods: *C. vulgaris* biomass was treated by high-pressure homogenization for cell disruption, followed by alkaline protein solubilization, centrifugation, microfiltration, isoelectric precipitation for protein extraction and purification, then enzymatic hydrolysis to produce protein hydrolysate. The resulting hydrolysate was processed by ED at 10 and 25 V for 90 min to fractionate peptides and their migration were determined by monitoring the 2,4,6-trinitrobenzenesulfonic acid (TNBS)-reactive amino groups. The antioxidant capacities of the fractionated peptides were analyzed using the 2,2′-azinobis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) assay.

Results: At 25 V, TNBS-reactive compounds in the hydrolysate decreased from 8.92 to 3.72 mM leucine equivalent, implying the migration of peptides containing amino groups. However, the peptides fractionated at 10 V exhibited a greater antioxidant capacity, reaching 67.7 µM Trolox equivalent after 90 min compared with 43.6 µM of that obtained at 25 V.

Conclusion: Increasing the electrical driving force enhanced peptide migration but did not increase antioxidant activity. In contrast, operation at the lower voltage provided fractions with higher radical-scavenging activity, suggesting that ED voltage influences not only the extent of peptide migration but also the selectivity of the fractionation process.

Significance: ED-based fractionation offers a solvent-minimized strategy for recovering bioactive peptides from microalgal proteins. Optimizing voltage may improve selectivity toward antioxidant peptides and support valorization of *C. vulgaris* as a sustainable source of functional food ingredients.

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Abstract 752 | Poster 137

Effect of e-beam on foaming properties of dairy ingredients

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ABSTRACT

Justification: Although dairy proteins are versatile ingredients, major challenges associated with high-protein powders include low solubility, foaming, emulsification, gelling, and the formation of aggregates. These factors decrease the stability of the proteins and limit their application in various products. The performance of these functionalities depends on factors such as the molecular structure of the protein, the solvent used to dissolve it, the concentration of the protein in the formulations, and environmental factors like pH, temperature, ionic strength, and the composition of the dairy proteins. Thus, altering any of these factors would change the functional properties of the dairy protein.

Objective: In this study, attempts have been made to modify foaming properties of dairy proteins (milk protein concentrates MPC85 and MPC90, nonfat dry milk (NFDM), whey protein isolate (WPI) and whey protein concentrate (WPC)) using e-Beam technology.

Methods: The e-Beam irradiation facility managed and operated by the National Center for Electron Beam Research (NCEBR) at Texas A&M University was used. To evaluate foaming capacity and stability, 12% protein solutions were prepared and transferred into a mixer a whipping attachment to incorporate. The solution was mixed for 2 min and then immediately transferred into a measuring cylinder. The initial liquid and foam levels were recorded, and the timer was set for 30 min. After 30 min, the final liquid and foam levels were recorded for calculations.

Results: Foaming capacity increased with an increase in energy level until 25 kGy for all samples. MPCs showed higher foaming capacity (188-313 mL). Foaming capacity for NFDM and WPC did not significantly change among energy levels. Foaming stability (80-95 mL for MPCs; 12-70 mL for NFDM and 20-45 mL for WPI) decreased with increase in energy level. The foam for WPC collapsed for any e-beam treatment immediately.

Conclusions: This study demonstrated that the foaming properties of dairy ingredients can be modified using e-Beam treatments.

Significance This study provides opportunity to explore e-Beam for protein modification and further optimization study is underway.

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Abstract 796 | Poster 138

Influence of agitation rate on the bioprocessing of lupin flour with *Aspergillus oryzae*

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ABSTRACT

The development of sustainable plant-protein ingredients requires bioprocessing strategies able to modulate both microbial activity and product functionality through well-defined operating conditions. In this work, the influence of agitation rate on the bioprocessing of lupin flour (*Lupinus albus*) with *Aspergillus oryzae* was investigated, with particular emphasis on process kinetics, oxygen availability and final product characteristics.

Lupin flour suspensions were processed in a 500 mL stirred bioreactor at agitation rates ranging from 100 to 400 rpm, using an aeration rate of 1.5 L/min and an operating pressure of 0.1 MPa. Orbital-shaken flasks without forced aeration were included for comparison. Dissolved oxygen (DO), pH and temperature were continuously monitored to characterize process evolution. Final products were analyzed for glucosamine, saponins, total phenolics, antioxidant activity, fat, alkaloids and protein content, together with selected techno-functional properties.

Agitation rate markedly influenced process kinetics. Increasing agitation to 300–400 rpm promoted a faster decrease in DO during the exponential growth stage, indicating a strong coupling between oxygen transfer conditions and fungal metabolic activity. Higher agitation rates also advanced the transition to a second metabolic stage, characterized by a progressive increase in pH to approximately 7.0, whereas this transition was delayed at 100–200 rpm. These results demonstrate that agitation can be used to modulate the temporal evolution of the bioprocess.

Bioprocessing significantly modified lupin flour composition and functionality, increasing total phenolics and antioxidant activity while reducing fat, total protein, soluble protein, and water and oil absorption capacities. Emulsion and foam stability remained unaffected.

Overall, agitation rate was identified as a key engineering variable governing process dynamics and hydrodynamic conditions with metabolic response and final product properties.

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Abstract 802 | Poster 139

A Novel Green Technology for Producing Bioactive Compounds with Enhanced Bioavailability

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ABSTRACT

Although the health benefits of curcumin (CUR) are well recognized, its high crystallinity and poor water solubility severely limit its bioavailability. Therefore, this study aimed to improve CUR bioaccessibility by producing low-crystallinity CUR nanoparticles (CUR-NP) using nanoporous bioaerogels (NSB) and supercritical carbon dioxide (SC-CO_2). A novel green technology was developed in which the nanopores and large surface area of bioaerogels act as a template to control CUR recrystallization during SC-CO_2 processing. First, NSB with different amylose contents were investigated as CUR carriers. CUR loading increased with amylose content, reaching 16.4, 21.4, and 24.9 mg/g for 25%, 55%, and 72% amylose aerogels, respectively. Following intestinal digestion, CUR release reached 7.2–12.1%, compared with only 0.5% for native CUR, while Caco-2 studies demonstrated enhanced permeation. Second, egg-white protein (EWP) aerogels produced by cold- and heat-set gelation were evaluated. Cold-set aerogels exhibited lower density, higher porosity, greater CUR loading and antioxidant capacity, and enhanced Caco-2 transport compared with heat-set aerogels. Third, a simplified SC-CO_2 process was developed by impregnating CUR directly into preformed NSB. Increasing impregnation temperature from 40 to 120°C reduced CUR crystallinity and promoted more uniform distribution. Optimal conditions of 120°C and a 1:9 CUR:aerogel ratio resulted in approximately 30-fold greater gastrointestinal bioaccessibility than native CUR and Caco-2 transport of 0.86 μg/mL. Finally, CUR-NP exhibited enhanced antioxidant and anti-inflammatory activities and inhibited mTORC1 signaling. CUR-NP reduced p70 S6 kinase and S6 ribosomal protein activity by 61% and 53%, respectively, in Caco-2 cells and p70 S6 kinase by 77% in HT-29 cells. In vivo studies demonstrated a 6.6-fold increase in oral CUR bioavailability compared with free CUR. Overall, these studies establish SC-CO_2-assisted aerogel technologies as green platforms for enhancing the delivery of water-insoluble bioactives. Together, these findings demonstrate potential of food-grade aerogel matrices to improve CUR loading, release, transport, and efficacy.

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Abstract 823 | Poster 140

Low-Moisture Extrusion of Nutrient-Dense Small Lima Bean-Based Snacks: Effects of Protein Fortification and Incorporation Methods on Physicochemical and Nutritional Properties

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ABSTRACT

Background and Objectives:
Small lima bean (Phaseolus lunatus) is an underutilized legume rich in protein, carbohydrates, and dietary fiber, yet its utilization in value-added food products remains limited. This study aimed to develop nutrient-dense, protein-fortified puffed snacks from small lima bean flour (SLBF) and evaluate the effects of protein source and low-moisture extrusion conditions on their physicochemical and nutritional properties.

Methods:
SLBF was fortified with whey protein isolate (SLBFWP), yeast protein isolate (SLBFYP), or mycelium protein (SLBFMP). Blends were processed using a twin-screw extruder at 32% (w/w) total moisture and screw speeds of 200 or 300 rpm. Protein was incorporated either by dissolution in process water or dry blending with SLBF. Extrudates were evaluated for proximate composition, expansion ratio, color, texture, surface, and cross-sectional morphology, total starch, resistant starch, and antinutritional factors. Experiments were conducted in triplicate ($n = 3$), and statistical differences were determined using ANOVA and Tukey's HSD test ($p < 0.05$).

Results:
All extrudates contained >24% protein (dry basis), demonstrating successful development of high-protein products. Protein source significantly affected expansion behavior. SLBFWP exhibited a significantly higher expansion ratio (1.62 ± 0.20) than SLBFMP (1.14 ± 0.20; $p < 0.05$), whereas protein incorporation method had no significant effect ($p > 0.05$). Extrusion substantially reduced resistant starch content. Resistant starch decreased from 12.53 ± 0.08 to 1.10 ± 0.04 g/100 g dry basis for SLBFWP and from 11.53 ± 0.13 to 0.06 ± 0.01 g/100 g dry basis for SLBFMP ($p < 0.05$).

Significance:
These findings demonstrate the feasibility of converting underutilized small lima beans into nutrient-dense, high-protein puffed snacks and highlight protein source as an important formulation parameter governing extrusion expansion and nutritional characteristics.

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Abstract 830 | Poster 141

Process Kinetics, Volatile Composition, and Nutrient Retention during UV-A Light Dehydration of Foods

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ABSTRACT

Low-temperature dehydration technologies require simultaneous control of drying performance and product composition. This study characterized process kinetics, physical quality, volatile profiles, and nutrient-related composition during non-thermal UV-A light dehydration of apples, mangos, white button mushrooms, and beef jerky. UV-A treatments were compared with fresh and relevant air-dried, hot-air-dried, and freeze-dried controls. Moisture loss and water activity were monitored over time, and texture profile analysis and instrumental color measurements quantified structural and appearance changes. Volatile compounds in apple and mango were evaluated by headspace solid-phase microextraction gas chromatography-mass spectrometry (HS-SPME-GC-MS), with retention indices supporting compound annotation. Lipid-soluble vitamins were measured chromatographically, and fatty-acid and metabolomic profiles were acquired to characterize broader compositional responses. UV-A dehydration reduced beef-jerky water activity below 0.85 within 5 h, confirming its capacity to reach the desired low-water-activity endpoint under the tested conditions. Drying kinetics, texture, and color responses were food-matrix dependent. Headspace analysis annotated approximately 170 volatile compounds across apple and mango, revealing treatment-specific aroma fingerprints. Vitamin responses also differed by matrix: vitamin C decreased in UV-A-treated apple relative to fresh apple, whereas vitamin C and beta-carotene increased in UV-A-treated mango relative to fresh fruit. UV exposure markedly increased vitamin D2 in white button mushrooms without altering ergosterol. Fatty-acid and metabolomic measurements provided complementary compositional fingerprints for comparing processing treatments. Overall, UV-A-assisted dehydration affected water removal, physical attributes, volatile chemistry, and micronutrient composition through distinct matrix-specific pathways. This multi-parameter process assessment provides food engineers with a basis for selecting UV-A operating conditions that balance dehydration efficiency with texture, appearance, aroma, and nutrient retention across diverse foods.

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Abstract 838 | Poster 142

Pin-to-Plate Non-Thermal Plasma Modification of Orange and Grapefruit Peel Fibers for Gut Microbiome Applications

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ABSTRACT

Citrus juice production generates substantial quantities of peel byproducts that remain underutilized despite being rich sources of dietary fiber, pectin, and bioactive compounds. This study investigates non-thermal atmospheric plasma (NTAP) as a green processing technology to modify orange and grapefruit peel fibers for potential gut microbiome applications. The objective was to determine whether plasma-generated reactive species can modify the structural and physicochemical properties of citrus fibers, potentially increasing their functionality and fermentability while preserving or enhancing antioxidant properties. Orange and grapefruit peel powders (20 g) were treated using a PlasmaLeap Leap100 pin-to-plate atmospheric plasma system at applied voltages of 215, 220, or 225 V for 3, 6, or 9 min. Samples were mixed twice at equal intervals during treatment to promote uniform plasma exposure. Following treatment, samples were analyzed for total phenolic content (TPC), DPPH radical-scavenging activity, soluble and insoluble dietary fiber contents, water-holding capacity, and structural changes to evaluate plasma-induced modifications in fiber functionality and antioxidant properties. Preliminary FTIR analysis indicated increased hydrophilic functional groups in plasma-treated citrus peel fibers, suggesting plasma-induced surface functionalization. Additionally, 9-min treatments at 215 and 220 V significantly increased water-holding capacity compared with untreated samples ($p < 0.05$), demonstrating enhanced hydration functionality. Ongoing analyses of dietary fiber composition and antioxidant properties will further elucidate the effects of plasma treatment and identify optimal processing conditions. These findings demonstrate the potential of NTAP as a sustainable, chemical-free approach for engineering citrus peel fibers with enhanced functional properties and provide a foundation for evaluating their fermentability and interactions with the gut microbiome. This approach offers a promising pathway for valorizing citrus-processing byproducts into functional food ingredients while advancing circular bioeconomy strategies for food and agricultural waste streams.

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Abstract 844 | Poster 143

Protein Interactions Impact Quality of UHT and Retort Processed Ready-to-Drink Coffee Lattes

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ABSTRACT

Shelf-stable RTD coffees are increasingly popular, and the global market is projected to reach $53.5 billion by 2032. Shelf-stability is achieved by ultra-high temperature (UHT) or retort processing with considerable impacts on quality, however the mechanisms underlying quality differences between UHT- and retort-processed RTD coffee, particularly the contributions of protein and phenolic reactions, remain poorly understood.

A model coffee latte beverage using 2% milk was processed by UHT (140 °C, 5 s) or retort (115 °C, 20 min) to achieve an equivalent F_0 of 5. An HTST processed latte served as the heated control. In addition to measuring color, sedimentation, and viscosity, a trained descriptive panel characterized sensory quality based on 17 attributes. HPLC, SDS-PAGE, FTIR, fluorescence spectroscopy, and antioxidant assays were used to investigate the Maillard reaction, protein-protein, and protein-phenolic interactions.

Retorted lattes had greater sedimentation and viscosity, thicker band formation in in the high molecular weight regions of SDS-PAGE gels, and greater tryptophan quenching and AGE production as compared to UHT processed lattes ($p<0.05$) pointing to greater protein-protein and protein-phenolic interactions in retorted lattes. Retorted samples also had higher concentrations of caffeic acid caused by breakdown of chlorogenic acid. The sensory panel characterized retorted lattes with strong cooked milk flavors and aromas, caramel aroma, and viscous mouthfeel while UHT lattes were similar to HTST controls.

These findings establish mechanistic links between sterilization method, protein and phenolic reactions, and quality attributes in shelf-stable RTD coffee, and provide a scientific basis for selecting processing conditions to optimize product quality.

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Abstract 850 | Poster 144

Non-Contact Capacitive Coupling Electrode Field (CCEF) Design, Modeling, and Application on Seafood-Based Supercooling

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ABSTRACT

Supercooling technology is an emerging preservation method that controls the meta-stable supercooling state below its freezing temperature to prevent quality damage from freezing processes; while synchronously inhibiting chemical and microbial spoilage processes in biological samples. Novel approaches such as oscillating magnetic fields (OMF) and pulsed electric fields (PEF) have shown intriguing results in supercooling meats in their synergistic applications, but produce coincident heat, which negatively affect consistency of set sample temperatures and consequently supercooling stability (Lee et al., 2024). Particularly PEF technology applies electric current and field to control and prevent ice nucleation through contact-based electrodes, where material selected must be food-grade and limit metal release, corrosion, and faradaic reactions that reduce the equipment's lifespan and overall food safety.

A potential alternative to PEFs are capacitive-coupling electric fields (CCEF) through the displacement current. A displacement current is time-varying electric fields that transfers electric energy through a sample via polarization between capacitive systems. These system types can aid in electric field distributions through dielectrics interfaces, while reducing temperature fluctuations for supercooling systems.

We aim to optimize OMF & CCEF design to enhance supercooling stability in cold-chain strategies towards fish preservation. In this study, we fabricated a non-contact dielectric CCEF system treated with OMF (15mT, 5Hz) on the preservation of salmon fillets (1, 3, 5 days). Finite element modeling in COMSOL Multiphysics will simulate electric field strength of 2 different electrode designs applied of dielectric films, input voltage, frequency, electrode distance, dielectric material selection, and power dissipation in modeled samples to estimate displacement current magnitude and compare findings to contact PEFs. A Box-Behnken design was made to assess the supercooling probability under CCEF voltage (5, 10, 15 V), frequency (20, 200, 2000, 2000Hz), and dielectric films.

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Abstract 851 | Poster 145

Influence of Non-thermal Assisted and Hybrid Drying Technologies on Drying Performance and Quality Attributes of Fruits and Vegetables

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ABSTRACT

Traditional thermal drying methods, such as hot-air drying, are evolving through the integration of non-thermal technologies to improve product quality while reducing drying time and energy consumption. Non-thermal technologies, including ultrasound, pulsed electric field, osmotic dehydration and cold plasma, induce physical and structural changes within food tissues rather than directly generating heat, limiting their ability to remove large amounts of water when used alone. By combining thermal and non-thermal techniques, hybrid drying technologies leverage the advantages of both approaches to improve drying efficiency while better preserving the nutritional and quality attributes of food products. This systematic review evaluates the drying performance and quality attributes of hybrid drying technologies applied to fruits and vegetables. Peer-reviewed studies on non-thermal assisted and hybrid drying were retrieved from Web of Science, AGRICOLA, and PubMed. A total of 311 records were initially identified, and 101 studies met the inclusion criteria after the screening process. The findings indicate that the integration of infrared drying, ultrasound, and pulsed electric field technologies generally improves drying performance by reducing drying time and specific energy consumption, whereas cold plasma shows greater potential for preserving nutritional quality. Multiple-pretreatment strategies showed relatively smaller improvements in drying performance but tended to have higher retention of quality attributes than single-pretreatment approaches, suggesting a potential trade-off between drying performance and quality preservation.

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Abstract 855 | Poster 146

Exploring Innovative Non-Contact Capacitively Coupled Electric Fields for Ice Nucleation Control in Supercooled Packaged Foods

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ABSTRACT

Ice nucleation is a stochastic event that determines when cooled food begins to freeze. Electric fields have been reported to both promote and suppress nucleation, and the mechanisms remain debated, in part because the field applied to the sample is often neither reported nor verified. Most reported systems also require high voltages and bulky equipment, and place electrodes in direct contact with the samples, permitting electrolysis and contamination. This study characterized the effect of a non-contact capacitively-coupled electric field (CCEF) on ice nucleation and tested whether the response is a genuine field effect. Agar gels were placed on interdigitated electrodes (5 mm strips and gaps) insulated by 25.4 μm polyimide, giving no galvanic contact. The internal field was computed from an equivalent-circuit model validated against finite-element simulation (COMSOL v5.5). Samples were cooled to and held at −3.5 °C, and nucleation was identified at the latent-heat onset. Square-wave fields from 50 to 500 kHz and 20 to 80 V_{pp} were applied (n = 5 per condition) with field-off controls; because the field scales with frequency while heating scales with its square, a 50 kHz condition reduced heating below 2% of the 500 kHz level, isolating the field from heating. Groups were compared with rank-based statistics. CCEF suppressed ice nucleation at −3.5 °C. No nucleation occurred in 5 of 5 treated samples, whereas 4 of 5 controls froze ($p < 0.05$). Heating measured above freezing was 1.5 °C at 500 kHz but only 0.02 °C at 50 kHz, where suppression persisted, demonstrating a field effect rather than a thermal artifact. No suppression occurred at 20 V_{pp}, indicating a response threshold. Non-contact CCEF thus suppresses ice nucleation at low applied voltage under a calculable, reproducible field without electrode contact, providing a mechanistic basis for systems that control ice formation in foods.

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Abstract 865 | Poster 147

Surface Dielectric Barrier Discharge Cold Plasma Pretreatment of Postharvest Produce: Effects on Drying Kinetics and Quality

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ABSTRACT

Drying is among the most energy-intensive operations in food processing and can account for a substantial portion of energy use and carbon emissions. Improving moisture removal during drying therefore offers opportunities to reduce processing time and energy demand. For many fresh produce, the outer cuticle and surfaces waxes provide a natural barrier to moisture transport and can limit drying rates. Cold plasma (CP), a partially ionized gas produced by electric discharge, can alter produce surfaces through reactive species and other energetic components. These changes to surface microstructure may reduce a food's resistance to moisture transfer during subsequent drying. This study aimed to evaluate the effects of CP pretreatment on drying behavior and selected quality parameters of fresh produce with different surface characteristics. Cherry tomatoes, mushrooms, grapes, blueberries, and plums were treated for 15 min using a 12 inch × 12 inch atmospheric-pressure plasma reactor operated at 12.51 kHz and 100 W. Samples were subsequently dried in a dehydrator (55 °C, < 10% RH) for 34 h. The effect of CP on drying was commodity dependent. The highest improvements in drying rate were observed for plums (48.8%) and cherry tomatoes (27.1%), whereas mushrooms and blueberries showing little or no improvement, indicating that CP effectiveness is strongly influenced by commodity-specific surface properties. CP pretreatment increased the color brightness (L*) of dried plums by 3.2 and reduced the red color (a*) of dried tomatoes by 1.8, while no other significant color difference was observed (Student's t-test, $p < 0.05$; n=6). Total phenolic content decreased by 8% and 52% for blueberries and mushrooms respectively, whereas increases of 24%-73% were observed for other tested produce. Results demonstrate the potential of CP pretreatment for improving drying efficiency while highlighting the need for commodity-specific process optimization.

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Abstract 890 | Poster 148

Laser Photobiomodulation of Beet Sprouts: Integrated Nutritional, Metabolomic, Physicochemical, and Powder-Functionality Responses

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ABSTRACT

Laser irradiation offers a nonthermal, chemical-free approach for improving sprout quality, but its effects on biological, molecular, structural, and processing properties remain insufficiently understood.

This study investigated wavelength- and exposure-dependent photobiomodulation of beet sprouts by LILT at 405 nm (4.5 mW), 635 nm (7.0 mW), and 980 nm (9.8 mW) and elucidated how laser-induced biological and metabolic responses influence subsequent structural, thermal, moisture-sorption, and powder-functional properties

Treated sprouts were assessed for germination and growth, nutritional and antioxidant attributes, LC-MS metabolite profiles, FTIR molecular characteristics, DSC thermal behavior, SEM microstructure, color, powder handling properties, and dynamic vapor sorption (DVS) behavior.

The 635-nm treatment for 200 min produced the strongest response, increasing germination to 99.3% and enhancing growth. This treatment increased total soluble sugars, β-carotene, total phenolics and flavonoids, antioxidant capacity (DPPH, FRAP, and ORAC), iron, magnesium, γ-aminobutyric acid, and phenylalanine ammonia-lyase activity. LC–MS profiling revealed pronounced changes in primary and secondary metabolites, while principal component and heatmap analyses separated 635-nm-treated sprouts from other treatments, indicating metabolic remodeling. FTIR spectroscopy showed changes in functional-group regions, including O–H/N–H, C–H, carbonyl, amide, and carbohydrate-related vibrations. DSC showed an increase in glass-transition onset temperature from 46.44°C to 62.13°C, indicating reduced molecular mobility. SEM revealed surface roughening, fissures, and micro-cracks in laser-treated sprouts. Bulk and tapped densities increased to 0.38 ± 0.01 and 0.46 ± 0.03 g/cm³, respectively, while Hausner ratio, Carr's index, hygroscopicity, wettability time, and mechanical resistance decreased by 1.6%, 7.5%, 79.0%, 49.8%, and 14.08%, respectively. DVS analysis revealed altered moisture sorption behavior after 635-nm treatment, supporting reduced hygroscopicity and improved moisture stability.

Overall, the red LILT treatment at 635 nm simultaneously enhanced metabolic, structural, thermal, and powder-functional properties of beet sprouts.

LILT shows promise as a nonthermal processing strategy for producing high-quality, value-added sprout powders for functional food applications.

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Abstract 896 | Poster 149

Frying Kinetics of Chin-chin: Linking Moisture Loss, Morphological and Colour Changes to Acrylamide Formation

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Abstract (word count: 295)

ABSTRACT

Chin-chin is a widely consumed West African snack prepared using ingredients and processing conditions that can promote Maillard reactions and acrylamide (AA) formation. Limited information is available on the kinetics of colour development, morphological changes, and their relationships with moisture loss and AA formation during frying. This study aimed to systematically characterize these reactions and identify relationships that could support kinetic modelling and assessment of chin-chin chemical safety.

Chin-chin was prepared from flour, margarine, sugar, water, salt, and baking soda, cut into 1 cm^3 cubes, and fried at 150–180 °C for up to 15 min. Moisture, temperature, dimensions (thickness and volume), and colour (L*, a*, b*, and Browning Index (BI)) were monitored at 1-min intervals, while acrylamide was quantified by LC-MS. Experiments were performed in triplicate. Kinetic models were used to characterize moisture, dimensions, and colour as a function of frying time and evaluate relationships among these variables and AA formation.

Increasing frying temperature accelerated heating, moisture loss, dimensional changes, and colour development. Within 6 min, moisture decreased from ~32±0.9% to 5.0–2.6%, indicating rapid water removal during the early stages of frying. Dimensions initially increased by ~60–90% due to vapour generation, followed by ~10% contraction. BI initially decreased, likely due to reduced sample opacity, and subsequently increased rapidly, exceeding 80 AU after 6 min. Moisture loss was strongly associated with both dimensional and colour changes, which were described using kinetic models. BI values were also positively correlated with final AA content.

The results demonstrate that frying-induced moisture loss, expansion/contraction, and colour development are kinetically interconnected and can provide complementary indicators of the process. These relationships provide a basis for integrating heat and mass transfer with reaction kinetics to predict and optimize chin-chin processing and potentially mitigate AA formation and associated chemical-safety risks.

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Abstract 899 | Poster 150

Ultrasonic Compression Induced Structural and Compositional Changes in Cornmeal Nutrition Bars

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ABSTRACT

Ultrasonic compression is an innovative approach for producing flour-based nutrition bars. The process generates heat that promotes particle bonding, thereby reducing the need for liquid binders. This study evaluated the structural, thermal, mechanical, and chemical properties of cornmeal bars produced using ultrasonic welding.

Cornmeal was fractionated into particle-size groups of 245 μm (small), 530 μm (medium), and 1461 μm (extra-large). Nutrition bars were produced using ultrasonic welding at an energy level of 3100 J and an amplitude of 60% and were compared with bars produced by mechanical compression. Micro-computed tomography (Micro-CT) and scanning electron microscopy (SEM) were used to characterize the surface morphology and internal structure. Differential scanning calorimetry (DSC) was used to evaluate thermal properties, while Fourier-transform infrared spectroscopy (FTIR) was employed to assess changes in chemical composition associated with particle size and processing.

Average fracture stress decreased with increasing particle size. Micro-CT analysis showed that ultrasonic compression reduced porosity to 24%, compared with 57% in unprocessed cornmeal and 43% in mechanically compressed nutrition bars. Principle component analysis (PCA) of cornmeal FTIR spectra for percent transmittance at the 1503 cm^{-1} and the 974 cm^{-1} wave numbers identified three clusters corresponding to small, medium and extra-large particles. A similar PCA analysis of nutrition bars at 1710, 1745, and 1773 cm^{-1} for carbonyl (C=O) stretching vibrations showed similar particle size clusters. The irreversible overlapping thermal transitions above 130°C were observed in DSC scans, indicating process-induced changes in the cornmeal matrix.

Overall, ultrasonic compression promoted the development of new internal structures and bar properties were affected by the particle size. The mechanical strength of the nutrition bars was altered through the combined effects of processing and particle size. Optimizing ultrasonic processing parameters and particle size may enable the production of nutrition bars with a range of textures tailored to consumer preferences.

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Abstract 764 | Poster 151

Effects of Oscillating Magnetic Field-Assisted Supercooling on the Viability and Quality of Bovine Embryos

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ABSTRACT

In vitro-produced (IVP) embryos are increasingly used for embryo transfer (ET) in bovine genetic improvement. Short-term embryo storage may facilitate synchronization between embryo availability and the reproductive stage of recipient cows. Although cryopreservation is well established for long-term storage, it involves freezing and thawing procedures that may be unnecessary for short transport or scheduling intervals. Supercooling may therefore offer a simple alternative for short-term embryo storage. This study was conducted to evaluate the effects of oscillating magnetic field (OMF)-assisted supercooling preservation on the viability and quality of Hanwoo blastocysts. A custom built OMF-assisted supercooling system could maintain the embryos at −4°C under a 10 Hz oscillating magnetic field of 15 mT. Four to eight blastocysts per straw were stored at −4°C for 1, 2, or 3 days in TCM 199 supplemented with FBS and HEPES. After storage, the embryos were rewarmed to 4℃ over 1 h and cultured for 24 h in modified CR2 medium containing 5% FBS at 38.5℃ under 5% CO_2. Survival was assessed after 24 h based on morphological integrity and blastocoel re-expansion. Intracellular reactive oxygen species (ROS) levels and mitochondrial membrane potential were evaluated by fluorescence staining in the fresh control embryos and surviving embryos from each storage group. Four independent replicates were performed. All preservation medium remained unfrozen at −4°C throughout storage. Embryo survival differed significantly among the storage-duration groups, with survival rates of 66.67 ± 15.59%, 23.75 ± 15.60%, and 18.75 ± 12.50% after 1, 2, and 3 days, respectively ($p < 0.05$). Among the embryos that survived storage, intracellular reactive oxygen species levels and mitochondrial membrane potential did not differ significantly from those of fresh control embryos. These results suggest that OMF-assisted supercooling may be suitable for very short-term preservation of Hanwoo blastocysts, but further optimization is needed to improve survival beyond 1 day.

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Abstract 912 | Poster 152

Scale-up and Purification-Process Optimization of Polylactose

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ABSTRACT

Polylactose (PL) is a dietary fiber produced from lactose (a dairy whey ingredient) via a reactive extrusion process (REX) using a twin-screw extruder, followed by purification and drying. However, current extrudate purification is limited to the lab scale and is not industry-viable. Therefore, this study designed a scaled-up extrudate purification system and optimized its parameters. Furthermore, the efficiency of the newly developed system was determined and compared with the current lab-scale process. The system integrated a resin-bed canister with a plate-and-frame filtration system. The removal of brown color pigment was determined by measuring sample absorbance at 420 nm using a UV-Vis spectrophotometer. Lower absorbance indicates greater pigment removal. To optimize the process, treatment time, number of carbon filters, and solid concentration (10-30 min; 8-24 charcoal filters; 5-15%) were treated as independent variables, and brown color removal as the response variable. Although no significant differences ($p<0.05$) were observed among the treatment conditions, the optimized condition was 30 min of treatment time, 20 filter pads, and 9% solid concentration, which resulted in the maximum removal of the sample's brown color pigment. Moreover, this purification system significantly improved purification efficiency ($p>0.001$) from lab scale to industrial scale by increasing throughput from 1 G/20 h to 6 G/min. Hence, this study scaled up post-extrusion PL purification with an integrated plate-and-frame filtration system, replacing the current batch process and improving PL purification efficiency, quality, and throughput.

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Abstract 929 | Poster 153

Filament Extension Atomization Enabled Spray Dryers as a Platform to Produce Novel Products and Ingredients

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ABSTRACT

Filament Extension Atomization (FEA) is a new method to produce sprays from even the most difficult to spray materials. This technology can handle viscosities up to 1000 Pa*s, spray formulations with irregular solids, and spray materials with extensional properties from macromolecular content that would normally suppress droplet breakup. To create a platform for testing FEA's ability to create new products, we integrated FEA into small bench scale spray drying system that allows for exploration of new powders that could be produced with FEA based spraying technology. Using our benchtop FEA system, we tested a variety of novel ingredients, foods, and waste products to produce small quantities of powder for initial testing. Our FEA based spray dryer was able to produce powder from even the most difficult materials. The low solvent content in our materials allowed for the exploration of new process latitude in our spray drying process. We tested a wide range of temperatures and inlet moisture content to demonstrate FEA's ability to reduce the temperature required for spray drying for temperature sensitive materials. Additionally, utilizing a spray chilling approach we were able to spray chill difficult to spray materials utilizing FEA as an atomizer. FEA was also tested for its ability to handle food waste streams laden with large irregular particles and we were able to demonstrate drying of these streams with potential for the technology to be used to create new products and minimize waste. We present the results of our exploration and a comparison of the particle morphology at a range process conditions and solids loadings.

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Abstract 947 | Poster 154

Cultivation-Based Postharvest Processing of Wild-Simulated Ginseng through Individualized Management

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ABSTRACT

Conventional postharvest management of fresh plant materials generally relies on refrigeration to delay deterioration or drying to stabilize products for storage and subsequent processing. For high-value plants, however, maintaining physiological activity after harvest may create an alternative processing window for preserving freshness while actively managing biological condition. This study aimed to evaluate cultivation-based postharvest processing of wild-simulated ginseng using an individual-plant management approach and to identify key controllable variables affecting postharvest responses. Each plant was transplanted into a separate pot and managed individually under controlled conditions. Three experiments were conducted. First, 3-5-year-old plants were maintained at 14-20 °C for 45, 90, 135, or 180 days in winter and 90, 120, or 150 days in spring; responses were evaluated using weight change rate (WCR) and relative growth rate (RGR). Second, watering was triggered at soil water content thresholds of 0, 5, 10, 15, or 20%. Third, aboveground tissues were either left intact or removed 70 or 90 days after emergence. Treatment effects were assessed by one-way ANOVA and Tukey's HSD test ($p < 0.05$). Spring processing for 120 days provided the best balance of growth efficiency and stability, with a WCR of 47.8 ± 15.4% and an RGR of 3.18 ± 0.90 mg/g/day. Watering triggered at 0-5% soil water content supported the highest germination, growth, and survival, whereas responses declined markedly at ≥10%, indicating a threshold for stable management. Cutting at 70 days reduced survival to 60%, while cutting at 90 days maintained 100% survival but reduced growth relative to uncut plants. These findings show that cultivation-based postharvest processing can be systematically designed through plant-specific control of duration, moisture, and physical intervention, providing a basis for individualized postharvest management of high-value plant materials.

Acknowledgement This research was supported by the Commercialization Promotion Agency for R&D Outcomes (COMPA) funded by the Ministry of Science and ICT(MSIT). (RS-2025-25422608, 2025 Technology Commercialization Enhancement Project (TLO Innovation) Seoul National University.

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Abstract 954 | Poster 155

Technifying Solar Drying of Coconut: Preliminary Links between Drying Performance and Oil Quality

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ABSTRACT

Passive solar drying remains an attractive option for small-scale agroindustry in tropical regions because of its low operational complexity and reliance on renewable energy. However, the absence of control over airflow and drying temperature makes the process highly dependent on weather conditions, which can limit consistency and product quality. This study explores the technification of solar drying as a strategy to improve process control while maintaining solar energy as the primary energy source. Grated coconut was dried in a traditional solar greenhouse (*marquesina*) and in a solar-assisted forced-convection dryer operated at a relatively low temperature of 50 °C. Drying behavior was evaluated through moisture-ratio kinetics, while the resulting coconut oil was assessed using oil recovery indicators, selected physicochemical quality parameters, and a preliminary volatile profile. The controlled solar-assisted system showed a well-defined drying behavior, with the Page model providing an excellent fit ($R^2 = 0.9938$). Although overall oil yield was slightly higher for the traditional greenhouse (23.1%) than for the solar-assisted dryer (20.8%), dry-basis yield was comparable (55.0 and 55.3%, respectively), while oil recovery efficiency increased from 85.6 to 87.8%. More importantly, the controlled system produced oil with substantially lower free fatty acids (0.405 vs. 2.111 g kg^{-1}) and peroxide value (0.778 vs. 1.186 meq O_2 kg^{-1}). Preliminary GC-MS results also revealed differences in the volatile profile, including the absence of 2-heptanone in the solar-assisted treatment, whereas it represented 26.63% of the relative volatile area in the greenhouse-derived oil. These results provide preliminary evidence that technifying solar drying can improve process control and contribute to more consistent oil quality without abandoning solar energy as the basis of the drying process. The ongoing engineering analysis will quantify the heat and mass transfer and energy performance of the system.

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Poster Session 6: Sustainability, Valorization & Packaging

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Abstract 585 | Poster 156

Opportunities and Challenges in fungal plastic bioconversion for mycoprotein and enzyme production

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ABSTRACT

Justification: To advance the circular bioeconomy, *Pleurotus ostreatus* was used to bioconvert LDPE into edible mycoprotein+laccase, diverting plastics from waste streams. By coupling plastic upcycling with alternative protein production, this approach addresses low LDPE recycling-rates and plastic accumulation while outlining a scalable route to reduce the environmental footprint of protein production.

Objective: Evaluate *P. ostreatus* to simultaneously degrade LDPE and produce mycoprotein+laccase under submerged fermentation, while assessing the effects of carbon availability and LDPE addition timing.

Methods: Fermentations were conducted with *P. ostreatus* (10^7 spores/100 mL) for 20 days at 30 °C and 160 rpm using three initial glucose concentrations (10, 20, 30 g/L). LDPE was added at inoculation (day 0) or on day 5. Carbon–hydrogen bond disruption in LDPE was monitored by FTIR, and UV-C pretreatment (3–24 cycles, 20 min/cycle) was evaluated. Reducing sugars, biomass, protein, and laccase activity were monitored.

Results: LDPE addition at day 0 yielded the highest laccase activities (≈40–80 IU/mL), with lower glucose levels favoring higher enzyme production, consistent with carbon-limited driven induction of ligninolytic enzymatic pathways. Co-inoculation of LDPE+fungus resulted in lower biomass and less CH2 band attenuation than LDPE addition on day 5. The greatest CH2 band reductions were observed when LDPE was added on day 5, when glucose was < 8 g/L. Maximum biomass was observed under these conditions at the highest initial glucose level (30 g/L).

Conclusions: This demonstrates that LDPE can be a potential carbon source for fungal fermentation. Its degradation and fungal growth can be balanced by controlling carbon availability and substrate addition timing.

Significance: This work highlights a novel bioprocessing strategy integrating plastic valorization with protein+enzyme production. It provides engineering insights into process optimization for co-producing mycoprotein and ligninolytic enzymes while enhancing LDPE depolymerization, supporting a scalable, sustainable biocircular conversion system for plastic waste.

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Abstract 642 | Poster 157

Robust Fermentation of Variable Dairy Whey for Acetate Production Supporting Protein-Rich Microalgae Cultivation

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ABSTRACT

Protein-rich microalgae have emerged as a sustainable alternative protein source due to their high nutritional value, rapid growth, and low environmental footprint. In our previous work, acetate-supported mixotrophic cultivation efficiently produced protein-rich microalgae. To further reduce production costs and improve resource circularity, this study developed a robust two-stage fermentation process that consistently converts compositionally variable dairy whey into an acetate-rich effluent suitable for downstream microalgal cultivation.

Three compositionally distinct dairy whey samples collected from local dairy stores in Connecticut were used as feedstocks. In the first stage, lactose was anaerobically converted into lactic acid by lactic acid bacteria. Response surface methodology (RSM) identified a common set of fermentation conditions (pH 6.88, 7.81 g/L yeast extract, and 38.1 °C) applicable to both traditional Camembert whey and Alpine whey, increasing lactose removal from 25.6% and 56.6%, respectively, to over 96%, in close agreement with the model-predicted value of 98%. The optimized conditions were subsequently validated using an independent Camembert whey sample and a randomly mixed whey sample without further optimization, achieving approximately 97% lactose removal and demonstrating robust performance despite variations in whey composition. In the second stage, RSM was further employed to optimize the yeast extract concentration (6.5 g/L), temperature (42 °C), and aeration rate (0.45 vvm) for the aerobic conversion of lactic acid to acetic acid, using first-stage fermentation broths prepared from randomly mixed whey batches. The resulting acetic acid-rich fermentation broth was mixed with BBM medium at a 1:1 (v/v) ratio for mixotrophic microalgal cultivation. The fermentation-derived acetate supported a protein productivity of 0.28 g/L/d, comparable to that obtained using commercial acetic acid.

This work demonstrates an effective and robust strategy for valorizing compositionally variable dairy whey into a sustainable carbon source for microalgal protein production, providing a scalable approach for integrating dairy waste biorefinery with alternative protein manufacturing.

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Abstract 660 | Poster 158

Upcycled Coffee Oil and Eggshell Byproducts as Functional Additives for PHBV: Advancing Circular Economy Solutions in Sustainable Food Packaging Through Waste Valorization and Performance Enhancement

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ABSTRACT

PHBV (poly(3-hydroxybutyrate-co-3-hydroxyvalerate)) offers strong potential as a biodegradable alternative to petroleum plastics, but its intrinsic brittleness and poor melt processability have long restricted commercial packaging applications. This study investigated whether food industry waste-derived additives- coffee oil epoxide (COE) as a plasticizer and eggshell-derived calcium carbonate as a reinforcing filler- combined with high-molecular-weight natural rubber (NR), could overcome these limitations while preserving full biodegradability.

Blends were prepared via twin-screw extrusion and sheet molding, then characterized using DSC, SEM, tensile testing, and oxygen transmission rate (OTR) analysis. Environmental performance was validated through field composting trials at two commercial facilities (Dayton Foodbank and London Facility), following ASTM WK80528, CMA, and Compostable Field-Testing Program protocols, alongside controlled laboratory mass-loss testing. Statistical differences were assessed via one-way ANOVA with Tukey's HSD ($p < 0.05$).

Results showed that COE significantly improved flexibility and processability, while eggshell-derived $CaCO_3$ enhanced mechanical strength. SEM revealed uniform filler dispersion without phase separation. DSC confirmed reduced crystallinity (68.5% to 50.8%) and melting point (170.4 °C to 166.5 °C), consistent with reduced brittleness. OTR values dropped substantially in COE-containing formulations, indicating improved barrier performance. Critically, unmodified PHBV/NR blends exhibited phase separation that prevented sheet formation entirely, whereas the fully formulated PHBV/NR/COE/$CaCO_3$ blend produced well-defined, processable sheets. Field and lab composting confirmed that modified sheets degraded significantly faster than neat PHBV, demonstrating that functional enhancement did not compromise end-of-life performance.

These findings show that upcycled food waste streams can simultaneously solve PHBV's processability bottleneck and reinforce its mechanical profile, without sacrificing biodegradability. By validating degradation across both controlled and industrial composting environments, this work provides a scalable, circular-economy pathway toward commercially viable, fully biodegradable packaging films-directly addressing the resource sustainability and functional performance gaps that have historically limited PHBV's real-world adoption.

Keywords: PHBV, coffee waste, eggshell filler, natural rubber, plasticizer, food waste valorization, sustainable packaging, industrial composting.

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Abstract 680 | Poster 159

Cosolvent -modified Supercritical-CO2 extraction of fish oil on marine waste

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ABSTRACT

Objectives:
The extraction efficiency and the subsequent bioavailability of Omega-3 polyunsaturated fatty acids (PUFAs) remain a critical concern in marine lipid processing. This study aimed to systematically compare three distinct extraction methodologies—ethanol-modified supercritical CO_2 (Cosolvent-SC-CO_2), pure SC-CO_2, and conventional organic solvent extraction (hexane and ethanol)—to evaluate their impacts on fish oil yield, EPA/DHA recovery, oxidative stability, and crucially, their gastrointestinal digestibility from marine waste product (salmon head in this case).

Methods:
Fish oil was extracted using the three methods mentioned before under controlled conditions. The extracted oils were analyzed for their total lipid yield, EPA/DHA profiles (via GC-MS), and lipid oxidation indicators (peroxide and acid values). Furthermore, an in vitro simulated gastrointestinal digestion model was conducted to monitor the release rate of free fatty acids (FFAs) and assess the micellarization efficiency, which serve as direct indicators of intestinal absorption and digestibility.

Results:
The comparative analysis revealed that Cosolvent-SC-CO_2 extraction achieved the highest cumulative concentration of EPA and DHA (32.4%), significantly outperforming pure SC-CO_2 (due to its non-polar limitations) and hexane extraction (which suffered from partial thermal degradation during solvent recovery). In terms of quality, the cosolvent-SC-CO_2 oil exhibited the lowest peroxide value. Most importantly, during in vitro digestion, the oil obtained via Cosolvent-SC-CO_2 demonstrated a significantly faster kinetic lipolysis rate (77.4%) compared to the other two methods (51.3% for pure SC-CO_2 and 36.6% for solvent extraction). The presence of ethanol as a cosolvent altered the initial lipid-matrix binding, resulting in a favorable self-emulsification pattern that drastically enhanced pancreatic lipase accessibility during digestion.

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Abstract 691 | Poster 160

3D-Printed soy protein–microalga films with potential for food packaging

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ABSTRACT

Edible films are sustainable, biodegradable materials that can reduce the transfer of moisture, gases, and volatile compounds. Incorporating functional ingredients such as *Chlorella vulgaris*, a nutrient-rich green microalga widely used as a food and dietary supplement, can further enhance the functionality of edible films. This study investigated the optimization and fabrication of 3D-printed soy protein isolate (SPI)–microalgae (MA) edible films. Different gels of 11% (w/w) SPI and MA (0, 1, 3, and 5%, w/w) were prepared by mixing at 23 °C for 2 h. Glycerol (3.3%, w/w based on SPI) was added as a plasticizer, followed by vacuum degassing. The pH was adjusted to 8.5 using 1 M NaOH, and the suspensions were heated at 85 °C for 30 min to induce gelation. The effects of MA concentration, nozzle diameter (0.52–0.81 mm), and printing speed (10–20 mm/s) on printability were evaluated. Printed films were dried and analyzed for rheology, color, mechanical properties, water vapor permeability, microstructure, secondary structure, and antioxidant properties. All formulations showed shear-thinning behavior with rapid structural recovery, indicating suitability for extrusion 3D printing. The optimal printing conditions were 3% MA, a 0.72 mm nozzle diameter, and a printing speed of 20 mm/s. Compared with the control (SPI 11% (w./w)), films containing MA showed more than a 40% increase in tensile strength, over a 12% increase in puncture strength, and more than a 16% decrease in elongation at break. Water vapor significantly decreased by over 40%, and antioxidant activity increased twice with MA incorporation. Microstructural and secondary structure analyses revealed the formation of a denser, less porous gel network as MA concentration increased. These findings show the potential of 3D-printed SPI–microalgae edible films for application as film and food packaging materials.

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Abstract 696 | Poster 161

Generating high-value porous materials from fruit and vegetable waste

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ABSTRACT

Fruit and vegetable waste is a global concern due to its significant environmental impact, economic loss, and implications for food security. In this study, fruit and vegetable waste was used as whole materials, avoiding extraction, to produce aerogels via supercritical carbon dioxide (SC-CO_2) drying for applications of dye removal. Aerogels were produced from banana peel (BPA), broccoli stem (BSA), cabbage leaves (CLA), imperfect carrot (ICA), and orange peel (OPA). The resulting aerogels exhibited low density (<1 g/cm^3), high porosity (>93%), and high surface areas (12-172 m^2/g), with OPA showing the highest value at 172 m^2/g. The CLA samples had the highest pore size (29 nm), contributing to their highest water absorption capacity of 95%. SEM images showed a promising porous structure and highlighted the fibrillar structure in OPA samples. The average methylene blue adsorption capacity was ~84%, except for OPA samples (53%). The methylene blue adsorption was driven by electrostatic interactions, which highly correlated with the pseudo-first order kinetic model (R^2 > 0.98). Overall, this study demonstrates that whole fruit and vegetable waste can be effectively converted into lightweight, highly porous aerogels with potential applications in biomedical and food fields, purification and filtration systems, and other functional materials sectors. This work addresses the global challenge of fruit and vegetable waste by valorizing the whole food residues into high-value, functional aerogels without extraction or chemical-intensive processes.

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Abstract 718 | Poster 162

Valorization of Tofu Press Water through Production and Recovery of Platform Fatty Acids

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ABSTRACT

Tofu manufacturing generates large volumes of nutrient-rich tofu press water (TPW), which is typically discarded as wastewater, posing an economic and environmental burden and an untapped resource for chemical production. Open-culture microbial chain elongation offers a pathway to convert TPW into short- and medium-chain fatty acids (FAs), with applications in bioplastics, animal feed, food ingredients, nutraceuticals, and pharmaceuticals. The objective of this study was to evaluate TPW as a chain elongation substrate, develop an integrated extraction system to recover FAs, and identify operating conditions that influence product yields and specificity.

A 3 L anaerobic bioreactor enriched for chain elongation was operated across multiple experimental phases to examine methanogenic suppression through pH control, increased organic loading rate (OLR), in-line liquid-liquid extraction, and feed optimization *via* pre-fermentation and acetate supplementation. Reactor performance was tracked through pH, total and volatile solids, chemical oxygen demand, biogas production, and carboxylic acid concentrations. Product recovery rates *via* liquid-liquid extraction were also determined.

Pre-fermentation of the TPW increased lactate availability, enabling lactate-based chain elongation to platform FA production, with *n*-butyrate and *n*-valerate emerging as major products, reaching peak concentrations of 180.2 mmol-C/L and 54.2 mmol-C/L, respectively. Acetate and propionate were also present at high concentrations, while *n*-caproate (17.5 mmol-C/L) was produced at lower levels. *n*-Valerate, *n*-butyrate, and propionate were the dominant fatty acids recovered by the in-line extraction system. Lowering reactor pH suppressed methanogenesis and favored FA accumulation, while product distribution was more sensitive to feed composition and the lactate-to-acetate ratio than to the OLR within the range tested. These findings demonstrate that TPW can be upcycled into a spectrum of recoverable platform FAs, providing a pathway to valorize food byproducts as part of a more circular and sustainable food system.

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Abstract 726 | Poster 163

The Impact of a "Move to −15°C" Sustainability Initiative on Ice Cream Quality

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ABSTRACT

Since maintaining the long-established storage temperature of −18°C frozen foods throughout the cold chain is energy intensive, the "Three Degrees of Change" and "Move to −15°C" initiatives have advocated for increasing storage temperatures from −18°C to −15°C to reduce energy consumption. While such a change is unlikely to impact the quality of many foods, ice cream is an exception because even small temperature deviations may adversely affect its texture and flavor. This work investigated the effects of storage (through 6 months) on physical and sensory properties of vanilla ice cream. "Control" (11% fat) and "Premium" (14% fat) formulations were stored under constant (−18 and −15°C) temperature or were treated to simulate transportation (single 45-min refrigeration event) and household freezer abuse (three 45-min refrigeration storage events). Although physical properties changed during storage, the differences were inconsistent over time and did not demonstrate clear progressive structural deterioration. In contrast, sensory quality was markedly affected by storage temperature and time. After only three months, sandy and lacks freshness defects were detected in ice cream stored at −15°C, whereas these defects were not observed in ice cream stored at −18°C throughout the study. After four months, the sandy defect in ice cream stored at −15°C became so pronounced that the samples were removed from further sensory evaluation. These findings indicate that a 3°C increase in frozen storage temperature is sufficient to accelerate quality deterioration in ice cream, emphasizing that energy-saving strategies for the frozen chain should be validated for individual products before broad implementation.

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Abstract 729 | Poster 164

Design and Experimental Evaluation of a Biomass-Based Boiler for Sustainable Thermal Energy Supply in Rural Agroindustries

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ABSTRACT

Coconut (Cocos nucifera) is one of the most economically significant tropical crops in coastal regions of the Global South, including Colombia, where it is primarily cultivated by small-scale producers. However, its processing generates large amounts of lignocellulosic residues, particularly coconut shells, which are often underutilized despite their high potential as a renewable energy source. In this context, the development of sustainable and decentralized thermal energy systems is essential to enhance the competitiveness of rural agroindustries. This study presents the design and experimental evaluation of a biomass-based boiler using coconut shell as fuel, within the framework of the Biopalmas program in Colombia. A systematic design methodology was implemented considering the thermal energy requirements of agroindustrial processes such as vacuum frying and tangential microfiltration, while promoting circular economy principles through waste valorization. Experimental tests were conducted to evaluate combustion performance, energy efficiency, and emissions. The system achieved an average combustion efficiency of 87.2%, indicating effective fuel oxidation, although the presence of CO and CH_4 in flue gases revealed partial combustion limitations associated with air–fuel mixing and residence time. The boiler delivered an average thermal power of 452.9 kW, with 305.7 kW effectively transferred to the working fluid, resulting in a global thermal efficiency of 67.5%. Energy losses were mainly associated with incomplete combustion (≈57.6 kW) and sensible heat in flue gases (≈89.7 kW), highlighting opportunities for improvement through air supply optimization and heat recovery strategies. Emission analysis showed low NOx levels, while CO emissions indicated the need for improved combustion control. The results demonstrate the technical feasibility and operational stability of coconut-shell-based systems as a scalable solution for sustainable thermal energy supply in rural agroindustrial applications.

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Abstract 734 | Poster 165

Comparing Phosphorus Sustainability of Plant-Based Protein Isolates Using Life Cycle Assessment

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ABSTRACT

Shifting towards plant-based alternative proteins is increasingly framed as a plausible pathway to more sustainable food systems. Life cycle assessments (LCAs) consistently demonstrate that plant-based proteins outperform conventional animal proteins across key environmental metrics, including greenhouse gas emissions, land use, and water consumption. However, the phosphorus (P) implications of plant-based alternative proteins are underexamined. P sustainability is recognized as an important sustainability metric due to both the upstream resource scarcity and its potential to damage downstream water quality. Since agriculture accounts for around 90% of global P use, it is important to accurately characterize the P footprint of food production systems, particularly those positioned as sustainable alternatives.

This study uses LCA to compare the P footprint of nine U.S.-grown crops—almonds, chickpeas, maize, oat grain, peas, potatoes, rice, soybeans, and wheat grain—commonly used as feedstocks for plant-based protein concentrates and isolates. P footprint is quantified as freshwater eutrophication potential (FEP), calculated using the ReCiPe (2016) method with Agri-footprint 7.0 life cycle inventory data. P impacts are assessed across multiple functional units, including per kg of crop grown and per kg of crude protein contained in the crop, to capture how protein density shifts the relative P burden of each crop. Preliminary findings indicate that the P footprint of growing 1 kg of peas or chickpeas is more than double that of the next-highest crop, but when normalized per kg of crude protein, potatoes surpass peas and chickpeas in P footprint. By systematically comparing these results, this study aims to clarify the P implications of plant-based protein sources, providing guidance for decisions aimed at minimizing P impacts in sustainable protein production. Future work aims to incorporate additional criteria (e.g., carbon footprint, cost, technology readiness, amino acid profiles) to construct comprehensive sustainability guidance for plant-based protein producers.

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Abstract 738 | Poster 166

Integrated Recovery of Lipids and Cellulose Microfibers from Spent Coffee Grounds for Functional Hydrophobic Coatings in Fiber-Based Packaging

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ABSTRACT

Spent coffee grounds (SCG) are among the most abundant food processing byproducts worldwide, containing substantial amounts of extractable lipids and cellulose-rich fractions. Conventional extraction methods are often energy-intensive and rely on organic solvents. Supercritical CO_2 (SC-CO_2) extraction provides a green alternative for recovering high-value lipophilic compounds while preserving the remaining lignocellulosic biomass for downstream processing. When integrated with wet milling, this cascading biorefinery approach enables efficient biomass fractionation and valorization. This study used SCG as a model feedstock to investigate an integrated biorefinery process that combines SC-CO_2 extraction and wet milling to simultaneously recover high-value lipid and cellulose fractions and to develop functional hydrophobic coatings for fiber-based packaging.

SCG underwent SC-CO_2 extraction to recover lipophilic compounds, producing cellulose-rich residues for further processing. The extracted SCG were pulped with peracetic acid, and the resulting pulp (5% solids) was wet milled at 8.12 or 12.18 m s^{-1} for 90 min using a bead mill to produce cellulose microfibers (CMF). CMF/wax coatings were formulated by combining CMF with the recovered wax fraction at CMF-to-wax ratios of 1:0.5, 1:1, 1:2, and 1:3, and glycerol as a stabilizer. Coatings were characterized by morphology, particle size, and zeta potential and analyzed with one-way ANOVA and Fisher's LSD test.

SC-CO_2 effectively extracted SCG into oil, liquid, and wax fractions while preserving cellulose-rich residues. Wet milling at 8.12 m s^{-1} resulted in greater fiber defibrillation and a finer particle size ($p < 0.05$) than milling at 12.18 m s^{-1}. The 1:1 CMF/wax coating exhibited the most emulsion stability and the highest zeta potential ($p < 0.05$) based on appearance and dispersion characteristics. These results demonstrate an integrated, cascading biorefinery strategy that simultaneously recovers value-added lipophilic compounds and produces cellulose microfibers for functional hydrophobic coatings, thereby promoting the sustainable valorization of agri-food byproducts.

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Abstract 740 | Poster 167

Selection of Agri-Food Biowaste Fibers and Optimization of Delignification Conditions for Enhanced Drainage in 100% Non-Woody Molded Pulp Fruit Baskets

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ABSTRACT

Agri-food biowastes (AFB) are promising feedstocks for molded pulp packaging; however, their high water-holding capacity can limit drainage efficiency during molding. This study identified suitable AFB feedstocks and optimized delignification conditions for pilot-scale production of a 100% AFB, non-woody berry basket. A completely randomized 3×2×2 factorial design evaluated hemp hurd, stalk, and fiber with or without onion skin and ball-milled hazelnut shell additions. Freeness (°SR) served as the primary screening criterion. Because onion skin and hazelnut shell did not improve drainage, hemp fiber was selected for optimization. A subsequent 3×3 factorial design investigated fiber size (>4 mm, <2 mm, and unmilled) and delignification time (1, 2, and 3 h) using 2.25% peracetic acid at 85°C. Freeness and various mechanical properties were measured. Optimized pulp was formed into molded fruit trays and compared with commercial berry baskets for mechanical performance and blueberry storage quality. Data were analyzed by ANOVA and Tukey's HSD test ($P< 0.05$). Hemp fiber exhibited the lowest freeness (72 ± 1.4 °SR), indicating the fastest drainage. Onion skin increased freeness to 92-93 °SR, whereas hazelnut shell provided no improvement ($P< 0.05$). Delignification time and fiber size significantly affected freeness ($P< 0.05$), while their interaction was not significant ($P> 0.05$). Freeness decreased from 43.2 °SR at 3 h to 23.0-24.4 °SR at 1-2 h and from 43.6 °SR for fibers <2 mm to 19.3 °SR for fibers >4 mm. The optimum condition (2.25% PAA, 85°C, 2 h) achieved 26.3 °SR while maintaining mechanical integrity. Molded pulp trays exhibited lower flexural yield strength (3.40 ± 0.59 MPa) but higher strain (0.06 ± 0.00) than commercial baskets (5.01 ± 0.27 MPa and 0.04 ± 0.00). During transportation simulation and storage, molded pulp trays reduced blueberry weight loss (7.10 ± 0.08% vs. 7.76 ± 0.02%) while maintaining comparable decay rates and firmness.

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Abstract 753 | Poster 168

From Bark to Barrier: Solvent-Directed Self-Assembly of Birch-Bark Extractives for Sustainable Food Packaging

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ABSTRACT

The global accumulation of plastic waste called "white pollution" specially, from food packaging, demands urgent sustainable alternatives. While renewable paper is highly attractive for food-contact applications, its inherent hydrophilicity necessitates barrier coatings to prevent moisture degradation. Conventional food packaging coatings rely on polyolefins and per- and polyfluoroalkyl substances (PFAS), which raise severe health, regulatory, and environmental concerns. To address this, we draw inspiration from the Algonquin people of Kitigan Zibi, who historically crafted birch bark containers for food preservation. Building on this traditional knowledge, investigates birch bark extractives to develop bio-based, biodegradable coatings for paper-based food packaging. Natural surfaces achieve water repellency through micro- and nanoscale morphologies rather than complex synthetic chemistry. We hypothesized that controlling the crystallization route of a single birch bark extractive could dictate distinct topographies and barrier regimes suitable for food protection.

Coatings were drop-cast onto cellulosic substrate from two solvents of contrasting volatility and returned to ambient conditions after complete solvent removal. Surface microstructure and topography were examined by scanning electron microscopy and optical profilometry, composition verified by ATR-FTIR, crystallinity quantified by powder X-ray diffraction, wettability assessed by static water contact angle, and barrier performance by water vapour transmission rate. Spectroscopic and diffraction data confirmed that molecular-scale structure and composition were effectively unchanged between routes, isolating topography as the controlling variable. The high vapour pressure medium drove rapid solvent removal and high supersaturation, favouring nucleation over growth and yielding layered porous sheets with fine micro- and nanoscale surface features, contact angles of 130°, and a tenfold reduction in water vapour transmission rate. The lower vapour pressure medium sustained slower crystallization at reduced supersaturation, allowing extended growth into larger microdomains and compact, irregular networks that lacked hierarchical texture and gave contact angles of 86° with correspondingly poorer barrier performance. Barrier function therefore tracks topography rather than chemistry: hierarchical structuring is what converts a bio-based extractive into a functional moisture barrier. Because solvent volatility alone spans this range, drying kinetics offer a single-step, scalable route to engineering biodegradable, food contact compatible coatings on cellulosic and geometrically complex substrates such as moulded fibre trays and cups.

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Abstract 755 | Poster 169

Plasma-Assisted Surface Engineering of Silica-Enriched Chitosan Films for Enhanced Moisture Barrier and Liquid Repellency

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ABSTRACT

Growing demand for sustainable food packaging has increased interest in chitosan films because of their biodegradability, film-forming ability, and excellent oxygen barrier properties. However, their strong affinity for water leads to moisture absorption, swelling, and deterioration of barrier performance under humid conditions, limiting applications with high-moisture foods. This study investigates a surface-engineering strategy combining silica nanoparticles (SiO_2), cold oxygen plasma, and fluorine-free organosilane functionalization to improve the moisture resistance of chitosan films. Rather than dispersing SiO_2 throughout the polymer matrix, a silica-rich surface layer is produced by depositing nanoparticles onto a thin chitosan-based tie layer, allowing partial particle embedment while maintaining an exposed nanostructured surface. The films are subsequently treated with atmospheric-pressure cold oxygen plasma and vapor-functionalized with dichlorodimethylsilane to generate a low-surface-energy dimethylsiloxane-rich surface.

Surface morphology and chemistry are characterized using scanning electron microscopy, atomic force microscopy, X-ray photoelectron spectroscopy, and Fourier-transform infrared spectroscopy. Liquid repellency is evaluated using water contact angle, contact-angle hysteresis, and droplet roll-off measurements, while water-vapor and oxygen permeability are assessed as key packaging barrier properties. The silica-enriched surface increased surface roughness and greater exposure of silicon-containing domains compared with unmodified chitosan. Following plasma-assisted organosilane functionalization, the films showed substantially reduced wettability, increased water contact angle, and lower droplet adhesion. The combined treatment also reduced water-vapor transport while maintaining the favorable oxygen-barrier characteristics of the chitosan substrate. These changes are attributed to the combined effects of nanoparticle-induced hierarchical surface texture, plasma activation, and formation of a low-surface-energy siloxane layer. This surface-selective approach provides a promising strategy for developing moisture-resistant, fluorine-free biopolymer packaging for contact with high-moisture foods.

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Abstract 763 | Poster 170

Novel Alternative Protein Products from Upcycled Agrifood Side-streams: A win-win approach for sustainability

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ABSTRACT

Background:
Population growth and rising demand for animal-based foods intensify pressure on land and water, increase pollution and greenhouse gas emissions, raise animal-welfare concerns, and promote antibiotic-resistant pathogens. Sustainable protein alternatives are therefore urgently needed. Agrifood side-streams, often discarded or used as animal feed, are underutilized nutrient-rich resources.

Objective:

To investigate corn plant biomass (CPB), wheat straw, and okara—a soy-processing by-product—as substrates for producing protein-rich foods, as alternatives to animal-based food.

Methods:
Yeast was cultivated on lignocellulosic biomass pretreated with sulfuric acid, followed by enzymatic hydrolysis to convert polysaccharides into fermentable sugars. The resulting yeast biomass was evaluated as the main ingredient in alternative protein products. Heat treatment and acidification were used to induce gel formation.

Results:
Carbohydrate contents were 57% in CPB, 42% in wheat straw, and 14% in okara, while protein contents were 12%, 2.2%, and 35%, respectively. Acidification followed by enzymatic hydrolysis produced the highest sugar and protein yields. Treated CPB contained sevenfold more protein and fivefold more reducing sugars than the reference yeast medium, YPD. When diluted to match YPD sugar levels and supplemented with 1% yeast extract, treated CPB and okara supported greater yeast growth than YPD. Yeast grown on enriched CPB had protein content comparable to YPD-grown cells.

Homogenized, acidified model yeast biomass formed heat-set gels suitable e.g. for fermented dairy analogues. A 25% (w/w) yeast dispersion containing 5% protein at pH 5 was pretreated using bead beating or high-pressure homogenization (HPH), then heated to 65°C. The resulting gels had log(G′[Pa]) values of 1 and 2, respectively. Further study is underway to characterize additional functionalities and develop functional yeast-based protein-rich ingredients for alternative protein products.

Conclusion:
Yeast grown on lignocellulosic agrifood side-streams offers a promising raw material for sustainable alternative protein products and supports a circular bioeconomy.

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Abstract 771 | Poster 171

Engineering a fortified breakfast cereal: using grape pomace and protein powder to create a functional product

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ABSTRACT

Food processing generates large quantities of byproducts that often go to waste streams. Ready to eat (RTE) cereals are a common breakfast option but are usually high in added sugar and low in fiber and protein. This study aimed to develop an understanding of the influence of grape pomace and protein fortification on the techno-functional properties of extruded cereal products. Grape pomace was upcycled to create a functional ingredient to add fiber and antioxidants to the cereal along with milk and fava bean protein. Operating parameters and product qualities were systematically studied. Grape byproducts were obtained from the juice industry before being freeze dried and ground. Corn grits were mixed with the dried grape pomace and either milk or fava bean 90% protein isolate. Combinations of 0/10/20 % pomace and 0/10/20/30 % protein powder were tested using set extruder parameters. Product moisture content, color, water activity, specific mechanical energy (SME), physical properties, texture, hydration kinetics, in-vitro digestion, and scanning electron microscopy (SEM) were measured. Samples had final moisture content between 1.65-6.41 % w.b. and water activities under 0.45. The Weibull model could accurately describe the hydration kinetics of the model. SEM results revealed more irregular, layered, and heterogeneous microstructure after fortifications, which were confirmed using in-vitro digestion that showed lower starch digestibility. INFOGEST and proximate analyses were completed. Samples with pomace and protein showed increased hardness and lower expansion ratio than the control for all samples. Introduction of non-starch additives into the formula decreased expansion potential which led to a harder product. The final recommended cereal has 20% fava protein and 20% pomace. This study revealed the effects of fortification on the techno-functional properties of cereal by focusing on 4 conditions (corn only, only fiber, only protein, and protein and fiber).

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Abstract 821 | Poster 172

Selective extraction of sorghum wax from bioethanol production side-stream using supercritical carbon dioxide: An alternative to carnauba wax for fruit coating

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ABSTRACT

The use of grain sorghum in bioethanol production results in a lipid side-stream that is wasted. Nevertheless, this lipid slurry is rich in sorghum wax that has a melting temperature comparable to that of carnauba wax. Therefore, this study aimed to extract sorghum wax from the bioethanol side stream using SC-CO_2 extraction and to evaluate the effects of sorghum wax coatings on the postharvest quality of oranges in comparison with commercial carnauba wax coatings. A three-factor response surface design was employed to optimize the SC-CO_2 processing conditions (i.e., the pressure (40 MPa), temperature (35-75 °C), and time (3-6 h)) for selective separation of the waxes. The extracted wax was then formulated into an emulsion and applied as a coating to oranges. The effects of sorghum wax and carnauba wax coatings on fruit quality were evaluated by measuring weight loss, percentage of unacceptable fruit, color changes, total soluble solids, pH, and titratable acidity during storage. The statistical analyses were conducted using the Minitab 19 software at a P value of 0.05. At the optimized operation conditions, sorghum wax was extracted using SC-CO_2 at 40 MPa and 75 °C for 3 hours with a constant CO_2 flow rate of 2 L/min (measured at ambient conditions). The DSC curves of sorghum wax showed similar melting behaviors (a major peak at 88.73°C) to that of carnauba wax. Finally, the efficacy of the sorghum wax-based coating was compared to that of carnauba wax in oranges. The sorghum wax-based coating effectively reduced weight loss in oranges throughout the storage period. Overall, the expected outcomes of this research are to (i) fractionate sorghum wax from a bioethanol production waste through a green technology, (ii) provide a sustainable alternative source for waxes (i.e., carnauba wax), and (iii) extend the shelf life of fruits using an effective edible coating.

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Abstract 826 | Poster 173

Pulse Electric Field-Assisted Valorization of Beet Cut-Offs for Enhanced Betalain Extraction and Co-Product Utilization

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ABSTRACT

Shifts in consumer demand and government regulations have required the food industry to rapidly adopt stable and vibrant natural food colorants such as betalain from red beets (*Beta vulgaris*). Beets are widely cultivated in New York, Wisconsin, and California and are commonly processed into canned products; however, trimming generates high quantities of "cut-offs" which are underutilized. This provides an opportunity to valorize beet cut-offs into a higher value natural colorant. Pulse electric field (PEF) processing induces cell membrane electroporation and has been used to enhance mass transfer and juice extraction in industry. This study evaluated the feasibility of using PEF to enhance the extraction of betalain from cut-offs, and assessed the quality and stability of the resulting extracts and press cake. Beet cut-offs were processed in a pilot scale PEF (25-225 kJ/kg specific energy) and pressed to produce a betalin- rich extract. Extracts were analyzed for betacyanin/ betaxanthin content, soluble solids (°Brix), color, and total phenolic content. Stability during refrigerated storage under acidified conditions and following pasteurization (50°C, 30 min) was compared with untreated controls. The press-cake was dried using forced-air drying and evaluated for color, betalain retention, proximate composition, and potential for value-added utilization. PEF studies indicated strong industrial feasibility with extracts exhibiting an increase in temperature during processing (0.23 °C/ KJ Kg-1, R2= 0.99) and an increase in betalain (93 to 250 ug/ ml) & soluble solid content (4.7 to 6.1 °Brix) compared to control. Color and betalain content remained stable over 4 weeks refrigerated storage with minimal loss from pasteurization. The resulting press cake was 14% fiber and 18% protein and represents an additional value-added ingredient. These results demonstrate a scalable approach for converting beet processing byproducts into natural colorants and functional food ingredients.

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Abstract 875 | Poster 174

Performance of bio-based polyurethane foams prepared with waste cooking oil-derived bio-polyol synthesized using cold plasma treatment as cushioning materials for strawberry packaging: a storage study

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ABSTRACT

The development of bio-based polyurethane foams (PUFs) and the valorization of waste cooking oil (WCO) as a renewable feedstock have attracted increasing attention for sustainable packaging applications. The objectives of this study were to synthesize a bio-polyol from WCO using cold plasma (CP) treatment and evaluate the resulting bio-based PUFs as cushioning materials for strawberry packaging. WCO was treated with CP and subsequently subjected to transesterification, urea complexation, and hydroxylation to produce the bio-polyol. PUFs were prepared by replacing petroleum-based polyol with the bio-polyol at different substitution levels. Strawberries cushioned with the foams were subjected to 10 drop cycles and vibration at 150 rpm for 1 h, followed by storage evaluation based on appearance, weight loss, color, firmness, soluble solids content, pH, and electrical conductivity. CP treatment increased fatty acid methyl ester (FAME) and unsaturated FAME yields by 38.4% and 37.7%, respectively. The bio-polyol exhibited acid, iodine, and hydroxyl values of 2.7 mg KOH/g, 23.0 g I_2/100 g, and 164.8 mg KOH/g, respectively, and its synthesis was confirmed by nuclear magnetic resonance (NMR) and Fourier-transform infrared (FTIR) spectroscopy. As the replacement of petroleum-based polyol with bio-polyol increased from 0 to 100%, apparent density, water absorption, and surface hydrophobicity increased, whereas compressive strength decreased (p<0.05), with increasingly irregular and open-cell structures. At 100% substitution, the addition of 10% glycerol to the bio-polyol decreased apparent density and increased compressive strength and thermal stability while producing a denser and more uniform cell structure. The PUF prepared with 100% bio-polyol substitution and 10% glycerol exhibited cushioning performance comparable to that of commercial expanded polyethylene (EPE) foam (p>0.05). These results demonstrate the potential of CP-derived WCO-based bio-polyol as a substitute for petroleum-based polyol and support the use of the resulting bio-based PUF as a sustainable cushioning material for strawberry packaging.

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Abstract 891 | Poster 175

Development of Non-O157 STEC-Specific Phage TP26lw Incorporated Gelatin/Nanochitosan-Based Antimicrobial Packaging

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ABSTRACT

Non-O157 *Escherichia coli* outbreaks in the food industry, including those associated with fresh produce, have been a global problem, underscoring the need for effective antimicrobial packaging. To address this issue, a new phage, TP26lw, specific to Shiga toxin-producing *E. coli* O26, was characterized and incorporated into a gelatin/chitosan nanoparticle-based biopolymeric film for fresh produce packaging. Gelatin/chitosan nanoparticle (GCNPs)-based biopolymeric film embedded with phage TP26lw (10^{10} PFU/ml) with and without citric acid crosslinking was fabricated. The tensile strength of the film decreased significantly with the addition of the phage and citric acid; the tensile strengths of the GCNPs, GCNPs/TP, and GCCNPs/TP films were 49.2±8.78, 36.7±8.14, and 26.8±2.59, respectively. On the other hand, adding citric acid to the gelatin/nanochitosan film improved the elongation at break of the film, whereas phage incorporation did not show a significant effect on elongation at break. The addition of citric acid to the gelatin/nanochitosan film significantly decreased the moisture content from 15.6±0.7% to 14.1±0.2% while increasing the degree of swelling from 480.6±11.0% to 848.7±77.1%. The inhibition zone of TP26lw-incorporated film against O26:H11 (BAA 2196) was found to be 10.3±0.5mm, whereas the control film containing gelatin/chitosan nanoparticles exhibited no inhibition. For the spinach-packaging application, samples treated with GCNPs/TP and GCCNPs/TP films had bacterial counts of 3.9 and 3.9 log cfu/ml after 6 h of storage at 4 °C. The bacterial counts increased to 4.63 and 4.49 log cfu/ml after 24 h of refrigerated storage. The findings of the study demonstrate the gelatin-based eco-friendly packaging solution in presence of citric acid improves mechanical and swelling properties of the film, while, with the phage incorporation, it also prevents the prevalence of foodborne pathogens.

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Abstract 894 | Poster 176

Ultrasound-Induced Exposure of Hydrophobic Residues in Zein: An Additive-Free Approach to Hydrophobic Film Development

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ABSTRACT

Hydrophobic films are essential for moisture-sensitive food packaging, yet sustainable bio-based alternatives remain limited by poor water resistance. Although zein is unusually rich in nonpolar amino acids, many of these hydrophobic residues remain buried within its native helical structure. In this study, zein solutions were subjected to ultrasound treatment (225 W, 0.5–2.5 min) to examine its effects on protein conformation and the hydrophobic, compositional, morphological, and functional properties of the resulting films. Intrinsic fluorescence, ultraviolet-visible spectra, and surface hydrophobicity assays identified 1.5 min as the optimal duration. Cast films exhibited a water contact angle (WCA) of 118.9° compared with 60.6° for the untreated control, and critical surface tension (CST) declined by 16.9%. Regression modeling combining ultrasound time with protein surface hydrophobicity achieved R^2 values of 0.91 and 0.90, with a mean absolute error of 5.45° and 0.45 mN/m for WCA and CST, respectively. FTIR and XPS analyses indicated a shift toward a more nonpolar film surface, and AFM showed a corresponding morphological change consistent with increased exposure of hydrophobic domains. Ultrasound-treated films also showed reductions in moisture absorption (43.8%), total soluble matter (50.3%), and water vapor transmission rate (41.7%), along with improved mechanical strength. This method converts an underutilized corn wet-milling byproduct into a functional hydrophobic packaging material through ultrasound processing, offering a chemically clean and sustainable alternative to petroleum-based moisture barrier films.

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Abstract 895 | Poster 177

Intrinsic Antimicrobial Activity of Rice Bran Films through Argon Cold Plasma–Mediated Surface Functionalization: Mechanisms and Effects on Functional Properties

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ABSTRACT

Rice bran is an agricultural byproduct with potential for biodegradable film formation; however, it lacks inherent antimicrobial activity. This study aims to induce antimicrobial activity without additives, rather by inducing functional group changes in films. Argon plasma was applied to rice bran (RB) and rice bran protein (RBP) films for 30 min to evaluate antibacterial, antioxidant, and functional changes. Treated RB and RBP films reduced E. coli O157:H7, S. aureus, and P. aeruginosa to 0.9 log CFU/mL within 8 h and inhibited regrowth up to 24 h. Plasma-treated films retained H_2O_2, and DPPH radical-scavenging activity increased to 79.68% in RB and 81.94% in RBP films. Atomic force microscopy revealed increased surface roughness from 0.17 to 0.18 μm in RB films and from 0.13 to 0.43 μm in RBP films. Hydrophilicity increased correspondingly, with water contact angles decreasing from 110.04° to 63.55° in RB films, while RBP films exhibited immediate water absorption. Fourier-transform infrared spectroscopy showed increases in RB carboxylate ratio (2.7 to 3.2) and RBP O–H/N–H ratio (0.9 to 1.6), indicating enhanced oxygen-containing functionalities. X-ray photoelectron spectroscopy further confirmed increases in the oxygen and nitrogen contents by 1.5% in RB films and 4.5% in RBP films, respectively. WVTR increased, tensile strength decreased (RB: 6.17–3.50; RBP: 1.88 to 0.56 MPa), and onset degradation temperatures increased (RB: 261 to 265°C; RBP: 249 to 256°C). This study demonstrates that argon plasma offers a green, novel approach to surface modification and valorization of rice-processing byproducts into sustainable functional materials.

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Abstract 905 | Poster 178

Cradle-to-grave life-cycle assessment of sustainable packaging for dairy products

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ABSTRACT

Life-cycle assessment (LCA) has been widely applied to quantify the environmental footprint of dairy systems, with most studies emphasizing raw milk production at the farm gate and associated emissions from enteric methane and manure management. However, post farm-gate processes remain understudied, particularly the combined impacts of packaging and dairy food waste. As the dairy industry increasingly invests in packaging innovations to extend shelf life and reduce consumer-level food waste, understanding the trade-offs between packaging types is essential. In this study, a cradle-to-grave LCA model was developed to compare the impacts of dairy product packaged in novel aerosol cans and conventional cartons. The results show that when excluding the impacts of food waste, cartons consistently exhibit lower carbon footprints (204–212 kg CO2e) than aerosol cans (256–297 kg CO2e for steel cans and 228–297 kg CO2e for aluminum cans) per 100 kg dairy products across all end-of-life scenarios. However, when accounting for food waste, aerosol packaging could offset its higher footprint since it enables reduction in product waste, the value of which depends on the material of cans, and recycling infrastructure. These findings provide evidence-based foundation for dairy manufacturers to evaluate packaging strategies, highlighting the critical role of both packaging design and food waste mitigation in reducing the overall carbon footprint of dairy products.

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Abstract 909 | Poster 179

Hybrid microwave–refractance window drying: a sustainable approach for valorizing citrus pomace

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ABSTRACT

Agro-industrial waste, like citrus pomace, is rich in bioactive compounds and used for feed or landfills. Higher moisture drives rapid spoilage and enzymatic degradation, and stabilizations routes, like refrigerated storage, chemical preservation, and hot-air drying have limitations of cost and quality. Freeze-drying, however, requires longer times and cannot absorb seasonal volumes. Hence, a novel approach combining high throughput with product quality is required.

Hence, a hybrid microwave–refractance window (MW-RW) drying process was used where an RW system is installed inside a 2450 MHz cavity (continuous 360 W power) coupling MW heating with conduction and radiation. The pomace remained under evaporative temperature, 64–72 °C and approached to the stabilized water temperature, 98 °C at the end of the process. For comparison, orange pomace was freeze-dried (FD) in a benchtop system with default configuration, and Total phenolic (TPC), flavonoid (TFC) contents, and DPPH radical scavenging activity were quantified in extracts (n = 4).

MW-RW drying reduced water activity from 0.98 to <0.2 in 40 min compared to 18–24 h freeze-drying. Bioactive retention was equivalent to the freeze-dried process. TPC was statistically indistinguishable (23.66 ± 1.09 mg GAE/g DW vs 23.38 ± 0.74 for FD, $p > 0.05$) while MW-RW significantly exceeded FD for both TFC (5.43 ± 0.23 vs 4.88 ± 0.19 mg GAE/g DW) and DPPH radical scavenging activity (17.65 ± 0.20 vs 14.83 ± 0.20 mg/g, 19% increase, $p < 0.05$). Rapid, uniform moisture removal limited the oxidative and enzymatic losses during the critical intermediate-moisture phase while short, intense thermal exposures disrupted the cell-wall matrix and released bound phenolic and flavonoid fractions.

These results establish the MW-RW hybrid drying as a rapid and energy-efficient route, and the process offers a practical pathway for valorizing high-volume citrus waste within an integrated sustainable biorefinery framework.

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Abstract 935 | Poster 180

Fermentation-Based Valorization of *Opuntia ficus-indica* Cladode Mucilage for Sustainable Ingredient Development

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ABSTRACT

Opuntia ficus-indica cladode mucilage is an underutilized, polysaccharide-rich hydrocolloid with potential as a functional food ingredient, but its high molecular weight and viscosity constrain processing. Although fermentation of *Opuntia* fruits and whole cladodes has been investigated, targeted bioprocessing of extracted mucilage and relationships among polymer structure, microbial genomic potential, and fermentation performance remain poorly defined. This study integrated glycosyl-linkage analysis, comparative genomics, and microbioreactor validation to select bacteria for controlled mucilage bioprocessing.

GC-MS glycosyl linkage analysis indicated a highly branched rhamnogalacturonan I (RG-I) structure with arabinogalactan-rich side chains. Twelve bacterial strains were screened using genome annotation and comparative genome analyses (RAST/SEED, BLAST, OrthoANI, and MUMmer). Six candidates were selected: *Bacillus subtilis*, *B. spizizenii*, *B. licheniformis*, *Lactobacillus acidophilus*, *L. johnsonii*, and *L. crispatus*. Each strain was inoculated at 6 log CFU/mL into cladode mucilage and fermented for 72 h in a BioLector XT Microbioreactor. Biomass-associated backscatter, pH, and dissolved oxygen were monitored; uninoculated mucilage served as the control.

Genome mining showed that *Bacillus* strains contained a broader repertoire of predicted polysaccharide-degrading enzymes relevant to branched RG-I, whereas *Lactobacillus* genomes contained fewer annotated polymer-deconstruction functions and were enriched in sugar-transport and catabolic functions. Consistent with these genomic differences, *Lactobacillus* growth was limited, while all three *Bacillus* strains exhibited increased biomass accumulation; *B. subtilis* exhibited the greatest response. *Bacillus* fermentation markedly increased mucilage pH, reaching final values of 9.16-9.43 versus 6.37 ± 0.04 for the control; net increases were 3.40- 3.71 versus 0.66 ± 0.04 pH units. These results identify *B. subtilis* as the leading candidate and establish a genome-informed strain-selection framework for scalable fermentation-based upcycling of cactus mucilage into value-added food ingredients. Future work will optimize fermentation conditions and use GC-MS and NMR to quantify changes in monosaccharide composition, glycosidic linkages, and polymer structure.

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Abstract 621 | Poster

Multivariate Chemometric Analysis of Structural and Volatile Profiles for Geographical Origin Discrimination of Roast Green Tea (Camellia sinensis)

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ABSTRACT

The increasing production and commercialization of roast green tea have raised concerns regarding geographical origin mislabeling, creating a need for reliable analytical tools for food authentication. This study evaluated the effectiveness of structural and volatile profiling combined with chemometric analysis for discriminating the geographical origin of roast green tea. Dried roast green tea leaf samples were collected from four geographical regions of India (Terai, Darjeeling, Tripura, and Cachar), with each origin analyzed in triplicate (0.2 g per sample). Fourier-transform infrared spectroscopy (FTIR) and X-ray diffraction (XRD) were used to characterize functional groups and crystalline structures. Volatile compounds were extracted from tea infusions using solid-phase microextraction and analyzed by gas chromatography–mass spectrometry (SPME–GC–MS). Principal component analysis (PCA) and hierarchical cluster analysis (HCA) were applied to FTIR spectral data. FTIR-based PCA explained 99.55% of the total spectral variance (PC1 = 79.12%, PC2 = 18.52%, and PC3 = 1.91%) and achieved complete separation of samples according to geographical origin, which was further confirmed by HCA. XRD analysis revealed broad diffraction halos centered at $2\theta \approx 20–23°$, with significant differences in peak intensity among origins ($p < 0.05$), indicating origin-dependent variations in crystallinity. SPME–GC–MS identified more than 40 volatile compounds, including nerolidol, α-ionone, and dihydroactinidiolide, with distinct origin-specific abundance patterns. These findings demonstrate that the integration of FTIR, XRD, SPME–GC–MS, and chemometric analysis provides a robust and reliable framework for authenticating the geographical origin of roast green tea, thereby reducing geographical origin mislabeling and enhancing consumer confidence in tea supply chains.

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