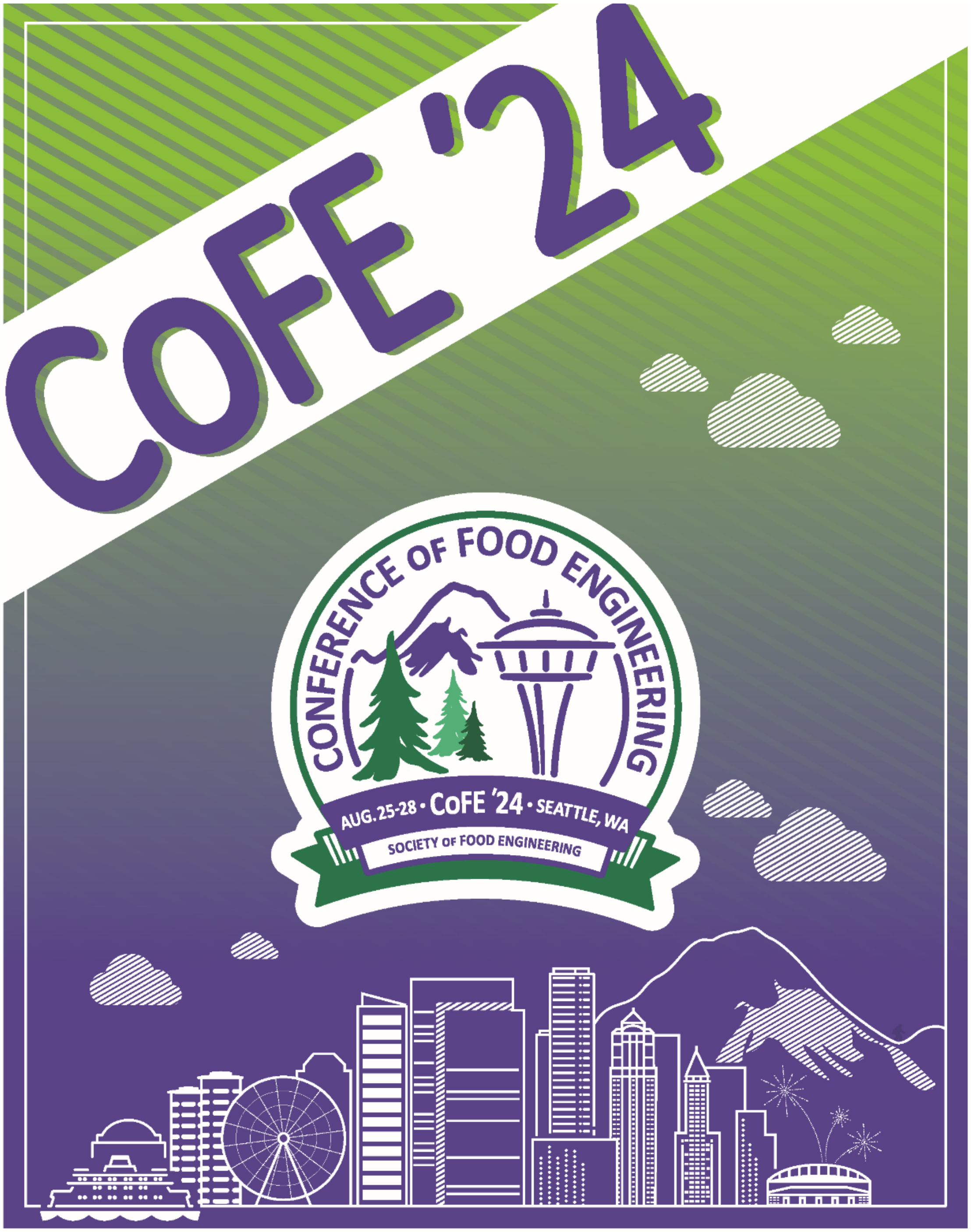
Book of Abstracts



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2024 CONFERENCE OF FOOD ENGINEERING

SOCIETY OF FOOD ENGINEERING

Welcome to Seattle for 2024 Conference of Food Engineering

From CoFE ’24 Chair
Gustavo V. Barbosa-Cánovas
Washington State University

Dear Colleagues and Friends**, Welcome to the 2024 Conference of Food Engineering (CoFE ’24),** we hope this meeting will be an enlightening experience to all of you! This Book of Abstracts is an attempt to summarize the CoFE ’24 technical content as well as to leave a good legacy from a meeting we have been crafting since the previous CoFE held at North Carolina State University in 2022.

This is the 16th CoFE edition where the first one was held in 1991 in Chicago. Even though that year the food engineering profession in the US established a milestone, there were previous efforts to gather food engineers from this country with participation of international colleagues. One of these efforts was the organization of the very first International Congress on Engineering and Food (ICEF ‘1) held in Boston, Massachusetts in 1976 under the leadership of Professor Joe Clayton. After this conference, similar ones were organized in countries like Finland, Ireland, Canada, UK, Japan, France, Germany, Australia, Mexico, Chile, Greece … Here in the US, food engineering evolved in different professional organizations like AIChE, ASABE, IFT. It will be very difficult to name all the excellent colleagues who contributed to this evolution. I had the privilege to attend the first CoFE meeting held in Chicago in the middle of a heavy storm. The leadership of Martin Okos to organize this event and provide continuity to future CoFEs was remarkable. I remember many other colleagues who help in consolidating these Conference like Henry Schwartzberg, Ken Valentas, J. Peter Clark who brought, together with Martin, quality, inspiration, energy, enthusiasm to our profession for many years. Later on I had the opportunity to lead the ones held in 1997 (Los Angeles, California) and in 1999 (Dallas, Texas), they were very successful because at that time we already had a sizable cluster of bright and dedicated colleagues. Before and after these two conferences we had two tremendous leaders that are in the audience, Steve Lombardo and Kumar Mallikarjunan, the SoFE President

In 2003, soon after September 11th, we realized that, after working with some of the above mentioned professional societies, it was time to have a standalone food engineering organization. A few years later that strong sentiment to have our own society came to fruition with the formation of the Society of Food Engineering (SoFE). The most recent CoFEs have been successfully organized under the SoFE umbrella and it is the hope that the growth of the profession will take place in an organized manner thanks to SoFE.

One day my dear Washington State University colleagues, Juming Tang and Shyam Sablani, approached me to jointly organize a CoFE meeting in the West Coast, something that didn’t happen since 2005 when we had one in San Francisco, California. At the beginning, I was reluctant to even think about being involved in such an effort, but they were so committed that I became part of the team. One of the first moves we did was to invite Yanyun Zhao from Oregon State University to come on board and to contribute her enormous talent and commitment to the profession. Her presence allowed us to expand our horizons and make the conference a northwest product not just one coming from the State of Washington.

Our preliminary goals were to work as close as possible with SoFE leadership, to host the conference in a cosmopolitan city, to give ample participation to the students, to put together best possible technical program, to reward excellence and since we are in the Olympic Games cloud, to beat a few records in terms of performance. I think our CoFE ’24 team met all of these goals. We identified Seattle as the site, a city which has been growing thanks to the presence of major international companies like Microsoft, Amazon, Boeing, Starbucks, Expedia to name a few. To warrant student participation, we requested support from USDA-NIFA, we were successful and we are very thankful for that. This grant allowed to partially support a good number of first class students to attend the Conference.

Indeed the strong SoFE/CoFE ’24 partnership was very successful at all times. This grouping (SoFE/CoFE ’24) identified 21 oral sessions, a good blend of classic topics together with some that are pioneering the evolution of the food engineering profession. Each session has 5 speakers where each speaker presents only one lecture in the whole oral program. All the abstracts were peer-reviewed for at least two colleagues, and these reviews and other factors, allowed us to develop two very strong programs, one for oral presentations and another for posters. We had close to 270 submissions, for this reason we increased the number of oral sessions to 26. It is worth mentioning that all the attendees (except students) including all the organizers didn’t receive support from SoFE, this is really remarkable, a demonstration of great commitment to the profession.

To add value to the Conference we included three very strong Plenary Sessions featuring outstanding food engineers as well as pioneers from other industrial sectors to share their experiences from other domains that could inspire food engineers to expand their activities into cutting edge topics.

Our enthusiasm with the technical program we were crafting promoted the idea to organize four Pre-Conference workshops in areas that these days are receiving significant attention. In terms of rewarding excellence we should mention that for the first time we selected the “SoFE Young Researcher Award” an undertaking that was very challenging due to the exceptional credentials of the nominees. We are also having a Student Poster Competition where the authors of the best three MS posters and the best three PhD posters will be recognized.

In addition to have what we consider a very robust technical program we will have ample opportunities for networking during the Opening Mixer, the Gala Dinner, a good number of Coffee Breaks and lunches, etc.

We should specially commend the SoFE-Student Division for putting together a session where speakers from the food industry will share the many years of experience in the private sector. Many of the members of this Student Division are CoFE ’24 volunteers together with other graduate students from a few universities. These helpers are instrumental for the success of the Conference, and we are very thankful for their contributions. By interacting with the students we confirmed that the future of food engineering is in very good hands.

Washington State University and Oregon State University are providing valuable support including secretarial help, preparing the printed programs, badges, pins, posters, stuffing the bags, etc. These contributions are truly supporting our endeavors to bring to all of you the state-of-the-art in food engineering.

We hope you will enjoy CoFE ’24! In addition to bring back home this comprehensive book of abstracts, we hope you will place this Conference among the best memories in your professional endeavors.

On behave of Juming Tang, Shyam Sablani and Yanyun Zhao, I wish you to all of you, a memorable stay in Seattle.

Gustavo V. Barbosa-Cánovas,

CoFE ’24 Chair

From SoFE President

It has been a pleasure to be associated with relatively young organization to lead the food engineering profession to the next level. Due to Covid we had to delay our last conference in Raleigh, NC but at the end it was a successful conference. With that momentum, we are very much delighted to organize this conference in Seattle, WA. Thanks to the enthusiastic leadership from Washington State University and Oregon State University organizing committee members (Drs. Gustavo Barbosa-Canovas, Juming Tang, Shyam Sablani and Yanyun Zhao). Special thanks to Dr. Gonul Klutenc for taking the leadership in putting the program with exciting 26 sessions, plenary sessions and preconference workshops. In addition, I am very thankful to Society of Food Engineering Executive Committee for their contributions, especially Dr. Sudhir Sastry (Past-President) and Dr. Rohan Tikekar (Secretary) for the tireless efforts in making the conference a success.

I am really honored to be the president of this society where we accomplished several new milestones with this conference. We have 26 sessions with excellent speakers, three charged plenary sessions that will provide outlook for the food engineering profession and brand-new Young Researcher award. For the first time, we have four pre-conference workshops on hot topics like AI/ML, 3D printing, LCA and Modeling. WSU and OSU were very successful in getting the funding from USDA that helped us support participation from graduate students in the conference. The fund-raising committee is very successful for this time to get industry support for the conference for a successful conference.

Seattle is a beautiful city on Puget Sound in the Pacific Northwest and is surrounded by water, mountains and breathtaking skyline. In addition to technical sessions, the participants can enjoy visiting the city attractions including the space needle, a 1962 World's Fair legacy. I am positive that we will have a wonderful meeting in Seattle and will raise the bar for future meetings.

With warm greetings and regards,

P. Kumar Mallikarjunan
President, Society of Food Engineering
Professor, Food Science & Nutrition Department,
University of Minnesota, St. Paul, MN

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Plenary Session 1. Research Needs and Funding Opportunities for the Food Industry of the Future

The landscape of the food industry and food supply chains has undergone rapid changes, driven by increased public concern over food and packaging waste, growing consumer demands for safe and healthy foods, and escalating costs associated with raw materials and labor. Additionally, the industry faces technical and economic challenges in its quest to achieve global net-zero greenhouse gas emissions goals by 2050. Food engineers and technologists must be prepared to develop and implement innovative solutions for a sustainable and resilient food industry. In this panel session, a distinguished group of thought leaders from the food industry, academia, and federal funding agencies will deliberate on the multifaceted issues confronting the food industry. They will discuss potential solutions and funding avenues crucial for steering the food industry toward a sustainable future within a circular economy framework.

Panelists:

Sheyla Ramsay, PhD., R&D Fellow & Director Baked Technical Excellence Foods Global Process Function, PepsiCo.

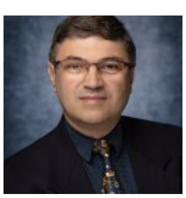
Presentation (15 min): Case studies on industrial decarbonization in PepsiCo – engineering challenges and needs for future research.

Paul Singh, PhD., US National Academy of Engineering, Distinguished Professor of Food Engineering Emeritus, University of California, Davis, CA

Presentation (15 min): Summary on findings of ASABE Circular Bioeconomy Systems Initiative (CBSI), Food Processing Workshop – knowledge gaps and research needs toward a circular food industry.

Hongda Chen, PhD., National Program Leader for Food Manufacturing and Nanotechnologies, USDA National Institute of Food and Agriculture

Presentation (15 min): USDA NIFA funding opportunities for food engineers.



Yaroslav Chudnovsky, PhD., MBA. Senior Technology Manager – Energy and Emissions Intensive Industries, U.S. Department of Energy | Energy Efficiency & Renewable Energy Industrial Efficiency and Decarbonization Office.

Presentation (15 minutes): DoE resources and opportunities to support the U.S. food and beverage industry decarbonization strategy.

Plenary Session 2. Sustainability in the Food World

Speaker 1: Isaac Emery

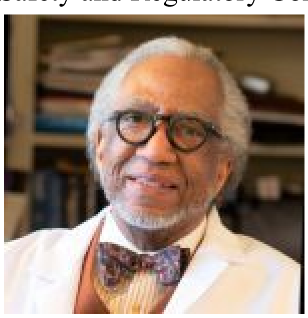
Presentation: Keys to a Sustainable Food System

Isaac Emery is the Project Director for WSP USA where he focuses on life cycle assessment, greenhouse gas accounting and sustainability metrics expertise to his clients, seeking answers to key eco-design and sustainability strategy questions. He has his Ph.D. from Purdue University in ecological sciences and engineering.

Isaac Emery works with organizations to identify the costs and benefits of fuels, foods, and industrial systems using life cycle assessment and other systems-level tools. With expertise in bioenergy, agriculture, plant-based and cell-based meats, and other systems, he helps his clients and collaborators to find the most beneficial paths forward. His specialties include Life cycle assessment, benefit-cost analysis, agriculture, biofuel, land use change, cellular agriculture, and sustainability.

Speaker 2: Larry Keener

Presentation: Advancing Innovative Processing and Preservation Technologies: The Food Safety and Regulatory Conundrum



Dr. Larry Keener, Fellow IFT, is currently serving as the President and CEO for the International Product Safety Consultants. He is in this role and as a Food Safety Scientist Consultant since 1996. His specialties include food microbiology and process Validation, and novel and emerging technologies.

Keys to a sustainable food system

Isaac Emery

Sustainability, Energy and Climate Change WSP USA, Inc

ABSTRACT

The food sector's contribution to global environmental impact is becoming clearer to scientists, engineers and policy makers. Recent reports indicate that food and agriculture generate at least a quarter of all greenhouse gas emissions, occupy half of Earth's habitable land, cause roughly 80% of atrophying water pollution, and drive both the causes and negative effects of water scarcity. Organizations and individuals motivated to reduce the impacts of their own food purchases have relatively few reliable options: meat reduction, which is often unpopular, and waste reduction, which is often time and resource intensive. Though more impact reductions exist, they suffer from high financial and logistical barriers to entry.

Systems problems, like the environmental costs of food, require systems-level solutions. Improved supply chain flexibility and data management, resource circularity, and improved efficiency are all vital to creating and enabling a more sustainable food system. Food engineers are uniquely positioned to develop collaborative solutions through their work and expertise across food production, processing, preservation, and distribution. Promising areas of research and collaboration to support global and organizational sustainability goals include selective sourcing, packaging impact reduction, waste reduction, and expanded impact assessment. Each of these can serve as links between the expertise of food engineers and levers for action to create and enable sustainable food choices.

Advancing innovative processing and preservation technologies: the food safety and regulatory conundrum

Larry Keener

ABSTRACT

The regulatory landscape is exceedingly complex and successfully navigating this nuanced dominion with the view to commercializing novel and nonthermal technologies can be a daunting challenge. The regulations for many countries, relating to novel technologies, are based on the "precautionary principle." Other countries, including the US, are increasingly demanding a complete assessment of risk before novel processing and preservation methods can be employed in the production of foods that are intended for human consumption. Bringing new preservation and processing methods to commercialization will demand that these novel techniques withstand rigorous scientific scrutiny while simultaneously navigating a nuanced global regulatory situation.

In short, the "precautionary principle" is a notion which supports taking protective actions before there is complete scientific proof of a risk; that is, action should not be delayed simply because full scientific information is lacking. In the fields of food safety, the need for taking precautionary actions in the face of scientific uncertainty, among EU member nations, has long been an accepted practice.

US Food Safety regulations are increasingly focused on prevention and preventative controls. The overarching principle being risk analysis. For example, "Generally Recognized as Safe" (GRAS) a long- standing concept in US Food Safety law is interesting to contemplate; on the one hand it appears to rely on implicit assessments of risk, but it also has stipulations consistent with those of the precautionary principle. The GRAS requirement for a "demonstrated history of safe use as human food" is an implicit, ipso facto, assessment of risk. But by contrast the regulation's ex-ante demand for scientific data prior to conferring GRAS status for novel foods and ingredients, for which there is no history of use, is clearly consistent with the principle of taking protective action in the absences of complete scientific proof. Risk analysis and validation appear to be the way forward in promulgating food safety legislation and regulations globally.

This presentation will highlight emerging regulatory trends and legislative developments that are likely to impact the procedures used in obtaining approvals for the commercial use of novel and nonthermal processing and preservation techniques in the production of human food.

Plenary Session 3. Information Technologies in Food Industry

Speaker 1: Sean Sims

Presentation: What is next for the role of Artificial Intelligence and Robotics in Food Industries

Sean Sims is Vice President, Automation and Solutions at Tetra Pak and provides leadership for their automation and digitalization efforts to modernize their industry.

Speaker 2: Jay Picconatto

Presentation: Brand Purpose in Tech Driven Marketing

Jay Picconatto is Vice President – Advanced Marketing Solutions, General Mills. He built General Mill's enterprise eCommerce team from the ground up, tripling the eCommerce business in three years and driving double-digit basket increases. Before that, he took over a struggling shopper marketing team, doubling the size, and driving 5x investment. He also digitized a 25-year-old program to modernize the experience for consumers and drive data and competitive advantage for General Mills.

Panel Discussion: Sean Sims, Jay Picconatto, Hongwei Zhang, Balu Nayak, Jordan Pennells

What is next for the role of artificial intelligence and robotics in food industries

Sean Sims

Vice President for Automation & Solutions, Tetra Pak

ABSTRACT

Food producers find themselves operating under an increasing number of constraints. Consumers are demanding the same levels of quality and predictable experience from the products they buy but are also becoming significantly more aware of the sustainability and health impact of their purchases. In an ever increasingly competitive market, producers also grapple with having to increase the flexibility of their manufacturing footprint in response to rapid market demand trends, as well as prepare their facilities for a workforce that has less experience in the field than ever before – all within a very narrow set of cost targets. One of the most impactful ways to address a lot of these complex, connected challenges is to lean into technology at ever increasing rates. Effective production automation, orchestrated by data orchestration and advanced analytics allow producers to run their factories more efficiently, with less variability in a much-reduced operating footprint and cost basis. Sean Sims, Vice President of Tetra Pak's Automation & Solutions team, sketches out a roadmap for the successful deployment of such a strategy – cutting through the buzzwords and hype to talk about how the practical application of everything from robotics to Artificial Intelligence will change the game in Food Engineering over the next decade.

Brand purpose in tech driven marketing

Jay Picconatto

VP - Advanced Marketing Solutions, General Mills

ABSTRACT

Rapid advances in technology are enabling marketers to finally realize the promise of digital marketing and personalization. Furthermore, the growth of ecommerce has put pressure on brand marketers across the entire supply chain of their business. However, as brands teams try to accelerate their digital transformation, staying current on the latest tech enabled capabilities becomes increasingly difficult. Equally challenging is ensuring your brand purpose and human centricity remains evident in the marketing output as more and more becomes completely automated. For this session, we will review some of the emerging technologies the make marketers more effective while highlighting important principles and watchouts to letting the tech just take over.

Oral Session 1: Thermal Processing Technologies

Co-chairs:

Hosahalli S. Ramaswamy

Anubhav Pratap Singh

Heat transfer considerations in short-time steam heating for surface decontamination

Hosahalli S. Ramaswamy

McGill University, Macdonald Campus Ste Anne de Bellevue, QC, Canada, H9X3V9

ABSTRACT

Steam is accepted to be an ideal heat transfer conditions for thermal processing of foods. Presence of air has been traditionally accepted to degrade the condensation heat transfer from steam. Usually many steps like blanching, exhausting and venting are procedures implemented in thermal processing to eliminate air from steam heating environment to promote better heat transfer. In instances where its presence is inevitable, techniques like forced convention with turbo fans have been employed. Ultrasound has also been effectively used with water, but has not been explore with steam or steam/air mixtures. This presentation is focused on the influence of low concentration air on the associated heat transfer from steam and improvements with the use of ultrasound in combination. Heat transfer from steam, steam/air and water as influence by ultrasound variables were evaluated using high thermal conductivity materials (steel, aluminum) using regularly shaped metal transducers of as used successfully in earlier steam/air studies. Discussion will be focused on differences in heat transfer rates indicating the importance of ultrasound for short term heating (5-15 seconds) vegetable surfaces for microbial decontamination studies.

Reciprocating agitation - thermal processing (RA-TP) sterilization of dairy milk: impact on physicochemical characteristics and nutritional properties

Anubhav Pratap-Singh & Madeleine Amanda Soegiarto

The University of British Columbia, Vancouver, BC, V6T 1Z4, Canada

ABSTRACT

Currently, Ultra High Temperature (UHT) treatment is the method of choice for obtaining shelf-stable dairy milk that would not require refrigeration as microorganisms of public health or spoilage concerns, including their spores, are inactivated. Yet, concerns regarding the physicochemical and nutritional properties of such UHT milk limit their application to flavored drinks. This study investigated the Reciprocating Agitation - Thermal Processing (RA-TP) technique as a potential milk sterilization technique and compared it with conventionally bath pasteurized, conventional retort sterilized (still) and UHT sterilized milk. Dairy milk with 0% & 2% fat were subjected to three different agitation speeds at 0 (Still Motion), 45 (Gentle Motion), and 90 (Shaka Motion) shakes per minute and analyzed for color properties, soluble protein contents, and Vitamin D3 content. The total color change and Vitamin D3 decrease of RA-TP milk was found to be significantly higher ($p < 0.05$) than bath pasteurized milk, but significantly lower ($p < 0.05$) than UHT and conventionally retorted (Still Motion) dairy milk. There were no significant difference for protein solubility ($p > 0.05$). Same trends were followed for both 0% and 2% fat milk. Amongst RA-TP modes, processing at Gentle Motion (45 shakes per minute) was found to yield better milk quality in terms of color and vitamin D3 retention than Shaka Motion (90 shakes per minute), perhaps due to damage due to very vigorous agitation. Overall, Gentle Motion (RA-TP at 45 shakes per minute) was found to be the most optimal method for milk sterilization. The study generates relevant data for use of reciprocating agitation thermal processing for milk sterilization. Lower color change associated with Gentle Motion sterilized milk may make possible distribution and sale of unflavored sterilized milk with longer shelf-life and environmental costs associated with cold supply chain requirements.

Energy efficient spray drying of high solids food products – enabled by filament extension atomization

David M. Johnson, Eric Weflen, Greg Anderson, Aditya Sangli, Ravi Neelakantan, Dogan Timucin, Matt Gallelli, Austin Hultmark

SRI, Future Concepts Division, Palo Alto, CA, 94304, USA

ABSTRACT

Spray drying is an important process for creating a wide range of powdered food products; it is also the most energy intensive part of creating a dry powder. While efforts have been made to reduce the energy required by reducing the water that needs to be removed, the operating requirements of current spray technologies severely limit the solid content in the fluid to be dried to as low as 24% depending on the fluid. To significantly reduce the water content and make this process more efficient, SRI has developed the Filament Extension Atomizer (FEA) to replace traditional nozzles. FEA is a new way to spray materials that removes viscosity and rheological barriers to spraying and can reduce energy consumption in spray dryers by 40% or more. We will present the results of adapting our FEA technology to spray Dry Whey and Whey Protein Concentrate (WPC-80) food products at increased solids loading of up to 70% for Dry Whey and 45% for WPC-80, up from industry standards of 53% and 33% respectively. Using a small pilot scale spray dryer, we replaced the nozzle in the dryer with an FEA system that was optimized to produce spray with particle sizes between 50-200um. The FEA system created high quality powder from high solids materials, and demonstrated that we can reduce water drying load considerably. FEA offers a promising means of reducing the carbon footprint of spray dried materials by up to 55%. We will also present an FEA design capable of achieving more industrially relevant flow rates of over 7.5 L/min and our plans to integrate this system into larger spray dryers.

Pasteurization of bottled low moisture foods with RF-heating

Mithila Anugolu[1], Fengsen Wang[1], Shivam Ubale[1], Surabhi Wason[2], Jeyam Subbiah[2], Rossana Villa-Rojas[1]

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[2]University of Arkansas, Fayetteville, AR, 72704, USA

ABSTRACT

Radiofrequency can pasteurize low-moisture foods (LMF) but still have an uneven temperature distribution. The present study focused on 1) the effects of steam retention and mechanical mixing on temperature distribution, 2) the effectiveness of RF-heating to pasteurize Salmonella inoculated in bottled LMF, and 3) evaluate E. faecium as a surrogate. Heat penetration curves were obtained for bottled black pepper with or without mechanical mixing, with or without steam retention, and static bottled cumin seeds with/without steam retention. Salmonella cocktail or Enterococcus faecium NRRL B-2354 inoculated cumin seeds equilibrated at aw 0.71, were RF heated for 40, 50, and 60 s with or without steam retention. Heat penetration studies showed an overall improvement in the heat uniformity index for mechanically mixed black pepper but no significant difference in temperature range or maximum temperature. Meanwhile, steam retention in bottled cumin seeds significantly reduced the maximum temperature, uniformity index, and temperature range. RF-heated bottled cumin seeds inoculated with Salmonella or E. faecium achieved >6 log reductions after 60 s of treatment with/without steam retention. E. faecium showed similar thermal resistance (0.3 ± 0.5 log CFU/g) after 40 s of RF heating with steam retention than the Salmonella cocktail (0.8 ± 0.9 log CFU/g). Overall, it is unclear if mechanical mixing significantly improves temperature distribution during RF heating of LMF. Meanwhile, steam retention improved temperature distribution for bottled cumin seeds. RF heating can pasteurize bottled cumin seeds, and E. faecium is a good surrogate for RF-assisted heat treatment with or without steam retention. Further studies on the impact of steam retention during RF heating on the quality attributes of LMF are needed to assess the potential benefits of this treatment. Nevertheless, assessing RF pasteurization of bottled foods offers invaluable insights into its efficacy and potential benefits for the food industry.

Evolution of particle flow monitoring and safety validation of low acid multiphase aseptic products: established methods and principles, validation examples, persistent misconception risks and recent progress

Pablo Coronel Rivadeneira[1], Dharmendra Mishra[2], Ferhan Ozadali[2], Michael Druga[3], Josip Simunovic[3]

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[3]SinnovaTek Inc, Raleigh, NC 27616, USA

ABSTRACT

Over more than two decades of collaborative research, development, innovations, pilot and industrial process validation projects, the co-authors have worked as team members and contributors to the establishment of a set of scientific principles, sensors, instruments and methods of process design, process monitoring software and data analyses.

Recent renewal of interest in particulate products by aseptic processing and packaging companies motivated the pursuit of the following objectives of this presentation:

- Review the established, experimentally confirmed principles and methods of particle property determination, adjustment, construction and use in process validation
- Provide illustrative examples of previous real and successful safety validation cases
- Examine and highlight the safety risks of persistent particle property misconceptions
- Note examples of implemented, evolving and pending recent developments

Methods using established principles for construction of "cold spot carrier" particles i.e. the "fastest moving" and "slowest heating" characteristics under conventional and advanced (ohmic and continuous flow microwave) thermal processing have been developed and implemented.

Real-time sensing, display and recording of tagged particles moving through processing systems: sensors, amplifiers, cabling and computers, as well as post-process analysis software were also developed.

Integrated, optimized bacterial spore-carrying particles were used for validation of processing systems, followed by incubation and growth/no growth detections.

Reported results will highlight the successful validation cases in U.S. and Europe and recent progress: 3D printing of particles, sensing network upgrades and significance of these cumulative developments to the appropriate statistical models and analyses.

Oral Session 2: Modeling and Computer Simulation

Co-chairs:

Francesco Marra

Ferruh Erdogdu

Digital technologies in sustainable innovative food processing for beyond the industry x.0

Ferruh Erdogdu

Ankara University, Ankara, Turkey

ABSTRACT

While the food industry has been challenged with significant food safety issues in the last several decades (e.g., microbial safety concerns in low moisture foods), introducing the sustainable processes with non-polluting and economically efficient approaches have become a significant concern. Besides the safety, reducing the energy requirement with increased quality has become the additional concern. These considerations have also coincided with the challenges of environmental-friendly food processing under the umbrella of the European Green Deal, and applied digital technologies seem to be the efficient solution for these required advances. Therefore, the aim of this presentation was to present the applied digital technologies in sustainable food manufacturing for beyond the industry x.0.

For this purpose, following the review of the computational modeling approaches for virtualization of the processes, this study will focus on presenting novel innovative approaches with their challenges to replace the conventional processing for sustainability in the view of process design in industrial scale. Virtualization (mathematical modeling-based simulation) approaches supported with digital twins, artificial intelligence, and machine learning applications (in addition to the use of IoT and big data) will also be introduced for the requirement of the industry x.0 and beyond in terms of digitalization and smarter sustainable food processes.

Optimization approaches for quality and safety improvement through the manufacturing will also be outlined to demonstrate a novel application of digital technologies. A hypothetical example of such a complete process supported with digital technologies for data flow, control abilities, and process design features with decision mechanism will also be presented.

Current and future challenges of the digital approaches in the view of food manufacturing will be introduced with the new enabling technologies while the computational performance, design and simultaneous decision mechanism is still a consideration.

Quick response (QR) tags kinetics and potential utilization for remote quality monitoring

I. Sam Saguy[1] and Eli Cohen[2]

[1]The Hebrew University of Jerusalem, Jerusalem, Israel

[2]Ben-Gurion University of the Negev, Beer-Sheva 84105, Israel

ABSTRACT

The expanding adoption of quick-response (QR) tags and progress in colored ink synthesis for time-temperature integrators (TTIs) present promising opportunities for remote in-situ quality assessments. Concurrently, the widespread proliferation of mobile phone and scanning capabilities facilitate consumer interactions, offering bidirectional information exchange that can implement complex kinetic modeling and potentially revolutionize inventory quality management.

A recent study underscores that if a QR-tag's color undergoes irreversible color changes, which can be captured by a single colorimetric measure, and if the kinetics of these transformations, dependent on temperature, are understood, then the color coordinates of a scanned and transmitted QR-tag at any point in time can be used to reconstruct a single equivalent constant-temperature history, or an array of varying-temperature histories yielding similar colorimetric readings. Also, the conventional notion of a meaningful constant-temperature equivalent may require reassessment, particularly for nonlinear color transformation kinetics.[1]

Simulations of both zero-order kinetics, and Weibull kinetics (characterizing nonlinear processes) will be highlighted. Challenges, including QR tag-ink and product kinetics, temperature differentials between the QR-tag and a product due to heat transfer, and statistical considerations, particularly regarding sampling, will be also discussed.

It is posited that this two-way communication, integrated into quality and potentially marketing campaigns, offers novel benefits for both consumers and manufacturers. For instance, consumers study indicated that wine temperature history is the a very important quality attribute.

QR future applications could be integrated into crowdsourcing initiatives and aligned with Internet of Things (IoT), cloud storage and computing, big data analytics, and AI. While the validity of the concept still poses several challenges, its potential for opening new and exciting future applications is significant.

[1] Peleg, M. and Saguy, IS (2024). Colorimetric quick response (QR) tags and other timetemperature indicators (TTIs) for remote quality assessment: Theoretical kinetics aspects. Food Engineering Reviews (in press).

Is food manufacturing ready for digital twins?

Nicholas Watson & Alexander Bowler

University of Leeds, Leeds, UK

ABSTRACT

The 4th industrial revolution (Industry 4.0) is an era where data and digital technologies, such as sensors and robotics, are leveraged to create planet-saving solutions. Despite the promise, the practical application and understanding of these technologies often remain unclear, with tangible benefits often difficult to quantify. One latest innovations birthed from this revolution is the concept of digital twins—a dynamic, connected, digital replica of physical assets.

This presentation delves into the essence of digital twins, demystifying their capabilities and limitations within the context of food manufacturing.

The presentation will debate the necessity of digital twins in the food industry, dissecting whether they are a superfluous luxury or a critical necessity. It will discuss what digital twins are not, and what they cannot achieve, as much as their actual functions and potential advantages. The presentation will navigate through the specific requirements of digital twins in food manufacturing, examining data-driven, first-principle, and hybrid approaches to their implementation.

The presentation will ground the discussion in two real-world case studies. The first will explore the application of digital twins in transforming agri-food side streams into consumable protein via precision fermentation. The second will evaluate the use of digital twins in achieving resilient bakery products, focusing on data-driven reformulation and multi-objective process optimisation. These real-world examples will not only illustrate the practical applications of digital twins but also highlight their limitations and role in enhancing sustainability and resilience in food manufacturing processes.

Mathematical models and digital tools for food product design

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ABSTRACT

Mathematical models and digital tools are ready to play an indispensable role in modern food product design. These tools streamline the development, optimization, and analysis of food formulations, addressing various considerations such as technological requirements, nutritional content, and consumer preferences.

In food formulation, diverse modeling approaches and mathematical methods can be integrated into digital platforms tailored for designing food products. These tools enable a comprehensive understanding of ingredient interactions, encompassing physical, chemical, and biological factors. By leveraging models based on Molecular Dynamics or first principles, designers can predict and optimize the physical and chemical changes occurring during processing and storage. This optimization ensures the attainment of desired product attributes, including texture, flavor, and shelf life.

Design of Experiments (DoE) methodology is another valuable resource in the food design toolkit. DoE software facilitates the systematic exploration of multiple variables, aiding designers in identifying significant factors and their interactions. This approach enhances the efficiency of formulation and process optimization, contributing to product quality and consistency.

Digital tools for sensory analysis play a pivotal role in gathering feedback on product attributes such as taste, aroma, appearance, and texture. Statistical analysis of sensory data enables designers to discern consumer preferences accurately, informing iterative product refinement.

As consumer awareness of nutrition grows, designers face the challenge of ensuring that food products meet regulatory requirements and align with dietary guidelines. Nutritional analysis software provides valuable insights into the nutritional content of formulations, facilitating compliance with regulatory standards and consumer expectations.

Furthermore, advanced analytical techniques, including machine learning algorithms, empower designers to analyze large datasets, uncovering patterns and correlations related to consumer preferences and market trends. This data-driven approach informs strategic product design decisions and market positioning strategies.

In essence, mathematical models and digital tools provide food designers with powerful capabilities to innovate, optimize, and tailor food products to meet evolving consumer demands while addressing regulatory compliance and sustainability objectives.

Why solid-state microwave generators are the future of microwave heating?

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ABSTRACT

Microwave heating has great potential to help the food industry and households save time and energy. However, the magnetrons that have been used to generate microwaves for the past 70 years have shortcomings, including a limited service life (~3,000 hours) and a lack of precise control. Solid-state microwave technology, which uses semiconductor devices to generate and control microwave signals, is emerging as a superior alternative. Solid-state microwave generators offer a much longer service life, precise control over frequency, power, and phase, and enable closed-loop feedback. This opens up possibilities that are not achievable with conventional magnetron generators.

This presentation will cover the fundamentals of solid-state microwave technology, how it differs from magnetrons, and our research on domestic ovens and a pilot-scale microwave-assisted pasteurization system (MAPS). We will also discuss system design considerations for developing solid-state-powered microwave heating systems and the role of computer simulations in facilitating their implementation.

Oral Session 3: Alternative Processing Technologies

Co-chairs:

Carmen Moraru

Sergio I. Martinez-Monteagudo

Combining membrane filtration and gentle heating to improve food quality and safety

Carmen I. Moraru

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ABSTRACT

Membrane separation processes allow separation / fractionation of desirable components or removal of undesirable components from fluid foods under gentle conditions, which allow the retention of quality and sensory attributes of the product. Membrane based applications in the food industry have enjoyed a surge in rennet years. This presentation will give an overview of the principles of membrane separation, as well as the factors of influence and challenges associated with membrane filtration. Membrane filtration can be described as a nonthermal process that can be conducted under cold conditions. Nonetheless, mild heating can significantly improve the permeate flux, making the process more economically attractive for processors. In this presentation, a particular focus will be placed on the use of microfiltration for microbial removal from fluid foods, for both food safety and shelf life extension purposes. Microfiltration can be used either alone or as part of a hurdle process, in combination with thermal or nonthermal methods, which allows for synergies in terms of microbial inactivation or removal. Using experimental data, we will demonstrate the benefits of combining microfiltration with mild heat processing for the manufacture of high quality extended shelf life products, such as milk and fruit juices.

Thermal and nonthermal effects of pulsed electric fields and ohmic heating

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ABSTRACT

For about thirty years, food engineering and processing research have distinctly separated the domains of thermal and nonthermal processing; however, there is considerable continuity in the thermal-nonthermal spectrum. Pulsed electric field (PEF) technology, originally envisioned as a purely nonthermal technology, has proven to consist of a considerable thermal component, which has not been addressed adequately in the limited physics-based mathematical modeling literature on the subject. A number of the variables in PEF, such as field strength and thermal distributions are very difficult to measure due to the fleeting and localized nature of such changes, but thermal distributions may be key to understanding some of the observed phenomena in relation to enzyme inactivation. Meanwhile, research on ohmic heating has shown a remarkable nonthermal effect on bacterial spores, with effects such as inner-membrane destabilization and disruption of core protein-DNA linkages; effects which can be demonstrated even at considerably lower-than-lethal temperatures. These highly related fields, when considered on a physics basis, show a remarkable degree of similarity in certain aspects, while retaining important differences in others. The applications and implications of both these technologies are only now being appreciated, especially given the increased need for reliance on renewable energy sources and an emphasis on sustainability.

Can ultraviolet-C processing inactivate microorganisms while preserving bioactive proteins in human milk?

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ABSTRACT

Background: Donor milk banks use Holder pasteurization to enhance the microbiological safety of donor milk. However, the heat used in Holder pasteurization damages many bioactive milk proteins. Literature indicates that ultraviolet-C irradiation (UV-C) can better preserve some milk proteins, but the process has not been optimized for exposure time or effect on an array of bioactive proteins.

Objective: The aim of this study was to determine the minimal UV-C parameters that provide >5-log reductions of relevant bacteria in human milk and how these parameters affect an array of bioactive proteins.

Methods: Pooled, raw human milk inoculated with relevant pathogens (Enterococcus faecium, Staphylococcus aureus, Listeria monocytogenes, and Cronobacter sakazakii) or microbial quality indicators (Bacillus subtilis, Bacillus cereus and Paenibacillus spp. spores) at 7 log CFU/mL was processed by UV-C at dosages from 1,000 to 18,000 J/L. Holder pasteurization (HoP) was performed at 62.5 °C for 30 min. Surviving microbes were enumerated using standard plate counting methods. The immunoreactivity and/or enzyme activity of an array of bioactive proteins and vitamin E were assessed in the raw, UV-C-treated and HoP-treated milk samples.

Results: Treatment at 6,000 J/L of UV-C resulted in >5-log reductions of all vegetative bacteria examined (S. aureus, E. faecium, C. sakazakii and L. monocytogenes). Achieving >5-log reductions of bacterial spores (Bacillus subtilis, Bacillus cereus and Paenibacillus spp. spores) required >12,000 J/L of UV-C irradiation. UV-C treatment of human milk at both 6,000 J/L and 12,000 J/L dosages better preserved concentrations of immunoglobulin A (IgA), IgG, IgM, lactoferrin, cathepsin D and elastase and activities of bile-salt stimulated lipase and lysozyme compared with Holder pasteurization. These UV-C doses caused minor reductions in α-tocopherol but not γ-tocopherol. UV-C treatment is a promising approach for donor human milk processing.

Modification of dairy protein functionality through Pulsed Electric Field Processing

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ABSTRACT

Proteins are gaining attention from the consumers from a health and nutrition perspective and thereby influencing the food industry to develop novel new products. Dairy proteins serve as complete protein and versatile ingredients. However, there is a problem with functionality, especially with dairy proteins like milk protein concentrate, hindering their use in the development of new products. To overcome this challenge, many thermal, enzymatic, and chemical modifications were previously studied. However, the industry is more concerned about using these methods and constantly looking into alternatives for protein modification. Non-thermal processing has been gaining a lot of attention in the food space particularly owing to minimal processing and clean labels. Among the non-thermal processing technology, pulsed electric fields (PEF) are currently studied to understand the effects of processing parameters on modification of dairy proteins for various applications.

Plasma is the fourth state of matter and consists of electrons, protons, atoms, and these particles together initiate a chemical reaction. The low temperature plasma, also called cold plasma or non-thermal plasma is known to modify protein functionality using surface modification. PEF works on the application of short high voltage electric pulses through the food product for a few microseconds. For PEF, various combinations of temperatures (25-65 ℃), electric field strength (4-20 Kv/cm) and frequency (30-300 Hz) were studied with reconstituted liquid Milk Protein Concentrate (MPC85) and Micellar Casein Concentrate (MCC), followed by spray drying. The samples were stored at 25 ℃ and various protein functionality analysis were carried out. The results from PEF showed significant improvement in functionality and can be improved through post treatment of MPC85 for specific product applications and also decreased the viscosity for MCC by 45% for the optimum process conditions.

Modeling Salmonella inactivation in paprika powder by ultra-high irradiance blue light

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ABSTRACT

Ultra-high irradiance (UHI) blue light-emitting diodes (LEDs) have emerged as a novel intervention to inactivate foodborne pathogens by photochemical and photothermal means. This study was aimed to evaluate the inactivation effects of UHI blue (405 nm) LED treatments on Salmonella spp. in paprika powder and the development of an alternative Weibull model to describe the inactivation kinetics. The impact of these treatments on selected paprika quality attributes was also investigated. Paprika samples were inoculated with a Salmonella cocktail, acclimated for 7 days, and irradiated with 405 nm LED at a fixed distance (5 cm) using different irradiances (548, 697, and 842 mW/cm2) and exposure times (60, 120, 180, and 240 s). Irradiation treatments resulted in a significant increase in the temperature of paprika, with values reaching sterilization-like conditions of up to 131.7 °C after 240 s at 842 mW/cm2. This photothermal effect caused a significant decrease in Salmonella counts, with reduction levels ranging from 2.1 to 7.8 logs after 240 s. A modified Weibull model with irradiance-dependent parameters satisfactorily described the Salmonella inactivation kinetics (>0.98). The moisture content, color profile and antioxidant capacity of paprika samples were significantly affected by the irradiance level and exposure time. In general, color degradation rates in paprika powder increased with increasing process temperature. Process parameters could be optimized with a developed kinetic diagram.

Oral Session 4: Advances in Food Packaging

Co-chairs:

Yanyun Zhao

Shyam Sablani

Plantic, the high barrier natural polymers option for extension of shelf life

Kevin A. Laux & David Chacon

Kuraray America

ABSTRACT

Based on high amylose starch, Kuraray's Plantic offering is shaking up the world of performance packaging. The ability to provide gas barrier with a plant-based solution is a unique proposal in the area of packaging circularity. A best-in-class LCA shares reduced carbon emissions with a product which offers shelf-life extension and food waste reduction. With end-of-life scenarios of compostability or recyclability, the Plantic offering can be reclaimed in the recovery of rigid plastics or repulped and recycled in the paper stream when used with paper or boardstock. This is truly a compelling offering for the multilayer barrier films market where recyclability is a challenge. The proposed submission plans to highlight the property space, market examples and adoption, and environmental contribution of this unique natural barrier solution.

Sustainable food packaging to protect environment and provide convenience to consumers

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ABSTRACT

Food packaging plays crucial roles in our food systems for protecting food during storage, transportation, retail, as well as providing communication and convenience to consumers. However, over packaging and some packaging materials, especially plastic packaging have significantly and negatively impacted our environment and ecosystem. This presentation will discuss some sustainable food packaging solutions and present the research and continuous efforts in the author‘s research team to develop sustainable packaging to protect environment and provide convenience to consumers through scientific discoveries and technological innovations. Some of the solutions to be discussed and presented include 1) replacing single-use plastic packaging through creating edible food packaging, 2) converting food processing and agricultural byproducts into biodegradable and/or compostable packaging, and 3) developing innovative food coatings (a form of edible packaging) for reducing food loss and waste across food chain. The relevance to food engineering profession and the food industry will also be discussed.

Transforming lignocellulosic waste into sustainable cellulose fiber packaging solutions

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ABSTRACT

Lignocellulosic biomass is composed of cellulose, hemicellulose, and lignin. These biomasses can be derived from unavoidable agricultural waste and food processing byproducts. The utilization of lignocellulosic biomass is gaining attention as sustainable cellulose fiber packaging solutions. Hence, this study was aimed to characterize polymeric, mechanical, and barrier properties of holocellulose converted from agricultural waste and food processing byproducts, such as coconut palm spathe, coconut palm leaf, apple pulp, wine grape pomace, hazelnut shell, hemp fiber, and hemp hurd and evaluate them as functional packaging materials.

Apple and wine grape pomace was treated by boiling water, dried, and ground to sieve via 20-mesh. Other byproducts were prepared about 1 cm in length. A 4% peracetic acid with adjusted pH 4.8 was treated at 85 °C for 45 min, washed by deionized water, and filtered through an 80-mesh sieve. This process was repeated four times. To remove residual hemicellulose, it was further treated by 0.5 M NaOH at 88 °C for 30 min, washed by deionized water, and filtered by an 80-mesh sieve. The obtained fibers were called holocellulose and its suspension was prepared by adjusting the solid contents to 1% (w/w wet basis) with deionized water.

Holocellulose from coconut palm spathe has long fiber and high aspect ratio suitable as the polymeric matrix, whereas that from wine grape pomace and hazelnut shell exhibits particles with low aspect ratio as reinforcing material or can be further refined to produce micro or nanoparticles. Biofilms with high UV absorbance or reflection can be suitable for packaging materials for food sensitive to light. FTIR analysis verified the presence of cellulose and hemicellulose in the biofilms along with a small amount of lignin. This study demonstrates that different characteristics of holocellulose could be extracted from those byproducts, and they can be employed to produce functional packaging materials.

Active and biodegradable antimicrobial packaging as a hurdle technology

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ABSTRACT

The waste produced from the disposal and accumulation of nonbiodegradable food packaging materials, as well as the high energy demands from the food industry, represent a serious threat against the environment and the sustainability of an increasingly growing human population. The concept of Hurdle Technology is a well-known food preservation approach that consists in exposing foods or edible biological materials to low doses or concentrations of different physical and chemical agents (either simultaneously or sequentially) in order to halt or eliminate the activity of different spoilage or pathogenic phenomena or microorganisms, with the added benefit of not only reaching a synergistic effect, but also minimizing the use of energy and/or preserving to some degree the quality and sensory attributes of the raw materials. Even though the concept of antimicrobial and/or biodegradable food packaging has been widely studied, the possibility of it becoming a Hurdle Technology in itself has not been, to the best of our knowledge, deeply explored. In this study, we have elaborated (via reactive blending) mixtures of bioplastics and biopolymers (such as polylactic acid, polybutylenes, chitosan, or vegetable proteins) which intrinsic antimicrobial activity can be substantially increased when the food materials in their direct contact are exposed to physical agents such as mild heat or UV irradiation, resulting in microbial reductions of > 3 log (CFU/g) or even below the limit of detection (< 1 log(CFU/g)), depending on the type of microorganism, material, or food sample. These materials also preserve their chemical and physical integrity upon being subjected to such physical hurdles, as confirmed by characterization techniques such as microscopy and infrared spectroscopy. These results suggest that the use of antimicrobial and biodegradable materials can represent an effective and sustainable approach for food preservation.

Assessing novel high barrier packaging for high pressure assisted thermal sterilization of low acid food products

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ABSTRACT

Pressure assisted thermal sterilization (PATS) is an advanced in-package food processing technique that utilizes flexible packaging having low oxygen and water vapor transmission rates (OTRs, WVTRs). In this study, pouches prepared from four metal oxide (MO)-coated films (A–D) and two ethylene vinyl alcohol (EVOH) containing films (E, F) were filled with water and mashed potatoes (MP), preheated at 98±0.5℃ for 10 min, and processed with a pilot scale high pressure processing machine (HPP) at 600±5 MPa with a holding time of 5 min (300 s). Subsequently after PATS processing, the water-filled pouches were emptied, gently dried with paper towels, refilled with a novel oxygen indicator, and stored at 40±0.2℃ for 80 days, while the MP-filled pouches were stored at 49±1℃ for 60 days in an incubator. Film D contained fewer defects, had an ultra-high barrier even after PATS processing, and showed minimal color change in both the oxygen indicator and the packaged MP during storage. This could be due to the presence of multiple AlO_x-coated PET layers in film D that prevented oxygen and water vapor permeation and imparted ultra-high barrier. At the same time, EVOH based Film F showed a 22.3% lower OTR than film E (*p<0.05*) due to a 16.7% higher EVOH-layer thickness, although film F had a lower overall thickness than film E. Overall, this study can assist packaging manufacturers in design and development of high barrier flexible packaging suitable for in-package shelf stable food products.

Oral Session 5: Food Materials Science

Co-chairs:

Johan Ubbink

Osvaldo Campanella

Application of the isoviscosity concept in modeling the temperature and water-content dependence of food powder agglomeration

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ABSTRACT

Agglomeration is widely used to produce food powders with desirable functional properties, such as improved flowability, easy reconstitution and convenient consumer handling. The control of agglomeration is challenging as the viscosity and thus the agglomeration of the drying particles are sensitively dependent on temperature and water content: even small variations will lead to major changes in viscosity, impacting the degree of agglomeration.

We propose a modified Williams-Landel-Ferry (WLF) equation that incorporates the water-content dependence of the viscosity. The modified WLF model allows to extract the so-called isoviscosity lines, connecting points of varying temperature and water content that have the same viscosity.

The modified WLF equation is validated using the zero-shear viscosity (η) of a systematic series of maltopolymer-maltose blends for water contents (Q_w) between 4 and 70% w/w. Based on data obtained using shear rheology (Q_w = 30 - 70% w/w ; T = -15 to 75 ºC) and dynamic mechanical thermal analysis (DMTA; Q_w = 4 - 9% w/w; T = 40 to 75 ºC), we conclude that the proposed modification provides a good fit of the experimental data over more than 15 orders of magnitude (η = 0.001 to >1012 Pas). The viscosity at the glass transition temperature (T_g) is found to be dependent on the composition and decreases with the content of maltose and water from $\sim$1014 $Pa \cdot s$ to $\sim$1012 $Pa \cdot s$.

We use the modified WLF model to determine Angell's fragility parameter m. m is observed to increase with increasing water and maltose content, signifying an increasing steepness of temperature dependence of the viscosity close to T_g with increasing content of low molecular weight compounds.

Finally, the application of the isoviscosity lines to unit operations in the food industry is discussed. Specifically, we analyze atomization, agglomeration, sintering and compaction in the context of the isoviscosity concept.

Exploring the influence of liquid oil feeds on high-moisture extrusion processing

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ABSTRACT

Incorporating lipids into the extrusion process for crafting composite protein-lipid high-moisture meat alternatives presents a significant challenge due to slip conditions induced by the oil phase. Nevertheless, lipids play a crucial role in enhancing the eating experience, contributing essential nutritional and sensory elements such as mouthfeel, flavor, and vitamins. Addressing the 'lipid bottleneck' in high-moisture extrusion processing could pave the way for innovative product categories, including marbled plant-based meats. This presentation will explore potential solutions to mitigate slip conditions arising from the use of oil in liquid feeds. The discussion will primarily focus on the impact of emulsified feeds on the processing dynamics and textural properties of high-moisture meat alternatives.

Methods to study the physicochemical properties of foods, their role in food processing, and the assessment of food quality

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ABSTRACT

The study of the physicochemical properties of foods is important in the processing of foods, the assessment of their quality and product development. Unlike many synthetic materials that are not of natural origin, the physicochemical properties of foods are strongly affected by enzymatic, chemical, and physical actions, which make them to change significantly in times relatively short, which often difficult their characterization. Foods have complex chemical structures and can form unique and intricate micro and macro structures that complicate the estimation of properties, which are very useful for food processing calculations in terms of the role they may have on the processing of foods and the assessment of food quality. The relation between the chemistry and structure of foods and their material properties is a continuous and relevant area of research, that is reaching notable interest these days with objectives focusing on the optimization of food processes in terms of saving water and energy and minimizing wastes and/or valorizing byproducts of these processes. Different experimental and theoretical approaches including standard and innovative methods, including acoustic rheology, atomic force microscopy to characterize the mechanical properties of foods will be presented. Results of other methods such as Fourier Transform Infrared (FT-IR) spectroscopy, Quartz Crystal Microbalance (QCM), and Molecular Modeling (MD) used to study the chemical structure of foods, their relationship with their physicochemical properties, food ingredients functionality and their role on processing will be discussed.

Continuum physics based modeling of transport processes and material behavior of food biopolymers

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ABSTRACT

Foods are soft and deformable, involve a hierarchy of spatial scales, and continuously change their material behavior during processing. Continuum physics-based approaches such as Hybrid Mixture Theory (HMT) can be used to model this complex behavior effectively. The framework of continuum physics involves integrating the constitutive behavior of materials with the laws of conservation of mass, momentum, energy, and entropy and imposing restrictions on the system using the 2nd law of thermodynamics. This approach results in mathematical models that can describe the experimentally observed physical processes in continuously changing porous materials and provides detailed information on underlying mechanisms. This presentation will discuss selected examples of food processing applications studied in the author's lab for utilizing this framework for food engineering applications. For example, foods undergo glass transition due to temperature and fluid content changes during processes such as drying, sorption, frying, and extrusion. Hybrid Mixture Theory was utilized to integrate the effect of glass transition on material quality changes at micro, meso, and macroscales. The model can predict Fickian and non-Fickian (or Darcian and non-Darcian) fluid flow profiles that have been observed experimentally in polymer science. HMT-based modeling of food materials with unsaturated pores (containing gas and liquid phases in pores) results in properties such as permeability and capillary pressure, for which data are lacking in the food engineering literature. The talk will also present outcomes of a pore scale model used to estimate the permeability in foods.

Overcoming moisture challenges in the food industry from start to finish

Zachary Cartwright

AQUALAB by Addium

ABSTRACT

Complete moisture control for the production of safe and high quality shelf-stable foods is possible, but requires overcoming a unique set of challenges at each step of the manufacturing process. In product development, these challenges include determining specifications to avoid microbial growth and prevent unwanted physical and chemical changes while understanding the impacts of water on sensory attributes and consumer acceptability. During production, challenges include monitoring incoming ingredients to reduce variability, and hitting moisture specs during drying steps to reduce rework, lost batches, and wasted energy. And finally, in post-production, challenges include choosing the right packaging and quickly predicting shelf-life. Since all of these hurdles are directly linked to water, an understanding of moisture content, water activity, and moisture sorption isotherms is critical to any food producer that wants to guarantee the safety and quality of their products.

Oral Session 6: Advanced Thermal Processing Technologies

Co-chairs:

KP Sandeep

Dharmendra Misra

Advancement of smart solid-state microwave processing in domestic heating applications

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ABSTRACT

Solid-state microwave processing offers various advantages over conventional magnetron-based systems, including precise control over microwave parameters of frequency, power, and relative phase. This presentation will discuss the recent advancement of solid-state microwave processing in domestic heating applications with smart, dynamic controls.

A solid-state microwave system was developed by integrating a multi-mode oven cavity, a multi-source solid-state microwave generator, and a cost-effective thermal imaging camera. The microwave system was operated by a customized control program that includes real-time data collection, data analysis, decision-making, and dynamic control functions. The integration of the thermal imaging camera with the solid-state microwave system allows for real-time heating performance monitoring. The customized program could analyze the real-time heating performance and achieve dynamic and precise control of solid-state microwave parameters to deliver more uniform and desired heating results. This developed approach could adapt dynamically to a variety of food products and accommodate sample variations with robust applicability in actual microwave heating contexts. This dynamic adjustment is particularly impactful because it unlocks the full potential of solid-state-based microwave technology that allows precise controls of specific microwave parameters and uses their complementary effects, facilitating flexible and uniformly efficient heating across different conditions.

The solid-state heating system and dynamic control strategy had been comprehensively evaluated for various commercial and/or prepared meals with different characteristics (e.g., single component, multi-component, multi-compartment, multi-layered), demonstrating superior microwave heating performance than magnetron-based heating. This innovative solid-state microwave process signifies a substantial leap toward the realization of smart kitchen technologies.

Sterilization of particulate aseptic products: practical considerations

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ABSTRACT

Aseptic processing of particulate products has commercially been very limited despite numerous scientific studies. The lack of practical knowledge and validation tools have hindered the adoption of the commercial manufacturing of particulate product aseptically. This study aims to provide practical guidance to the food industry by addressing the challenges it faces. The study involved investigating the residence time of particles using simulated particles made from combinations of polymers and food materials such as Polyethyleneimine and alginate. These simulated particles were created in two different sizes, with diameters of 12.77 mm and 15.88 mm. Density of the particles were adjusted to mimic lower and higher density of the food particles. Real-time magnetic implants were integrated into the center of these simulated particles to precisely measure their locations from the insertion point. They exhibited an observed minimum flow factor of 0.73-0.85 depending on the fluid viscosity. Temperature dependent thermal properties of the particles and fluid were measured using TPCell. Microbiological validation was conducted by inoculating the particles with surrogate organisms with defined inactivation parameters at a concentration to achieve a lethality of 6 minutes. The results showed that the system was able to achieve commercial sterility of the aseptic particulate products. The practical tools used in the validation process would be beneficial for commercial manufacturers.

Microwave processing as a sustainable alternative for high-quality, shelf-stable foods

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ABSTRACT

Flexibility and efficiency of microwave processing enabled a new incremental scale-up capability for aseptic food and beverage production. Companies such as YamCo, LLC first set the stage for adoption of industrial microwave processing in the bulk ingredient space by providing the highest quality sweet potato puree on the market in a shelf stable format. Subsequent microwave processing systems installed at FirstWave Innovations' co-packaging facilities enabled the rapid implementation of these scalability breakthroughs for food service and retail markets for high-quality products enabled by the clean, efficient application of microwave heating. Safe, sustainable processing to generate market introduction and consumer testing samples, limited volumes, and seasonal product quantities are now possible and routinely implemented for new product lines using these abilities. Applied systems range from 18 kW @ 2450 MHz to 400 kW @ 915 MHz allowing for processing batch sizes as small as 5 gallons and incrementally sized systems for 50 to 5000 gallons of shelf-stable packaged products per production shift. The key differentiators are the accessibility to high quality shelf stable processing for small runs, and the consistency in results as that product grows in the marketplace and requires larger and longer production runs. This scalability provided by microwave processing has enabled new entrants into the shelfstable foods market and provided a platform for established brands to launch new, innovative products with minimal upfront investment. This scalable platform is easing the adoption and conversion to microwave processing as the industry works to move away from burning fossil fuels for steam heating and evolves into a more sustainable electric powered reality that can take advantage of renewable energy and achieve decarbonization initiatives.

Challenge between cutting-edge green technology to conventional technology: a case study in the inactivation behavior of C. Sporogenes

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ABSTRACT

Consumption of natural, non-alcoholic beverages has grown considerably in recent years. Concentrated maple sap is one of these new natural products sought by consumers in North America and around the worldwide. This product is rich in micro-organisms resulting from the filtration process. Appropriate treatment is required to inactivate these micro-organisms and maintain the product's quality throughout its shelf-life. Conventional heat treatment is the traditional candidate that could be used to guarantee the safety and shelf life of the processed product. However, severe heat treatment can adversely affect the quality of the final product for consumer acceptance. Advanced technologies are promising for their efficiency, low energy consumption and small environmental footprint. Ohmic heating is one such green technology, offering a range of advantages for processing liquid foods to produce high-quality, value-added products. Interesting research activities have been carried out on evaluating the effectiveness of this process for inactivating microorganisms using various complicated ohmic heating systems. In this study, we set out to establish kinetic parameters for the sterilization of maple sap concentrates from 10 to 30 °Brix by conventional and ohmic heating processes. The kinetics of C. sporogenes spore destruction as a resistant and reference microorganism were established under defined heating conditions. A new micro ohmic heating cell with an active volume of 3 ml was designed and validated in our laboratory to easily evaluate the destruction kinetics of microorganisms such as the capillary tubes used for the conventional thermal process. The death rate and kinetic parameters (D and Z values) obtained by the conventional thermal process and ohmic heating were discussed. Scanning electron microscopy (SEM) and transmission electron microscopy (TEM) analyses were carried out on spores treated by both technologies. Some differences in the mechanism of action of the two processes on spore destruction were recorded.

Preliminary study of fruit dehydration using refractance window (RW) coupled with microwave: Effect on drying time and bioactive compound retention

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ABSTRACT

Refractance window (RW) and microwave (MW) are two drying technologies characterized by short drying time and high-quality retention. The aim of this work was to study the effect of drying apple slices as a model food, using RW and RW coupled with microwaves (RW-MW), on drying time and bioactive compound retention. Additionally, this study aimed to model the drying process through Fick's second law and an anomalous diffusion model based on fractional calculus for apple slice drying. RW and RW-MW were performed at 80°C and 95°C, and three different power levels—90, 180, and 360 W—were applied for the RW-MW. Moisture content and water activity (aw) were measured as functions of the drying time. Bioactive compound retention was measured as total polyphenol content (TPC), and antioxidant capacity (AC) was measured at the end of each process. The result showed that the application of MW at power levels of 180 and 360 W during RW drying at 80°C and 95°C reduced drying time by up to 38% compared to RW drying alone. Concerning TPC and AC, the use of MW resulted in bioactive compound retention values similar to those of RW. The results showed that the anomalous diffusion model was better fit (R2 > 0.9796) than Fick's model (0.8999 < R2 < 0.9688) for both drying processes, the anomalous diffusion model showed superdiffusive behavior ($\alpha>1$). Finally, this study showed that the RW-MW drying process was a technology that allowed the production of dried apple slices with aw <0.4 and a moisture content <12 g water/100 g sample in a short time while maintaining high retention of bioactive compounds.

Oral Session 7: Rheology for Food Quality and Health

Co-chairs:

Jin Hong Mok

Paul Takhistov

Tribology, friction, and hard surface cleaning

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ABSTRACT

Hard surface cleaning is a common operation in domestic and process plant cleaning, using (for example) brushes, mops and sponges. Most surface cleaning studies are focused on the chemical part of cleaning. The role of mechanical friction in cleaning though (friction), is crucial and is less well understood. Thus, in this work frictional forces during a cleaning process have been obtained and compared with cleaning efficiency.

A method was developed to evaluate cleaning and frictional force. A ForceBoard that can measure applied vertical and horizontal force was used, with a camera to evaluate the cleaning efficiency, by image analysis. Enamel tiles were stained with black Sharpie marker for use in the cleaning experiments. A range of sponges were used as cleaning devices, and the viscosity and polarity of the cleaning fluids varied. To characterize the cleaning devices, Atomic Force Microscopy (AFM) was used to characterize surface interactions and X-Ray Tomography was used to measure the voidage of the cleaning agents and thus the contact force.

Cleaning takes place in three stages, which are best seen in the higher glycerol concentrations:

- an *induction period* before which there is no significant removal; this increases with increasing viscosity, in some cases to the point where there is no removal at all;
- a *period of cleaning* at an approximately constant rate;
- a *falling rate period* as cleaning ends; this can be at 100% removal, or at lower values.

As expected, the rate of cleaning increases with applied force. The effect of the cleaning fluid is significant, with significant decrease in cleaning with increased viscosity and increasing hydrophobicity, showing the importance of hydrophobic and hydrophilic interactions between soil, surface and cleaning material. The variation of friction coefficient is also significant; the friction coefficient builds up during the induction period until cleaning starts, and then decreases. The data shows how to develop better cleaning devices and suggests how to optimize cleaning processes.

A physics-informed image analysis framework to infer the rheology and mechanical stresses in foods

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ABSTRACT

The acquisition of dynamic images of foods at both microscopic and macroscopic scales is commonplace. Particle Image Velocimetry (PIV) techniques enable the reconstruction of velocity fields in fluids and displacement fields in solids. However, reconstructing forces and stresses is challenging due to the unknown initial and boundary conditions in structured foods. We propose an innovative Lagrangian-based approach for describing fluid-solid and solid-solid interactions. The foundational concept assigns streamlines or strain lines to the movement of virtual particles larger than colloidal scale, termed "food-atoms," which are indivisible and limited in variety.

Because food-atoms interact through pair-wise forces—dependent only on the distances between atoms for conservative forces and on their relative velocities for dissipative forces—we achieve a formulation that is independent of boundary conditions and weakly dependent on past configurations for low particle Reynolds numbers. For liquids, Tait's equation reconstructs a pressure field from the fluctuation of food-atom packing. A smoothed particle hydrodynamics formulation accommodates the coarse description of object contours and density fluctuations.

We have validated the capability to reconstruct mechanical stresses and auto-learn rheological properties solely from 2D experimental images using confocal laser scanning microscopy and from detailed 3D simulations mimicking food deconstruction. The feasibility of implementing this method on GPUs paves the way for real-time digital twin construction linked to observation, allowing foods to be studied during transformation and digestion. Potential applications of our open-source software, Pizza3, which can utilize experimental images, are demonstrated through various case studies, including the homogenization of emulsions under varying shear rates.

Continuous-flow viscoelastic profiling of calcium alginate hydrogel microspheres using a microfluidic Lab-on-a-chip device

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ABSTRACT

Calcium alginate (Ca-alginate) hydrogel microspheres, distinguished by their unique viscoelastic attributes, have found valuable utility in encapsulating bioactive components and facilitating targeted release applications. However, the rapid profiling of the viscoelasticity of these hydrogel microspheres has posed a significant challenge. In this study, we have developed a continuous-flow methodology for swift viscoelastic profiling of a substantial population of hydrogel microspheres, employing embedded electrode pairs and validated with 0.5–2.0% *w*/*v* Ca-alginate hydrogel microspheres. Our approach involves the measurement of microsphere size and travel trajectories through the observation of electric signal variations across the embedded electrode pairs. These signals arise from the displacements of the leading and trailing edges of the microspheres. By applying a quasi-linear viscoelastic (QLV) model to interpret the electric signals, we can effectively deduce the viscoelastic properties of the microspheres. Notably, this innovative technique enables fast viscoelasticity screening with a concise constriction channel featuring a minimal number of electrode pairs. The measurement is independent of the applied flow rate. The outcome of our work has led to significantly improved measurement throughput of up to 2650 counts/min for Ca-alginate hydrogel microspheres with 0.5% *w*/*v*. Furthermore, this approach can distinguish hydrogel microspheres of varying qualities and chemical compositions based on their viscoelastic properties. This breakthrough holds significant promise for real-time sorting and separation of microspheres, which is particularly useful for developing innovative food structures and texturizers, along with possibilities across a wide spectrum of engineered foods, such as plant-based, printable or bioinspired hydrogels.

Effect of non-thermal processes on protein interfacial properties and formation of novel food structures

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ABSTRACT

In response to the growing demand for nutritious food products with enhanced protein content, novel techniques for fortification are continuously sought after. Utilizing these techniques to develop novel food structures enables advanced delivery of functional foods that yield benefits beyond basic nutrition.

Plant proteins provide an alternative to traditional animal proteins in beverage applications. However, poor solubility of many plant proteins, such as soy protein isolate (SPI), can lead to formulation complications and undesirable mouthfeel of these products. Non-thermal processing methods like high-intensity ultrasound (HIU) can play a critical pre-processing role in exposing hydrophobic regions of the tertiary structure, which greatly improves solubility via electrostatic stabilization. Applications of HIU in formulation required investigation due to the complex interactions of colloid species present. For example, formulators have been looking towards non-nutritive sweetener options to reduce calories and sugar content, but substitution for these sweeteners can result in drastic changes to the interfacial properties and have unexpected consequences on sensory characteristics. Therefore, these relationships were studied under model systems to determine the impact of HIU on sweetener-protein samples.

Electrophoretic deposition (EPD), another non-thermal processing method, effectively fabricates gel-like structures fortified with iron nanoparticles, achieved through the synergistic effects of anodic dissolution. Utilizing a custom-designed electrochemical reactor setup comprising an iron anode and a stainless-steel cathode, controlled application of DC voltage facilitated the process under precisely regulated conditions. This phenomenon leads to the localized concentration of iron ions within the protein matrix, promoting controlled nucleation and subsequent formation of nano-crystalline iron nanoparticles. Integrating charged biopolymers, such as whey protein isolate (WPI), further enhanced metal ion accumulation and facilitated controlled crystal growth within the hydrocolloid matrix. This approach, characterized by its non-thermal nature and absence of salt additives, offers a continuous and scalable means of nutrient fortification.

The combination of HIU and EPD presents an innovative approach to the formation of novel food structures, controlling the electrokinetic properties of plant proteins. These three-dimensional film-like structures demonstrate protein networking without any heat or chemical modifications. The use of non-thermal processing methods like HIU and electrophoresis in food processing is a cutting-edge area of research that can help avoid thermal degradation and loss of nutritional quality. The exploration of these applications and their impact on interfacial properties showcase the fundamental theory and principles behind potential novel food structures for functional food applications, sparking excitement about the possibilities of this research.

Incorporation of corn stover-derived nanocellulose and Beeswax to improve Polyvinyl Alcohol Film Characteristics

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ABSTRACT

Coating is a technique to surround a target substance with a thin layer to obtain desirable properties. Polyvinyl alcohols (PVAs) are biodegradable plastics and have shown good applicability as a coating or film material. Cellulose nanocrystals are a promising green nanomaterial that has been shown to enhance the properties of PVA after blending. However, these PVA/CNC films have concerns in a moist environment due to high hydrophilicity. To overcome this issue, the current study incorporated beeswax into PVA/CNC films and investigated the effects of CNC and beeswax on the properties of the films. Results showed that the addition of corn stover-derived CNCs to PVA films increased tensile strength (from 11 to 25 MPa) and Young's modulus (from 32 to 173 MPa) and reduced water vapor transmission rate (from 25 to 20 g h^{-1} m^{-2}). Beeswax added to PVA/CNC films further improved water vapor barrier properties (from 20 to 9 g h^{-1} m^{-2}) and maintained Young's modulus (from 173 to 160 MPa), though it caused a reduction in the tensile strength (from 25 to 11 MPa) of the films. This information can help to select materials for blending with PVAs by obtaining the desirable endmost properties depending on applications.

Oral Session 8: Innovations in Plant Protein Technology

Co-Chairs:

Girish Ganjyal

Sajid Alavi

Use of machine learning in predicting protein solubility

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ABSTRACT

Protein solubility is a critical attribute that directly impacts various protein functionalities and key characteristics of food products. Accurately predicting protein solubility is essential for screening suitable candidates for food application. Existing models often rely solely on sequence data, potentially overlooking important structural details. In this study, we utilized AlphaFold 2 to generate 3D structures of 2,983 E. coli proteins. From the predicted structures, 20 sequence and structure features were extracted and subjected to multilayer perceptron. Using the same structures, three residue level features and contact maps were utilized to construct a graph convolutional network. The outputs of these two models were integrated and fed into a support vector regressor to create a stacking model. The stacking model demonstrated state-of-the-art performance for regression tasks, achieving R2 of 0.501 and 0.454 on test and validation datasets, respectively. The stacking model also outperformed other models in binary classification task (0.805 vs ~0.787 accuracy). Furthermore, the model's transferability was validated on a dataset of seed storage proteins, indicating its potential applicability beyond microbial proteins to those relevant to food and agriculture. The proposed model shows promise for screening alternative protein sources and could be extended to other techno-functional traits such as emulsification and gelling properties, which are closely related to solubility.

Ultrasonication based extraction and processing of plant proteins

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ABSTRACT

Introduction:

Increase in the demand for plant-based proteins have paved way for applications of novel technologies in extraction and processing of plant proteins. In addition, the limited functional properties of rice protein are constraining its potential applications. This study investigates the use of ultrasonication (US) to assist in the precipitation of alkaline-extracted rice bran proteins (RBP), as well as modifications of isolated proteins using US to enhance their functionalities.

Methodology:

The defatted RBP was extracted at pH 11.0 and precipitated at (i) isoelectric point pH 4.5 (IEP) and (ii) IEP in ultrasonic bath (117 V; 60 Hz) for 1 hr followed by freeze drying. The extracted proteins were also subjected to US treatment for 2, 4 and 6 minutes using a 450 W generator running at 100% amplitude. The molecular structure and functional properties of the isolated rice proteins were analyzed.

Results:

Fourier-transform infrared spectroscopy data showed that the intensity of β-sheet and random coil increased, and α-helix decreased during US-assisted precipitation. Rice protein isolated using US-assisted precipitation showed the highest solubility of 8.33 mg/mL. After ultrasound treatment of the isolates for 4 minutes, the solubility decreased to 1.70 mg/mL, compared to 3.06 mg/mL for the control. However, ultrasound treatment of isolates for 6 minutes showed the highest emulsion capacity 88.2% and stability 596.6%, whereas US-assisted precipitation showed 77% capacity and 198.4% stability. Similarly, 6 minutes ultrasound treatment of isolates increased the foaming stability to 366.6% whereas control was 137.5% up to 40 minutes.

Conclusion:

Ultrasound-assisted precipitation of rice protein showed better solubility properties than the control, with a threefold increase in protein solubility. However, ultrasound treatment of the control isolates showed better emulsion and foaming properties. Overall, ultrasound processing showed promise in improving the functional properties of rice protein; however, optimization of the process is needed based on the application.

Characterization of structural attributes of plant-based meat alternatives using machine learning based image analysis

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ABSTRACT

This study explored machine learning for characterization of internal structure of plant-based meat. Three faba bean concentrate based formulations were tested, comprising of pea protein isolate (PPI), soy protein isolate (SPI) or wheat gluten as the secondary protein component. The formulations were extruded using a pilot-scale twin-screw extruder, using three different in-barrel moistures (IBM), resulting in nine treatments with end products having varying microstructures.

To characterize internal structure, products were rehydrated (20-minute water immersion) and cut horizontally and vertically. Exposed microstructure was imaged using a Nikon-D750 camera with a 105-mm Macro-lens against an 18% grey card background.

Roboflow image processing platform was employed for internal structure segmentation, based on Region-based Convolutional Neural Networks (R-CNN) and You Only Look Once (YOLO) algorithm. To enhance reliability of predictions, images were augmented by rotating them 90, 180 and 270 degrees and horizontally flipping, resulting in 288 total images.

Machine learning based image analysis procedure yielded product ratings on a 10-point scale for fibrousness (inverse of cellular). An overall correlation existed between physical characteristics and internal structure. For example, lower BD corresponded with higher WHC and more porous internal structure. Cold swelling proteins (formulation with SPI as secondary protein) exhibited lowest bulk density (BD; 151g/L) and highest water holding capacity (WHC; 484.6g), corresponding with microstructure with least fibrousness. While lower cold swelling properties (PPI treatment) had highest BD (333g/mL) and lower WHC (134.5g).

This research advanced understanding of formulation, processing and quality of plant-based meat by utilizing machine learning for characterization of internal structure.

Extrusion processing of plant proteins for the development of high moisture meat analogs (HMMA): an overview of chemistry and engineering aspects

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ABSTRACT

Texturization of plant proteins is a complex phenomenon. Despite the challenges, extrusion processing is a viable tool for manufacturing plant protein products. The chemistry of the ingredients and the extrusion processing parameters influence the degree of texturization and, thus, the final product quality.

Chemistry and Functionality of Proteins: Experiments were conducted to determine the importance of disulfide bonds and their modifications in the texturization process. Some findings include i) the quantitative amount of disulfide bonds is likely not the only factor affecting the degree of texturization, ii) the formation of large disulfide-linked polymers was observed, iii) it was suggested that certain protein functionalities or characteristics are of significance during protein texturization.

Engineering Aspects: The effect of various heat transfer and shear rates on controlling the texture and structural orientation of wheat-based HMMA was undertaken with the cooling die. Some findings include i) slower cooling rates result in softer HMMA products, ii) taller product cross sections result in more structural orientation of HMMA, which was found to be a result of a balance between slow cooling, adequate time for laminar flow development, and minimization of slip-flow behavior in the cooling die, iii) increased anisotropy in samples was found to also result in an increased release of latent energy in the samples, likely due to enhanced phase transition extent in the product.

Overall, the fact that the applied processing conditions significantly alter the quality of the samples without resulting in a noticeable process-dependent chemistry trend infers that producing quality of HMMA requires mastery of two separate problems: (1) a chemistry based protein selection problem, where certain proteins have a propensity to texturize; and (2) an engineering problem, where the quality of the HMMA (assuming the prerequisite chemistry qualities are met) can be controlled with the right choices in processing parameters during extrusion.

Optimizing the extrusion of pea protein isolate for novel meat analogue applications

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ABSTRACT

There is an urgent need to broaden the range of applications of meat analogues to cater to diverse culinary practices. We report on the optimization of the cooking stability of extruded pea protein isolate (PPI) by varying the water content and specific mechanical energy (SME) during extrusion, opening up the use of such products for stew-based dishes as they are prepared around the world.

Method:

The PPI was extruded at water contents varying between 40% and 60% using a Brabender lab 20/40 twin screw extruder at a screw speed of 200 RPM, and a barrel temperature profile of 40, 60, 80, 110 and 110 °C. The textural properties were determined using Texture Profile Analysis (TPA) before and after cooking. The texturization degree was determined using a newly developed swelling behavior technique. The samples were cooked for 1 hour at 95 °C in water, water + 2% salt w/w, water + 5% vinegar (pH 5), and water + 5% garlic w/w to mimic the impact of condiments. Extruded meat analogues were used to prepare five stews from internationally inspired cuisines to demonstrate potential applications.

Results:

The SME decreased with increasing water content from 221 to 57 kJ/kg. Only the samples extruded at 40 and 45% water content were able to withstand the cooking at 95 °C for prolonged times and in the presence of salt, vinegar, or garlic, while PPI extruded at higher water contents disintegrated. We observed that adding fats during cooking lead to disintegration of the structure of the extruded meat analogues.

Significance:

We demonstrate that the water content during extrusion is a critical parameter determining the properties of PPI extrudates and thereby is one of the controlling parameters for optimizing the physicochemical and textural properties of the exudates for a variety of applications.

Oral Session 9: Sensors and Imaging Technologies

Co-Chairs:

Colm O'Donell

Jose Reyes-De-Corcuera

Categorizing crispness/crunchiness of snack foods with audio sensors

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ABSTRACT

Texture attributes characterized as crisp, crunchy, or crackly are usually associated with foods that fracture in multiple places, creating noisy and seemingly chaotic force and sound responses, but can be challenging to quantify with instruments. In this work we tested a small compression probe fitted with a 3-D printed simulated molar, that could break snack foods while sounds were collected through an Arduino Nano 33 acoustic sensor placed near the sample. It was hypothesized that advanced signal processing or machine-learning algorithms could be used to identify several different snack chips based on sound and assess the intensity of the texture attribute. Alternately, potato chips equilibrated to different moisture levels were tested. Signal analyses indicated that sound intensity, number of peaks and accumulated frequency distributions were related to identifying snacks. Machine-learning algorithms were trained based on 6000 sound files, with 80% for the training set and 20% for a testing set. With this model, the type of snack chip could be predicted with >93.7% accuracy, while chips at different moisture had >89.6% testing performance. In addition, trained panelists were used to determine the degree of crispy/crunchy/crackly sensation for the same food items. Overall, the assessed crispness level was predicted with 83 to 95% accuracy. Crispness and similar attributes are some of the most important texture cues that determine consumer enjoyment of snack foods, but are ultimate affected by the structure and physical properties of the food. The ability to measure how such products change over time or are affected by processing and formulations is important for helping processors monitor shelf life, detect defective product and develop new products for the market.

Electrochemical biosensors for food-borne pathogen detection

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ABSTRACT

Foodborne illnesses caused by pathogenic microorganisms are a significant public health concern worldwide. The Centers for Disease Control and Prevention (CDC) estimates that 48 million Americans fall ill each year from eating contaminated foods. The National Outbreak Reporting System (NORS) of the CDC reports that major foodborne pathogens such as Escherichia coli, Listeria, Salmonella, vibrio, Hepatitis A, Norovirus and Cyclospora caused 20,854 outbreaks from 1998 to 2017. Therefore, it is important to develop accurate and robust detection methods to isolate and enumerate pathogens in the food sample as early as possible in the food supply chain. Even though predominant conventional detection methods such as standard microbiological and biochemical tests are highly reliable, inexpensive, and allow both qualitative and quantitative assessment of pathogens, these methods require laboratory space and skilled labor and are time-consuming. Compared to other methods, biosensors are portable and easy to use in the field and detect pathogens quantitatively. The specificity of the biosensor is considered an important criterion, and it highly depends on the type of biorecognition element used. We have developed a bacteriophage-based biosensor to detect Listeria monocytogenes and an epithelial cell-based biosensor to detect Hepatitis A Virus (HAV). The binding of HAV to the cells and binding of L. monocytogenes to the phage cause changes in electrical impedance measured by electrochemical impedance spectroscopy. The fabricated biosensors exhibited high sensitivity and could detect L. monocytogenes and HAV at low concentrations but also effectively differentiated the target pathogen from two other non-target bacteria and viruses found in similar food matrices, respectively.

Investigation of spectral technologies for scorched particle detection in dairy and infant formula powders

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ABSTRACT

Scorched particles refer to burnt residues in milk powder formed during powder manufacture. This study investigated the use of hyperspectral imaging (HSI) for scorched particle detection in dairy powders. Commercial dairy powders including skim milk, whole milk, enriched milk, and infant formula powders were measured using a portable Vis-NIR hyperspectral imaging system (400-1000 nm). The GEA Niro Method No. A4 was used as a reference method for estimation of milk powder quality levels (i.e., AA, A, B, C, and D) based on the level of scorched particles observed in powder samples.

Principal component analysis (PCA) and support vector machine discriminant analysis (SVMDA) models were developed for milk powder quality levels based on the acquired HSI/spectral data and quality values obtained from the conventional reference method. HSI images at specific wavelengths were extracted from the raw data for model development. PCA was carried out on pre-processed HSI data to extract score images to enhance the scorched particles observed using a filter developed on a selected threshold. Scorched particle blob areas were estimated at a pixel level based on domain statistics. Overall, this study demonstrated the strong potential of the Vis-NIR HSI to predict milk powder quality levels with > 97% accuracy for all measured samples. SVMDA models developed had a total correct identification ratio of 89% for discrimination of milk powders with AA and A quality levels from other quality levels.

Electrochemical biosensors – an overview in the context of the food supply chain

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ABSTRACT

Almost 70 years have passed since the first report of a glucose biosensors by Clark and Lyons in the late 1950s. In their 1967 visionary Nature report, Updike and Hicks anticipated the use of implanted glucose sensors for telemetry. However, it wasn't until 1975 that Yellow Springs Instruments (YSI) commercialized the first amperometric glucose biosensors. Other early enzyme biosensors for several analytes were developed using other oxidoreductases but following the same electrochemical transduction principle. Biomedical applications have been the driving force in the development of biosensors. Without any doubt, the glucometer for individuals suffering from diabetes has been the most successful electrochemical biosensor. However, since the 1980s the potential application of biosensors to food and agriculture has been recognized and has extended to the detection of foodborne pathogens using for example electrochemical impedance spectroscopy. Nowadays, the electrochemical biosensor literature is quite vast with over 25,000 papers published on the subject. Most of the research is driven by the biomedical and health industries. However, nanotechnology-inspired architectures, the development of the Internet-of-Things (IoT), and the accelerating emergence of artificial intelligence algorithms have resulted in novel biosensors with potential applications in an increasingly integrated food supply chain. Here we present a critical overview of the current state-of-the-art in electrochemical biosensors that describes existing technologies, current challenges, and opportunities for the integration of electrochemical biosensors into the food supply chain. We emphasize the potential contribution of electrochemical biosensors to the formation of circular economies and the sustainability of the food industry.

Contactless assessment of intramuscular fat content in pork loin by using air-coupled ultrasound

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ABSTRACT

Airborne ultrasound offers a contactless approach for analyzing intramuscular fat (IMF) content, a crucial quality factor in meat, particularly in beef and pork. Unlike real-time ultrasonic imaging (RTUI), which requires contact with the meat tissue, airborne ultrasound enables non-invasive measurements. This study investigates the potential of airborne ultrasound to estimate IMF content in pork loins. Three sets of pork loins with varying IMF content (2%, 4%, and 6% wet basis) were selected and analyzed using airborne ultrasound at temperatures of 4 and 37°C. Air-coupled ultrasound measurements were performed using a pair of widthband piezoelectric transducers (250 MHz) operating in through-transmission. A pulser-receiver (5077, Olympus) was used for emitter excitation (400 V, pulse repetition frequency of 100 Hz) and conditioning the receiving signal (+59 dB). Digitalization (USB-5133, National Instruments) was carried out at 10 MS/s, averaging 128 signals and recording 10 kS. Signals were analyzed in the time domain for computing the ultrasonic velocity. The experimental results revealed a distinct pattern in ultrasonic velocity corresponding to IMF content at both temperatures. At 4°C, the higher the IMF content, the higher the ultrasonic velocity, whereas at 37°C, the relationship was reversed due to fat melting. Linear trends were observed between ultrasonic velocity and IMF content at both temperatures (R2 of 0.985 at 4°C and 0.983 at 37°C). Ultrasonic velocity figures assessed using air-coupled ultrasound were close to those obtained using a conventional direct-contact ultrasound technique (1 MHz). This study demonstrates the feasibility of using airborne ultrasound for non-invasive classification of pork loin according its IMF content, suggesting its potential for industrial implementation.

Oral Session 10: Food Engineering and Health

Co-Chairs:
Ilce Medina Meza
Fanbin Kong

Effects of specific volume and lipid level on indicators of satiety in engineered food systems

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U.S. Army

ABSTRACT

The military seeks to reduce the weight/volume and increase the energy density of rations to maximize energy intake while limiting Warfighter load. The newest ration system, the Close Combat Assault Ration (CCAR), contains compact, low moisture, energy dense foods. However, effects of such foods on energy intake and appetite are not characterized. This randomized, double-blind, crossover study assessed—in like food items—how ingestion of condensed vs. relatively expanded and higher vs. lower lipid components influenced appetite. Prototypes represented 3 typical CCAR components (egg casserole; dehydrated cheesecake; and chicken salad sandwiches), systematically varying in physical density (PD) and energy density (ED), engineered using puffing or compression techniques; lipid content was adjusted by substituting high vs. low fat ingredients. Twelve test specimens comprising 4 test "diets"—high ED/high PD; high ED/low PD; low ED/high PD; and low ED/low PD--resulted. 20 volunteers consumed a standard base diet (SBD) ad libitum and reported perceived hunger/fullness/desire to eat before and after consuming breakfast, lunch and an afternoon snack consisting of engineered foods specific to each test diet. Results showed increased PD increased total energy and fat intakes ($p < 0.01$): participants didn't compensate for higher energy/fat contents of the engineered items with reductions in energy/fat from the self-selected foods. However, increasing ED resulted in higher total fat intake ($P < 0.01$) but not total energy intake; participants adjusted selected intake to compensate for higher energy contents, but not higher fat contents, of the high ED engineered foods. Hunger ratings were higher after consumption of high ED foods ($P = 0.02$) while fullness and desire-to-eat ratings weren't affected by PD or ED. Findings suggest that increasing ration physical and energy density may reduce Warfighter load without compromising energy intake. Results will contribute to development of future ration products that are both compact and sustaining.

Improved lipid quality of human breast milk after high-pressure processing

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ABSTRACT

Human breast milk is a complex fluid abundant in bioactive compounds essential for infant nourishment and is widely supported by global health authorities for its role in fostering optimal infant growth and development. When maternal milk is unavailable, donor breast milk sourced from human milk banks (HMBs) stands as a vital alternative. The preservation of HMB milk predominantly relies on Holder pasteurization (HoP), a method effective in pathogen reduction yet prone to compromising the nutritional integrity of breast milk. In contrast, high-pressure processing (HPP) emerges as a promising alternative pasteurization technique, leveraging elevated pressure to eliminate pathogens while preserving the nutritional profile of breast milk. This study investigates the impact of HPP (450 and 600 MPa) and time (0 and 5 min) on the lipid and antioxidant content of donor breast milk. The lipidomic analysis unveils a diverse array of bioactive compounds within breast milk, encompassing lipids, polyphenols, and polyketides, thereby shedding light on its mosaic composition. Results indicate varied responses of lipid subclasses to HPP treatment and time, with ceramides demonstrating a reduction under both processing methods, while fatty aldehydes and esters exhibit an increase under specific HPP conditions. Furthermore, the study quantifies the presence of oxidized lipids, notably dietary oxysterols (DOxS), recognized for their pro-oxidant and pro-inflammatory properties. These findings deepen our understanding of targeted approaches employing HPP and underscore the complexity of breast milk composition. Moreover, they offer insights that could fuel the development of innovative milk preservation techniques, thereby advancing specialized infant nutrition and bolstering the efficiency of donor milk banking systems.

Engineering the gut microbiome using designer prebiotics and consumer-resource modeling

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ABSTRACT

The human lower gastrointestinal tract harbors trillions of microorganisms, and the interactions of these microorganisms with the host influences health. Dietary fiber consumption shapes the microbiome, but there is insufficient knowledge regarding how fibers with specific physical structures influence the taxonomic composition of the microbiome. In this project, a library of six corn bran arabinoxylans differing in their physicochemical properties were produced and their effect on the microbiome was determined using in vitro fecal fermentation with taxonomic composition determined using 16s rRNA sequencing and short chain fatty acid production assessed using gas chromatography. Results showed that taxa were differentially promoted by the fibers in the library, leading to distinct changes in the short chain fatty acid profile. The gut microbiome is notoriously complex and highly variable, but our project establishes that taxa have differential access to arabinoxylans with specific modifications. This information can be leveraged using a canonical population dynamic model (consumer resource model) to reveal a new avenue for quantitative, forward engineering of the gut microbiome using designer prebiotics. Overall, results from this project could help to develop more effective prebiotic therapies for improved consumer health, and potentially create opportunities for value-added prebiotic products from cereal bran.

Food process engineering for health impact: application of standard in-vitro assays for cancer cell viability and proliferation to screen potential anti-cancer bioactivity of fruit, vegetable and fungi sources and comparison with clinically established effective chemotherapeutic drugs for different cancer types

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ABSTRACT

Objectives:

- Investigate potential for maximization of health-promoting functionality/retention of bioactive compounds of fruit, vegetable and fungal materials by novel methods for rapid thermal (microwave) processing
- Use established standard assays to evaluate anti-cancer activity of tested materials
- Use obtained results for screening, strategic decision-making, selection of materials, varieties, ingredients and processing methods

Methods:

Standard In-Vitro Assays (e.g. MTT technique for cell metabolic activity) for Cancer Cell Viability and Proliferation to Screen Potential Anti-cancer Bioactivity of Fruit, Vegetable and Fungi Sources and Comparisons with Clinically Established Effective Chemotherapeutic Drugs for Different Cancer Types (Colon Cancer Cells and Glioblastoma Cell Cultures)

Results:

For each tested group of materials (berry fruits, stone fruits, root vegetables, purple-fleshed sweetpotatoes, fresh mushrooms) and for each tested cancer cell culture, at least one or more materials have been identified as possessing a comparable or higher anti-proliferative efficiency compared to the respective clinically established chemotherapeutic drugs for each cancer type (temozolomide for glioblastoma cells, 5-fluoroacil for colon cancer cells).

Impact of nanocellulose on food digestion and nutrient absorption

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ABSTRACT

Nanocellulose, comprising cellulose nanocrystals (CNC) and cellulose nanofibers (CNF), has evoked considerable interest across diverse industries due to its distinct physicochemical attributes. Within the realm of the food industry, nanocellulose is recognized for its potential utility as a thickening agent, emulsifier, and functionally beneficial dietary fiber. Nevertheless, Nanocellulose has not yet been approved for food applications, primarily due to lingering uncertainties surrounding its potential impact on human health.

In the past decade, we have studied the behavior of nanocellulose during digestion and its influence on nutrient absorption using in vitro, ex vivo, and in vivo methods. The results indicate that NC can hinder the digestion of macronutrients and impede nutrient absorption due to its effect in increasing the viscosity of gut content, decreasing the permeability of mucus layer, and binding of nutrients. CNC can also prolong gastric emptying, potentially resulting in increased feelings of satiety and decreased calorie absorption. In general, NC cannot penetrate epithelial cells and does not affect cell viability. These insights contribute to a deeper understanding of nanocellulose, providing valuable data that may facilitate the path toward regulatory endorsement for achieving "GRAS" (Generally Recognized As Safe) status.

Oral Session 11: Food Engineering Education

Co-Chairs:
K. Niranjan
Jorge Welti Chanes

Food Engineering Education – its evolution

Keshavan Niranjan

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ABSTRACT

Food industry is critical to any nation's health and well-being; it is also critical to the economic health of a nation. Food Engineering is a discipline that ought to be at the heart of the food industry, but it is not playing its rightful role. Amongst the many reasons for this unfortunate state of affairs is the inadequacy of education and training in this discipline as practised today. This paper takes a step back and examines the evolution of this discipline in higher education degree programmes, identifying some novel developments that have taken place over the years. The paper then makes recommendations for a fit-for-purpose educational programme - basing the recommendations on health, sustainability and security as the key drivers of the discipline. At the heart of the approach proposed here is an attempt to combine engineering of process and food product in a purposeful way, termed here as Food Product Realisation Engineering, which is not only intended to produce graduates with a unique set of competencies that is valued by industry, but also make the subject more intellectually stimulating and attractive to the brightest young minds.

Training the next generation of engineers in the food industry

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ABSTRACT

Continuous learning is key to a successful career and training can help food engineers adapt to the changing skill sets needed to be effective engineers now and in the future. Corporate training programs to develop employees are beneficial for both the company and employees. According to Forbes, companies with training programs earn double the income per employee and have a 24% higher profit margin overall. On average, the Fortune 100 Best Companies to Work For provide 73 hours of training per year for each full-time employee compared to 38 hours in corporate America overall; this contributes to these same Fortune 100 companies having 65% less staff turnover. Surveys have shown that most workers feel that effective training helps them do their job better, gives them more confidence, improves their time management skills, and positively impacts their job engagement. Employees want training that is personalized, relevant to their position, engaging, and fun. However, one study found that among people who received formal training in the workplace, 43% found it ineffective. The food industry faces a challenge to provide effective training for engineers at all stages of their careers with a variety of educational backgrounds, specializations, and work experiences. Creating impactful training programs for food engineers requires us to define what makes a good engineer and how we can cultivate these attributes in our teams. Tools that can be used to help train engineers include customized onboarding materials and templates, engineer-to-engineer job shadowing for both new and experienced employees, and mentoring. In the future, creating new opportunities for training and improving existing programs will be critical to employees and employers in the industry, as we adapt to changing consumer expectations and challenges in the global food system.

The views expressed are those of the author and do not necessarily reflect the position or policy of PepsiCo, Inc.

Challenge-based learning, a new approach to teaching Food Engineering

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ABSTRACT

Challenge-Based Learning is a pedagogical approach that actively involves the student in a real, relevant problematic situation linked to the environment, which involves the definition of a challenge and the implementation of a solution. With this approach, since 2009, the Tecnológico de Monterrey (Mexico) has implemented the TEC21 Educational Model for all the BS academic programs, including Food Engineering. A challenge is an experiential experience designed to expose the student to a challenging environmental situation to achieve specific learning objectives. The challenges contribute to the development of disciplinary and transversal competencies of the students, since they apply, individually and collaboratively, their knowledge, skills, attitudes, and values. It is based on Experiential Learning, which has as its principle that students learn best when they actively participate in open learning experiences, instead of passively intervening in structured activities. In this sense, Experiential Learning offers students opportunities to apply what they learn in real situations, where they face problems, discover for themselves, test solutions, and interact with other students within a certain context. A relevant element of the model is related to the definition of the challenges to be solved, which is done by interacting with industries and other organizations that support this definition and the evaluation of the solutions, these organizations are called "Training Partners". This contribution presents the basic elements of the model, the structure of the Food Engineering program, the objectives of the program, the competencies to be developed and the results obtained in the training of students. A comparison is presented between the new and the traditional model, in terms of the achievement of the training objectives and the opinion of the partners. The results have shown important improvements in the development of competencies and in the understanding of the applicability of theoretical concepts.

Virtual and remote laboratory kits as innovative pedagogies for enhanced student learning of food engineering and packaging courses

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ABSTRACT

Laboratory-based courses are a vital part of food engineering, food packaging and related curriculum. Studies show that laboratory activities enhance students' conceptual understanding and improve cognitive growth. However, many students struggle to gain access to laboratory facilities and physical experiments for a variety of reasons. The development of virtual modules and remote laboratories, so called VR-Labs, using low-cost tools and apparatus that replicate laboratory equipment and set-ups offers a promising solution to support engineering education and provide equal access to all, including students taking online degree programs and students with physical disabilities that prevent them from taking in-person lab classes.

We have designed and developed low-cost yet user-friendly take-home laboratory kits for measuring a variety of performance functionalities of food packaging materials, such as water vapor transmission and gas permeation rates on certain polymer films, puncture resistance of chosen thermoplastics and paper-based packaging materials, and rapid testing of potential effectiveness of intelligent packaging. Four take-home kits and paired virtual modules were tested by 100+ students in food processing and packaging courses from six participating institutions. Pre- and post-lab quizzes were used for formative assessment on student learning outcomes. Focus group interviews with instructors who helped implement the VR-Labs and surveys on student learning experience have been conducted to evaluate the effectiveness of these innovative pedagogies on student learning.

The majority of student responses confirmed that these VR-Labs provided an invaluable hands-on experience and motivated them in various ways, such as the development of competence, fostering of their interest in the topic areas, and increased efforts when participating in these novel and unique lab activities. The comparison of students' performance on the same quiz questions before and after operating the same lab kits also suggested a general trend of improved understanding of key principles embedded in these VR-Labs.

Cranking up training in food physics and modeling in industry and academia: Novel resources

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ABSTRACT

Sustaining the rapid growth in computer-aided food manufacturing needs capacity building. It being such a niche area, we have roadblocks such as unavailability of content at an appropriate level, missing pedagogical frameworks for effective learning, and the lack of sufficient learners at any one place to justify the effort. Free, pedagogically rich, modularized, active learning-enabled, multistage content that is synthesized from recent research can effectively address this need in industry and academia.

The modules are multi-level and connected for three groups of learners—engineers with basic transport phenomena knowledge, researchers interested in modeling of complex processes, and food or related scientists without significant mathematical background. The learning outcomes include the ability to: 1) Explain a food physics framework in terms of its basic building blocks that can describe many food processes, 2) Compare and contrast between simpler and more comprehensive physics frameworks for understanding food processes, 3) Apply a food physics framework to complex food processes for understanding and optimization. Emphasis is on the underlying frameworks that apply to process groups, quality, and safety, away from individual processes.

To date, 26 modules, 60+ videos (8-53 minutes in length) have been produced. Complete courses have been taught at two universities and additional places have used the modules. Learner evaluations showed that the MOOC-based approach with active learning should work for a range of backgrounds and abilities in an international setting, covering industry and academia. The modular approach will enable customization and inclusion in existing courses. The MOOC platform will provide scalability, assessment with instant feedback, and ease of evolution through crowdsourcing. All this should jump start digital food physics/engineering education and author is looking for collaborations with industry and academia.

Oral Session 12: Encapsulation and Delivery of Bioactive Compounds

Co-Chairs:
Youngsoo Lee
Kang Huang

Bio-inspired carrier systems for enhanced delivery of bacteriophages

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ABSTRACT

Biopesticides have emerged as an alternative promising strategy to reduce the risk of antibiotic resistance caused by conventional agrochemicals. Despite proven efficacy in laboratories, biopesticides e underperform in fields, holding just 5% of the overall pesticide market. Challenges for microbial pesticides such as bacteriophages include UV-induced instability, shortening their field half-life.

This work demonstrates a scalable and eco-friendly strategy to enhance the stability of phages under field conditions. Nature-inspired sporopollenin exine capsules (SECs) were utilized to improve the UV tolerance of phages and to enhance their biocidal efficacy. The T7 phages, as a model, were encapsulated into SECs using a vacuum infusion approach. The stability of these phages under field conditions and their effectiveness in preventing bacterial diseases were evaluated. The results demonstrate that SECs can protect phages from UV-induced instability and enhance their antibacterial efficacy under field conditions. More than 8 log (PFU/g) of T7 phages were successfully encapsulated in SECs. The SECs significantly improved the stability of the encapsulated phages on leaf surfaces after exposure to UV irradiation. After 2-hour exposure to UV-B, the number of non-encapsulated phages on leaf surfaces reduced from 6 log PFU/cm2 to below the detection limit, resulting in a reduction of more than 5 logs. In contrast, encapsulated phages on the leaf surface showed less than 1 log reduction. The results of bacterial inactivation suggest that the encapsulated phages significantly reduced the bacterial count on the leaf surface by more than 3 log units after a 4-hour incubation, whereas freely dispersed T7 phages did not inhibit the growth of their host bacteria.

Enhancing bioactive potential through food gel encapsulation

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ABSTRACT

Bioactive compounds promote health benefits to humans when being incorporated into foods. However, many of them are heat and/or oxygen sensitive, which undergo degradation/oxidation during food processing resulting in loss of bioactivity unless encapsulated. Food gels are structured as interconnected network containing high voids content where water or oil resides. The dense gel network limits solvent mobility and oxygen diffusion, making gels an ideal encapsulation system for both hydrophilic and hydrophobic bioactive compounds. This presentation will outline the design principles of hydrogels and microgel to enhance their encapsulation efficiency for bioactive compounds and clarify the effects of gel structure on the release profile of these compounds. For hydrogels, focus will be given to cryo-gels, a highly porous system created by freezing, which maximizes the potential to maintain the bioactivity of heat-sensitive hydrophilic compounds. Challenges of using gels as encapsulation systems and the potential solutions will also be included.

Enhanced gastrointestinal stability, persistence, and colonization of probiotic cells by growing biofilm in an apple-derived 3D scaffold

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ABSTRACT

This study develops a novel low-cost delivery system for the probiotic cells by growing biofilm of the cells in the apple-derived 3D scaffold. Apple tissue scaffold was constructed by decellularization of intact tissue using a minimal amount of sodium dodecyl sulfate (0.5% w/v). Probiotic cells Lactobacillus casei and rhamnosus GG were infused in apple-derived 3D scaffold using vacuum-assisted infusion. The biofilm of infused probiotic cells in 3D scaffolds were grown by incubating cells in nutrient rich media for 48 h. The infusion and biofilm formation of cells led to high loading of cells (10^10 CFUs) in 3D scaffold. Compositional characterization of scaffold with biofilm grown cells using ATR-FTIR illustrated the generation of extracellular polymeric components such as proteins and polysaccharides in the 3D scaffold after growth of biofilm in the scaffold. The formation of biofilm of probiotic cells in 3D scaffold significantly enhanced the survivability of infused probiotic cells during simulated gastric and intestinal digestions. Mouse model study demonstrated significant improvement in the persistence and colonization of probiotic cells delivered using 3D scaffold with grown biofilm of cells in comparison to the delivery of planktonic cells without scaffold. Overall, these results highlight the potential of the plant- derived 3D scaffold with grown biofilm of cells to deliver probiotic cells with enhanced persistence and colonization of cells in the gut.

Food structure design towards encapsulation application: protein assembly, gelation, and interfacial stabilization

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ABSTRACT

Cold-set protein hydrogel and protein stabilized emulsion may be used as vehicles for effective delivery of micronutrients. This presentation discusses 1) aggregation of whey proteins into colloid particles mesoscopic scale with different structural features. 2) cold-set gelation of whey protein particles for superior phase stability and tunable rheology behavior. The cold-set soft gel may be used for encapsulation purposes. 3) protein ingredients are often used to stabilize oil-in-water (o/w) emulsion droplets, which may also be used as encapsulation vehicles. Emulsification capacity and emulsion coalescence stability are important properties determining the emulsion shelf life and delivery efficacy. Characterization of these emulsifying properties normally requires preparation of emulsion and evaluation of oil droplet particle size distribution using laser diffraction technique over a period of storge time. Particularly, the characterization of emulsion coalescence stability has been a technological challenge, and it may be time consuming due to it is not governed by the Stokes' law, instead it is more determined by the mechanics of protein adsorbed interfacial layer and the DLVO theory. In this presentation, the relationship between protein o/w interfacial behavior and emulsifying nature is elaborated, subsequently, some practical correlations between interfacial property and emulsion particle size are shown based on interfacial films stabilized by different milk protein ingredients. The identified correlations suggest what selected interfacial parameters may be useful predictors for indicating emulsion coalescence stability.

Fabrication of zein nanoparticles using a nozzle simulation chip and their application for encapsulating bioactives and probiotics

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ABSTRACT

Zein exhibits exceptional properties as a nanocarrier material for bioactive components. Despite the promise of zein-based nanocarriers, challenges persist in controlling particle size and distribution, potentially affecting product sensory attributes and sustained release properties. A nozzle chip was developed for the scalable production of self-assembled zein nanoparticles, allowing precise control over their properties. Under optimal conditions, curcumin-loaded zein nanoparticles with enhanced stability and improved in vitro antioxidant properties were achieved as well as significantly improved productivity. The surface of zein nanoparticles was modified to enhance the stability of zein nanoparticles by introducing zein-tween-80-fucoidan (ZTFD) composite nanoparticles via the nozzle simulation chip. The modification exhibited exceptional colloidal stability across a spectrum of environmental conditions, including varying pH ranges, salt concentrations, heating, and extended storage periods. To expand the application of the nanoparticles, LGG, a renowned probiotic with potent health benefits was encapsulated. Encapsulation via a layer-by-layer (LbL) technique, utilizing oppositely charged polymers chitosan (CHI) and zein/tween-80/fucoidan nanoparticles (ZTFD), aimed to enhance LGG's functional attributes and resilience in the GI tract. It was demonstrated that the double layer coated LGG, designated as (CHI/ZTFD)2-LGG, exhibited superior survival rates even under extreme conditions such as freezing, heat, and storage treatments. In simulated gastrointestinal fluid, (CHI/ZTFD)2-LGG displayed a milder decrease (2.15 log CFU/mL) compared to plain LGG (3.92 log CFU/mL). In vivo studies in mice further validated the enhanced survivability of double-layer coated LGG, holding immense promise for advancing probiotic applications and delivering enhanced health benefits to consumers.

Oral Session 13: Sustainable Food Systems

Co-Chairs:
Jen-Yi Huang
Giovanna Ferraria

Conceptual approaches to reduce footprint of combat rations

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ABSTRACT

The US military has a need to reduce the weight and volume of the soldiers' load in field operations, especially in a prolonged close combat mission when logistical resupply is limited. Field rations are one of the soldiers loads but are necessary to support soldier lethality in the operation. Several concept approaches have been tested and trials conducted to reduce the footprint of rations while retaining their energy content, sensory properties, and nutritional quality. Exploring technologies such as novel drying methods, densification through ultrasonic agglomeration/compression, and extension of shelf life through application of edible films, a wide range of food commodity prototypes and their packaging have been developed. These prototypes have shown a 30-70% reduction in weight and a 40-80% reduction in volume with validated microbial safety, shelf stability, nutrient retention, and sensory acceptability. Many of these approaches furthermore have provided potential benefits to the NASA space feeding program and to special commodities in the commercial marketplace.

Environmental impact analysis and development scenarios to increase the sustainability of tomato processing industry

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ABSTRACT

The agri-food sector has been identified as one of the most significant contributors to environmental degradation and emissions.

To respond to the societal demand of cleaner and greener products, in recent years the food industry has been striving to identify and apply more sustainable practices allowing minimizing the negative impact on the environment.

Within the Italian industrial food processing sector, tomato processing industries are among those with the most energy and water intensive users and efforts are highly recommendable to mitigate their environmental footprint. The efficient utilization of the resources and the adoption of innovative methods in the production lines in tomato processing industry represent strategic measures to increase the sustainability.

The results of a study carried out in an Italian tomato processing company, obtained in the frame of the H2020 European Project “Accelwater”, are presented and discussed.

LCA methodology was applied for environmental impact evaluation and the foreground data were obtained from a tomato processing facility located in Southern Italy. Feasible conservation strategies in the production lines have been evaluated through water-energy nexus simulation by SuperPro Designer® software and the different scenarios to decrease the environmental load have been evaluated by SimaPro® software. Some of the technical solutions envisaged were implemented in the tomato processing lines of the company and the environmental footprint was evaluated considering the new scenario.

The findings of the study provide new insights for tomato processing companies wishing to adopt more sustainable processing practices, allowing reducing to a considerable extent their environmental impact, and improving their economic performance.

Sustainability of frozen foods

Dennis R. Heldman

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ABSTRACT

The "sustainability" of the frozen food supply chain Is being questioned by policy and trade groups. The freezing process is energy intensive, and storage of the frozen product at -18 C for several months has received increased attention over the past 2-3 years. Much of the initial attention has an origin in Europe where concerns based on Life Cycle Assessment (LCA) are becoming more frequently. These concerned have resulted in recommendations to elevate the temperature during storage and distribution of the frozen product from -18 C to -15 C. Preliminary Life cycle Assessments suggest this adjustment could have significant impact on sustainability of the supply chain. This presentation will review published literature on the LCA of the frozen food supply chain, and the impacts of higher storage temperature on shelf-life and quality of the frozen product.

The proposed discussion will be based on a thorough review of published literature on impact of storage temperature on quality and shelf-life of frozen foods. The overall impact would be a reduction frozen food shelf-life, but with an impact depending frozen product categories. In general, published results indicate that frozen food shelf-life at -18 C varies with product category. In addition, the sensitivity of a frozen product category to storage at an elevated temperature depends on the product category. The most current results will be collected and analyzed for the presentation.

An additional dimension to be considered is the impact of frozen food on food waste. Generally, preservation of food by freezing reduces food waste. A thorough Life Cycle Assessment (LCA) must include the impact of reduced food waste associated with food freezing and frozen food storage and distribution. This presentation will include a review of the best available data on food wastes and the impacts on the LCA for frozen foods as compared to alternative preservation and distribution methods for similar food products.

Close the nutrient loop for sustainable blue food production

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ABSTRACT

Americans consume nutrient-poor diets—diets that not only contribute to environmental change but also increased incidence of diet-related obesity and chronic diseases. These crises are compounded by the fact that the US imports ~90% of its seafood (blue food). Aquaculture, including aquaponics, intensively produces diverse blue foods using less land and water than conventional food production, which, however, requires high energy input and creates considerable nutrient wastes, leading to high operational costs and significant pollutions. The "When Blue is Green (BiG)" project led by Purdue University aims to design, construct and evaluate zero-waste blue food production systems that integrate aquaculture/aquaponics with microalgae cultivation, anaerobic digestion and biorefining to fully convert nutrients in wastewater into energy and high-value bioproducts. These novel systems will increase Midwestern production of adequate, nutritious, and affordable blue foods with a minimal environmental footprint, ultimately diversifying US agricultural systems and dietary pattern.

To evaluate the environmental performance of combining aquaculture with microalgae cultivation, a life cycle assessment (LCA) was conducted on microalgae-based treatment for shrimp aquaculture wastewater. Microalgae treatment accounted for less than 10% of the total freshwater eutrophication potential (FEP), marine eutrophication potential (MEP) and global warming potential of shrimp aquaculture, and electricity use was the dominant hotspot. Replacing coal in electricity mix, particularly with renewables, reduced the impacts of aquaculture by up to 90–99%. Microalgae treatment performed comparably to activated sludge treatment in terms of FEP reduction, but was much more effective against marine eutrophication. Utilizing algal biomass for biogas production can reduce the MEP of aquaculture; however, production of feed ingredient and biodiesel were not environmentally beneficial. This LCA study proved the environmental feasibility of microalgae-based wastewater treatment for aquaculture, and the results provide important groundwork for developing the zero-waste blue food production systems.

Waste valorization for food system circularity

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ABSTRACT

The current food system has bolstered rapid population growth, fueled economic development, and facilitated urbanization, resulting in a substantial increase in global food and packaging waste. Valorizing this waste is pivotal in combating climate change, enhancing urban health, and restoring biodiversity. We have developed a comprehensive integrated biological conversion process to effectively utilize food waste. This process encompasses several stages: carbon nitrogen balancing, excess ammonia removal via thermal vacuum stripping-assisted pretreatment, anaerobic digestion, biochar conditioning, microalgae treatment, hydroponic cultivation, and the production of black soldier fly larvae and worms for feed. Our approach ensures thorough conversion and utilization of food waste, while also producing energy, materials, and fresh food.

Furthermore, we have innovated a continuous catalytic microwave-assisted pyrolysis process and system for converting plastic packaging waste into valuable fuels and chemicals. This technology has proven to be both highly efficient and commercially viable for transforming waste plastics from food packaging into valuable products. By converting these waste materials into useful products, we aim to mitigate their environmental impact and promote sustainable resource use. This initiative not only addresses the critical need for waste reduction but also drives innovation in recycling technologies and sustainable product development, thereby contributing to a circular economy where waste is minimized and value creation is maximized.

Oral Session 14: 3D Food Printing

Co-Chairs:
Maria Corradini
Ali Ubeyitogullari

Enhancing the bioaccessibility of lutein by loading into food-grade biopolymer gels using 3D food printing

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ABSTRACT

Bioactive food compounds, such as lutein, have numerous health-promoting activities. However, they have poor chemical stability and bioavailability, limiting their efficacy. Thus, in this study, lutein was encapsulated into food-grade biopolymers (i.e., starch, ethyl cellulose, and zein) using a novel 3D food printing approach. Briefly, lutein-loaded ethyl cellulose/zein gel was employed as the core layer, while starch gel was used as the outer layer in a coaxial extrusion 3D printing. A spiral-cube-shaped geometry was used to investigate 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%). The effects of different zein concentrations (20, 40, and 60%) and printing speeds (4, 8, 14, and 20 mm/s) were also investigated. The 3D-printed samples were characterized using scanning electron microscopy, Fourier transform infrared spectroscopy, x-ray diffraction, microCT, chemical stability, and simulated digestion methods. The sample printed with a zein concentration of 40% at a printing speed of 14 mm/s exhibited the best shape integrity. When lutein was encapsulated in starch/zein gels, only 39% of lutein degraded after 21 days at 25 °C, whereas 78% degraded at the same time when crude lutein was studied. After storing at 50 °C for 21 days, 20% and 1% of lutein were retained in the lutein-loaded 3D print and control sample, respectively. With the developed 3D printing encapsulation approach, the bioaccessibility of lutein was increased by ~7-fold compared to the crude lutein. As a result, the developed dual-layered starch-ethyl cellulose/zein encapsulation approach can serve as a platform technology to enhance the stability and bioaccessibility of bioactive compounds. The proposed approach allows the food industry to design functional foods loaded with bioactive compounds with higher flexibility and precision.

Interest of functional starch in the development of starch-based 3D printing inks; optimisation of the ink formulation based on an innovative and patented concept

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ABSTRACT

One of the major issues faced in the case of 3D printing of a gel is the solidification of the gel needed before the deposition of an additional layer. Increasing the flow rate in 3D printers requires a low-viscosity ink capable of rapid hardening after deposition.

This presentation proposes a new concept (patent-EP2022/058028"Method of additive manufacturing by hot-extrusion"). The ink is based on modified starches with enhanced gelling properties thanks to Dry Heat Treatment (DHT), ozone, or pulsed electric field (PEF) pre-processing; such starch is dispersed in pregelatinized starch mother-gel to prevent sedimentation. A dual-temperature hot extrusion system is used ensuring starch gelatinization during inflow-thermal-treatment. This combination provides a low-viscosity ink and a stiff gel. The firmness of the obtained gel allows rapid superposition of layers. A focus is proposed on the impact of the viscosity of the mother gel and on the volumic occupation ratio of the dispersed starch on the firmness of the deposed gel which is a colloidal system containing a primary starch based gel with dispersed gelatinized and inhibited starch granules. The DHT process yields "inhibited starch" with enhanced water holding capacity and limited dispersion. The occupation ratio of the dispersed inhibited starch grains act on the final firmness of the deposed gel. Adjustments of the model of Mendoza (2013-Model for the Shear Viscosity of Suspensions of Star Polymers and Other Soft Particles. Macromol-Chem-Phys.) is proposed with experimental results covering 2 different starches (DHT and chemically modified) with 3 different concentrations using experimental design. The temperature is also considered as a parameter. Viscosity of the initial ink and G'-G'' of the final gel have been considered as responses. The obtained results permit to visualize the key parameters and to propose an optimization of the ink composition.

Food components structuring and their role in food stability using 3D printing

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ABSTRACT

The difficulty of fabricating structures with high reproducibility has stalled fully understanding the role of structural features in food deterioration. 3D printing can be effectively used to rationally design and prototype food matrices, allowing for the systematic study of the role of structure on component layout and food quality deterioration. Zein (in 70% 2-propanol) scaffolds with either a lipid blend (trilinolein/tristearin) or an oleogel (molecular vs. polymeric) deposited in the interstices were produced using a 3D bioprinter (100um resolution) under different printing conditions. The selected conditions allowed for obtaining matrices with "fused" or "interrupted" structures (i.e., with and without pores). Structural features of the matrices and lipid distribution were assessed using atomic force microscopy (AFM) and micro-computed tomography (uCT). Lipid oxidation, protein structure, scaffold rigidity, and formation of disulfide bonds were monitored using optical tools (luminescence and Raman (micro)spectroscopy, FTIRS) at selected intervals. Lipid crystallinity was assessed using Wide-Angle X-ray spectroscopy (WAXS) and Differential Scanning Calorimetry (DSC). Surface smoothness, number and depth of the pores and channels significantly differed among the samples. The fused structures were smoother, with shallower pores providing less lipid compartmentalization. BODIPY-C11 emission intensity in the interrupted and fused structures increased by 4.1±0.3 vs. 6.3±0.5 fold, respectively, by the end of the study. Better lipid compartmentalization and more stable lipid polymorphic arrangements resulted in less lipid oxidation in the interrupted matrices, as confirmed by uCT. Structuring oil using polymeric gelators delayed lipid oxidation (1.3 fold<molecular gel=unstructured oil). 3D printing can develop food prototypes with identical composition but subtle structural differences, allowing for the systematic study of the role of structural components on component structuring and deteriorative phenomena. Structures designed with tailored separations between deposited layers and lipid structuring within the matrix allowed for less lipid oxidation, demonstrating the potential use of structural design to extend food freshness.

Optimization of 3D food printing processing parameters to modulate texture of future military ration components

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ABSTRACT

The US Army is investigating food additive manufacturing or 3D food printing technology with the goal of providing individual warfighters with foods personalized for specific texture, appearance, flavor, and nutrition. Soldiers often experience increased energy expenditure and reduced caloric intake leading to net negative caloric balance which can compromise optimal performance and health. Controlling textural properties of foods through 3D food printing may help improve their caloric intake.

In this study, multi-layer nutritional bars were 3D printed with varying internal features of the base layer. The following infill patterns were created: zig zag, triangular, concentric, grid, and octet. Thermal post-processing time and temperature conditions were evaluated, and the corresponding Young's modulus and maximum yield strength was determined by a 3-point bend test and uni-axial compression.

The results show that infill geometries consisting of diagonal print lines, such as the zig zag and triangle patterns, had greater stiffness and yield strength compared to rectilinear infill patterns.

In the temperature range between 275-350F, higher post-processing temperatures and longer bake times resulted in both higher Young's modulus and yield strength. These findings suggest that the texture of printed foods can be modulated by controlling internal structure and post-processing conditions. Future sensory studies are planned to explore how bar texture may enhance consumption behavior which will lead to improved nutritional and caloric intake.

Digitally customized. 3D/4D food printing as an opportunity to reshape the way in which foods are manufactured and consumed

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ABSTRACT

The concept of human-food-interactions, HFI, is not fully realized, and the current modality of such interactions creates several distortions undermining the right of adequate amount of food and of appropriate nutritional quality. For instance, in the current scenario of how foods are manufactured, distributed and consumed, the goal of delivering a healthy diet to all, supporting the sustainable development goals of ONU, SDGs, has several gaps. In addition, although the principle of a Personalized Nutrition is widely recognized, the so-called 'Personalized Food Industry' has limited applications. 3D Food Printing has ambitions of renewing the HFI toward the modern and smart concept of Human-Digital-Food-Interaction, HFDI. 3DFP utilizes a 3D digital model which is converted into tangible food through complex 3D printing movements which realizes a layer-by-layer deposition of food materials. To fulfil the ambitions of 3DPF, such as digital food manufacturing, on-demand production, nutritional and sensory personalized food products, food waste reduction, etc., which have huge benefits on SHD and SDGs, 3D food printing requires a deeper scientific understanding and innovative technological solutions for the practical exploitation on the market. The main points regard the creation complex printable food formula (meat-, fruit/vegetable, cereal-, fish, gels, etc.), the precise control of printing movements, multi-materials dosing, programmable texture properties, inhomogeneous structures and related multi-sensory perceptions, food prototyping to modulate post-printing process (i.e. baking), safety, shelf life, 3D printing system for mass production. This talk is dedicated to the main aspects and challenges, and it is organized in three main chapters: 1. 3D Food Printing ambitions and opportunities; 2. Technical background, processing variable, and engineering aspects; 3. Recent advances and future opportunities

Oral Session 15: Baking and Drying

Co-Chairs:
Hao Feng
Joao Laurindo

Novel drying, baking, and heating technologies for food industry

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ABSTRACT

The removal of water and organic compounds through drying processes is one of industry's most energy-intensive activities. Drying accounts for approximately 10% (1.2 quads annually) of all process energy used in American manufacturing. With the new efficient drying technologies, 0.5 quads of energy per year may be saved, impacting the corresponding carbon footprint. Furthermore, drying directly affects product quality and throughput. Industries such as food and agriculture, paper and forestry products, chemicals, textiles, and biopharmaceuticals all depend on inefficient drying technologies that have not substantially changed in many decades.

Advanced electric drying, baking, and heating technologies are needed to decrease energy consumption (i.e., cost reduction), to reduce carbon footprint (i.e., sustainability), and to improve product quality and throughput. This presentation will introduce novel technologies such as laser, ultrasound, slot jet reattachment nozzle, and dielectrophoretic technologies while focusing on drying, baking, and heating of various products pertinent to the food industry sector.

Mathematical modeling bread baking: correlating temperature with color and 5-(hydroxymethyl)-2-furfural formation

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Maillard reactions are responsible for attributing desired sensory characteristics to baked products. However, these series of reactions also produce undesired and harmful newborn compounds depending on their intensity, which is a consequence of local temperature, moisture content, and processing time, among other factors. The 5-(Hydroxymethyl)-2-furfural (HMF) is one of the main toxic molecules formed when relatively high temperatures are extensively applied, promoting the burned aspect in the product. This study aimed to measure bread's physical properties throughout the baking under different oven temperatures (180, 200, and 220 °C) and mathematically correlate them with HMF formation. The controlled experimental setup assessed the kinetics of bread' temperature, moisture content, volume, porosity, color, and HMF content. Depending on the temperature, the bread sample lost up to 17% of the initial humidity despite increased values observed close to its center. On the other hand, the volume increase was higher (23% to 28%) at lower temperatures. The CIELab color parameters presented sigmoid behavior as a function of the temperature. Also, bread crust temperature correlated highly with the HMF content, following a power function. HMF was not found while samples were below 150 °C, independently of baking conditions. The yellowness (b*) and luminosity (L*) presented a good model for predicting HMF content, suggesting that crust color measurement can indicate chemical safety. These mathematical correlation among temperature, color, and HMF content allows to predict bread quality and safety, which will be a tool for oven cavity design and optimization.

Challenges and promising solutions for açaí pulp drying

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ABSTRACT

Açaí fruit is rich in fibers, unsaturated fatty acids, and anthocyanins with high antioxidant activity. As the fruits are highly perishable, they must be pulped within 24 hours after harvesting and immediately processed. Frozen açaí pulp is the primary way of açaí commercialization.

Another possibility for açaí preservation is drying, selecting the process based on the stability of anthocyanins and unsaturated fatty acids, production scale, and energy use. Freeze-drying results in dried products with preserved bioactive compounds; however, concerns about its economic feasibility persist. Spray-drying is also used to produce powdered açaí after pulp filtration to retain solids and add large amounts of carrying agents. However, it causes undesirable nutritional loss and dilutes the resulting powder. This study reports the suitability of vacuum drum drying (VDD) and cast-tape drying (CTD), energy-efficient drying techniques, for processing whole açai pulp, keeping its main quality properties at acceptable drying times.

VDD dried açaí pulp under a pressure of 140 mbar for 30 seconds, resulting in an açaí powder with 1.5% moisture and water activity around 0.2. This condition prevented oil separation during drying while retaining anthocyanins (87% and preserving antioxidant activity. CTD was able to dry açaí pulp in 32 minutes by adding 3% pectin, which hindered oil separation during drying, facilitated the dried sample removal from the support, and resulted in powder with 2.2% moisture and water activity of about 0.4, with 90% of anthocyanins preserved and high antioxidant activity. The VDD process and adding 3% pectin to açaí pulp before CTD are suitable strategies for obtaining high-quality açaí powders. However, the stability of açaí pulp to lipid oxidation during drying is still a concern since neither the vacuum nor the added hydrocolloids prevented lipid oxidation. After solving or reducing this problem, CD can produce safe açaí powder at any production scale.

Atmospheric plasma pretreatment for enhanced drying of blueberry

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ABSTRACT

Drying is a vitally important technique in food-processing engineering, as it can reduce foods' volumes and weights, thus lowering the costs of transporting and storing them, while also extending their shelf lives. Hot-air drying is prevalent due to its easy setup and operation, but tends to be time-consuming and energy-intensive. Also, it can cause thermal degradation of nutrients such as bioactive compounds. Therefore, new drying and/or drying pre-treatment methods are urgently needed. In this study, we explored atmospheric plasma pretreatment's potential to enhance conventional hot-air drying. We first evaluated how operational parameters affected the drying kinetics of blueberry. Specifically, we adjusted two operational parameters of such pretreatment: treatment time, and treatment head-to-sample distance. We then evaluated four key quality characteristics of the resulting dried blueberry samples, i.e., their antioxidant activity, total phenolic content, total anthocyanin content, and vitamin C content. As pretreatment time increased and/or treatment head-to-sample distance shortened, drying time decreased; and we concluded that optimized plasma pretreatment can reduce blueberry drying-time requirements. Our results also suggest that introducing plasma pretreatments may lead to higher total post-drying phenolic, anthocyanin, and vitamin C content, as well as higher antioxidant activity. We speculate that these observed quality benefits resulted from our approach's marked reduction to overall drying time. In sum, plasma pretreatments show excellent potential for reducing blueberries' drying time and improving their quality characteristics.

Drying of protein solutions and emulsions with high intensity ultrasound

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ABSTRACT

In recent years, plant-based proteins, derived from sources like legumes, grains, and seeds, are increasingly recognized for their importance in human health. More importantly, shifting towards plant-based proteins can lessen environmental impacts, lower GHG emissions, and decrease energy, water, and land use, contributing to a sustainable food system. The production of plant protein typically involves a multi-stage process, starting with protein extraction from plant sources, followed by precipitation and neutralization. However, to ensure stability for transportation and storage, the protein extracts must undergo a drying process.

This final step transforms plant proteins into a powder form, making them suitable for various applications. Drying is an operation that utilizes thermal energy, typically produced by burning fossil fuels, to remove water from protein extracts. It is recognized as the most energy-intensive step within the process industries. Drying is also a significant contributor to greenhouse gas (GHG) emissions, including in the plant protein production process. There is a clear need to develop innovative drying technologies for plant proteins that facilitate mild drying to minimize protein quality degradation. Simultaneously, these technologies should aim to minimize greenhouse gas (GHG) emissions and reduce energy usage and production costs.

In this presentation, the recent application of ultrasound as a potential low-carbon emission solution for drying of heat sensitive protein products, especially plant proteins and their emulsions will be discussed.

Oral Session 16: Artificial Intelligence/Machine Learning

Co-Chairs:
Hongwei Zhang
Balu Balunkeshwar

Deep learning-powered model predictive control of beer fermentation dynamics

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ABSTRACT

The craft beer movement has dramatically altered the global brewing industry and continues to gather momentum. As of 2012, craft beer accounted for only one-tenth of the US retail beer market, rising substantially over the subsequent decade to over one-quarter of the total US retail beer market in 2021. While the craft beer sector is renowned for novel organoleptic profiles and innovative flavours, the craft brewing industry lags from a technological and process control perspective. Craft breweries are typically SMEs, therefore lacking the same capital to invest in process control and instrumentation as more established breweries. Furthermore, more flexible and robust control strategies are required due to the diversity of beers produced at craft breweries.

A Long Short-Term Memory (LSTM)-based data-driven predictive model of beer fermentation dynamics developed using MATLAB and Simulink was proposed to address the unique needs of craft breweries and offer software sensors and decision support. Training and testing data were produced using a sensor array to monitor critical fermentation parameters of monoculture IPA-style beers to create the LSTM-based deep learning model. These experiments were conducted at both pilot and commercial scales to ensure correspondence to real-world process dynamics. These empirical data were then used to train, test, and optimise the LSTM-based artificial neural network to form the basis of a model predictive control schema.

The data-driven model successfully simulated and predicted the fermentation behaviour for monoculture *S. cerevisiae* fermentations of IPA-style beer. The model's accuracy and performance were evaluated based on comparison with experimental data, demonstrating its effectiveness in capturing the dynamics of craft beer fermentation and in producing accurate soft-sensors for key fermentation parameters.

A study of plant meat made of soy protein isolate and defatted soybean flour

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ABSTRACT

Due to the continuous increase in population and limited natural resources, most people worldwide have consciously turned to a diet based on plant-based materials, especially plant meat. It has been popular for many years and is now gradually accepted worldwide. By extrusion technology, commercial plant meat is made of soy protein, pea protein, and starches. In this study, defatted soybean flour (DSF) was used to replace starches, and different levels of defatted soybean flour were added to explore the textualization of the protein mixture. Results of the texture analysis revealed that the hardness, elasticity, and chewiness of extrudates decreased along with the increase in defatted soybean flour. Higher DSF content resulted in a complete structure; when comparing 0% and 20% DSF content, the structures were denser, whereas the fibrous structures were easily observed at 40% and 60% DSF contents. The degrees of texturization of extrudates were 1.25 and 1.23 when DSFs were set at 40% and 60%, respectively. In conclusion, the addition of DSF can improve the fibrous structure of extrudates, with favorable results observed at a 60% feed moisture content.

Development of an intelligent extrusion platform for food and feed applications

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ABSTRACT

Extrusion is a widely used technology in food and feed production, responsible for creating products such as breakfast cereals, snack foods, animal feeds, and plant-based meats. However, it is often described as a “black box” or “more of an art than a science” due to limited understanding of the internal mechanisms, leading to variability in product quality and reliance on expert operators. To address these challenges, our team at CSIRO’s Food Innovation Centre is developing an Intelligent Extrusion Platform aimed at enhancing the understanding, predictability, and efficiency of extrusion processes for food and feed applications. The platform proposes the integration of academic literature data, market data on ingredients and products, and commercial-scale processing data to provide predictive capabilities and real-time insights into the extrusion process. Key features will include interactive visual interfaces for exploring concepts and data relating to food and feed extrusion, a predictive tool for product development and process configuration, and a digital twin for process simulations and visualization. These components will be designed to support formulation optimization, process configuration, and quality control, streamlining the development of new extruded products. The development of the platform has involved extensive stakeholder engagement, user discovery, validation, and collaboration with industry and academic partners to ensure it meets the practical needs of the extrusion community. This presentation will showcase the background of extrusion technology, major challenges faced by the food and feed extrusion community, and a prototype version of the platform's interface and modular architecture, demonstrating its potential to streamline the development of extruded products and provide decision support for industrial extrusion practices.

Potential utilization of AI in food industry for consumer centric goals

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ABSTRACT

Power of AI can be utilized to address critical challenges in a food system starting from circular economy to sustainability. Specific to food industries, better resource utilization, efficient use of machines and equipment, optimal design for the delivery of finished products, reduction in manual interference with the machine for errors and deviations, and cleaning decisions for improved sanitation for reduction in pathogenic contamination are important. Moving forward, PepsiCo has many initiatives known as Pep+ for positive agriculture, value-chain and choices for consumers. AI utilization for these initiatives through ingredients, products and process functions during development, production, efficiency in supply chain for nutrition is important to provide consumer satisfactions. AI will enhance deep understanding of product properties i.e. textural, sensorial, shelf-life, conditions during metabolism, degree and kinetics of component delivery for healthy-eating and development of a consumer prefer product. In this presentation, in additional to pep+ initiatives, an overview of AI utilization in the development of a perfect Cheetos snack will be discussed.

Predicting physicochemical properties of papayas (Carica papaya L.) using a convolutional neural networks (CNN) model approach

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ABSTRACT

The current state of quality assessment methods for agricultural produce, particularly fruits, heavily relies on manual inspection techniques, which could be subjective, time-consuming, and prone to human errors. Consequently, there have been emerging trends and commercial needs for non-destructive methods to evaluate fruit quality accurately and practically. The objective of this research was to develop a novel approach for predicting the physicochemical properties of papayas using a convolutional neural network (CNN) model that combines image analysis and weight assessment. This study involved capturing images of various papayas at different ripening stages, alongside measuring papaya weights and various physicochemical properties such as texture (peel firmness, pulp firmness, and adhesiveness), pH, total soluble solids, moisture content, and seed weight. The CNN model was trained using 2,128 papaya images obtained through image augmentation from a total of 133 papayas, along with their weights, as input values to predict and estimate the physicochemical property values. Model performance was evaluated using the mean absolute error (MAE), mean squared error (MSE), and the coefficient of determination (R2) as the evaluation metric, aligning with standard regression practices to develop a multi-output and accurate predictive machine learning model. The CNN model, integrated with image processing, could predict the diverse physicochemical properties of papayas with high accuracy. The MSE values estimated for the training and validation sets were 0.0149 and 0.0148, respectively, while R2 values for both sets ranged from 0.96 to 0.99. These findings demonstrate that CNN-based models could provide detailed and quantitative insights, facilitating improved understanding and management of papaya quality and characteristics. The application of this technology holds promise for enhancing the accuracy and efficiency of predictive modeling in the agricultural sector.

Oral Session 17: Microbial and Chemical Kinetics

Co-Chairs:
Kirk Dolan
Ren Yang

Mild heating and ambient storage following gaseous chlorine dioxide treatment of chia seeds enhanced inactivation of *Salmonella* spp.

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ABSTRACT

Objectives:

Chia seed powder has been implicated with a multistate foodborne outbreak in the United States in 2014 due to Salmonella contamination; antimicrobial intervention technologies for chia seeds are limited and needs further exploration. The objective is to investigate the efficacy of interaction of chlorine dioxide (ClO2) gas with mild heat in inactivating Salmonella enterica in chia seeds.

Methods:

Chlorine dioxide gas was generated using a Minidox-M (Clordisys) system and the target gas concentration and RH was monitored and maintained throughout the treatment. Chia seeds were inoculated with a cocktail of five Salmonella enterica serovars and equilibrated at a target aw of 0.53. The gaseous treatment was performed at relative humidity of 80 and 90% and gas concentration of 5 mg/L and 3 mg/L respectively exposed for 2 h. The ClO2 treated samples were subjected to mild heating at 40 and 60°C for 1 and 2 hours and further analyzed for Salmonella survival during storage at ambient conditions for one month.

Results:

Gas treatment of chia seeds at 90% RH achieved significantly ($p<0.05$) higher log reduction (2.7 log) of Salmonella than 80%RH (1.8 log); additional log reductions of 1.0 and 0.8 log, respectively, were achieved by mild heat treatment at 60° C for 2 hours immediately after treatment. Storage study revealed that Salmonella population continued to decrease over time. ClO2 treatment at 80% and 90% RH without mild heating achieved a cumulative log reduction of 2.4 and 3.6 after 3 days of storage. ClO2 treatment followed by mild heating at 60°C for 2 h achieved 4.4 log reduction after 3 days of storage.

Significance:

The combination of antimicrobial ClO2 gas and mild heat is effective in achieving desired log reduction in chia seeds after 3 days of storage. This treatment could be used by industries to improve the safety of chia seeds.

One-step dynamic inverse analysis and microbial growth kinetics

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ABSTRACT

Predictive microbiology is an area of research that applies mathematical modeling to predict the growth and survival of microorganisms in foods under applicable conditions. Kinetic analysis is an essential tool in establishing fundamental parameters that define how a microorganism responds to a change in the environmental conditions, such as time and temperature, two of the main factors affecting microbial growth and survival. Inverse analysis is a mathematical method used to extract pertain kinetic parameters from experimental observations. One-step dynamic analysis is a new methodology for inverse analysis. The objective of this presentation is to demonstrate its application in determining the growth kinetics of Bacillus cytotoxicus in liquid egg yolk (LEY) during treatment with phospholipase A2 (PLA2).

During commercial LEY production, PLA2 is used to hydrolyze lecithin to improve its thermal stability and emulsifying power. The treatment can occur in a range of temperature conditions but mostly at 50°C for an extended period. It is a concern that certain foodborne pathogens may grow and produce enterotoxins, potentially compromising the safety of LEY. B. cytotoxicus was selected due to its thermotolerance. Sequential one-step dynamic analysis was used to determine the growth kinetics. Inoculated samples were exposed to dynamic changes in temperature between 20 and 53°C to observe growth curves. Numerical analysis and optimization was used to determine the best combinations of primary and secondary models and extract kinetic parameters from the growth curves.

The results showed that one-step dynamic analysis could determine the minimum, optimum, and maximum growth temperatures as well as the optimum growth rate of B. cytotoxicus in LEY during PLA2 treatment in an efficient and effective manner. The kinetic model has been incorporated into the USDA Integrated Pathogen Modeling Program (IPMP) - Dynamic Prediction.

Developing thermal control of *Salmonella* in food drying and roasting processes using predictive models

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ABSTRACT

In recent decades, the food industry has faced growing concerns stemming from numerous outbreaks and recalls associated with a diverse range of low-moisture foods. While Salmonella spp. have emerged as the most prevalent pathogens in these incidents, Shiga toxin-producing E. coli and Listeria Monocytogenes have also been linked to contaminated products. Despite the effectiveness of thermal pasteurization in reducing the risk of pathogen contamination, the dynamic temperature and humidity fluctuations inherent in processes such as drying and roasting present formidable challenges in accurately predicting microbial lethality through conventional means.

This presentation aims to delve into the latest research findings aimed at elucidating the mechanisms underlying the high resistance of foodborne pathogens, particularly Salmonella, to heat inactivation within low-moisture food systems. We will scrutinize quantitative data correlating thermal treatment temperature with water activity (in food matrices) and relative humidity (in the environment) to ascertain the log-reduction rate (D-value) of bacterial pathogens. Additionally, we will explore the intricate thermal dynamics inherent in typical drying and roasting processes.

Furthermore, we will introduce an innovative strategy designed to develop a universal model for predicting thermal lethality based on drying and roasting conditions, offering insights into the most recent advancements in this field. Finally, we will present two case studies illustrating the application of this approach in the development and validation of pilot-scale thermal treatments for controlling Salmonella across diverse food commodities and employing various methods.

This endeavor holds promise for the food industry, offering a smart and sustainable solution that empowers food processors to enhance safety and quality control systems while minimizing the risk of food contamination without compromising product integrity.

Sequential estimation of *Salmonella* inactivation parameters in flaxseed during nonisothermal heating at elevated temperatures

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ABSTRACT

Introduction:

Processors of low-moisture foods are required to show FDA evidence of a 4-5 log reduction of pathogens. Using a model to predict inactivation is less costly and labor-intensive than doing validations for many foods under all conditions. Estimation of inactivation parameters during heating above 90C is challenging because of the inability to reach isothermal conditions before most of the pathogens have been inactivated. The objective of this work was to sequentially estimate Weibull inactivation parameters directly from data obtained during nonisothermal heating.

Material and Methods:

We heated 0.8-g samples of flaxseed nonisothermally in sealed cylindrical aluminum test cells submerged in an oil bath held constant at temperatures of 95, 105, 110, or 120 °C. The flaxseed (at water activity = 0.60) was inoculated with lawn grown cultures of Salmonella Enteritidis PT30 (ATCC BAA-1045) at ~8 log(CFU/g). Following inoculation, the flaxseed was equilibrated to water activity = 0.60±0.01. Inoculated flaxseed was loaded into aluminum test cells, with chamber diameter = 18 mm and inner height = 4 mm, giving 1 ml volume of sample. Temperature of the flaxseed was measured every second by the tip of a 0.5-mm diameter thermocouple installed through the top of the cell and located at the center of the product. Duplicate samples were removed from the oil bath at 30-sec intervals (15-sec intervals for 120°C) over a heating period of 3 to 5 minutes and were immediately placed in ice. Final microbial concentrations were measured by standard plating methods. MATLAB was used to sequentially estimate the parameters.

Results:

The Weibull estimation results were delta97 = 25 + 1.0 s, z= 30 + 3.1°C, and n= 1.2. Root mean square error =0.48 log(CFU/g), 10% of the total reduction. The success of this research is a first step toward helping processors meet regulation requirements.

Improving process performance of food fermentations by pulsed electric fields

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ABSTRACT

Foods and food constituents are increasingly produced through fermentation, owing to the significant potential to improve sustainability of food systems. In this context, the utilization of pulsed electric fields (PEF) is a promising approach for process intensification and optimization. Hence, this talk will provide examples from research, considering the enhancement of microbial growth as well as the selective recovery of valuable target compounds from microbial cells.

Growth stimulation by mild PEF treatment (0.5-5 kV/cm, 5-50 kJ/kg, 3-5 µs pulses, batch and continuous: 1 L/h) was demonstrated to increase the rate of biomass formation as well as the production of microbial target substances. Growth stimulation was carried out using the yeasts Saccharomyces cerevisiae and Pichia pastoris. PEF treatment led to an acceleration of fermentation time of up to 14 %, whereas CO2 formation (S. cerevisiae) and production of recombinant food proteins (P. pastoris) was increased by up to 8 %.

Selective extraction of recombinant proteins by continuous PEF treatment (10-50 kV/cm, 50-300 kJ/kg, 3-5 µs pulses, 1-1.5 L/h) was investigated using E. coli and P. pastoris. Product release, yield, as well as purity of the extract and viability of the cells were evaluated. It was shown that lower electric field strengths were sufficient to obtain protein release (up to 89 %), whereas energy input levels in the higher range (corresponding to pulse repetition frequencies of up to 1 kHz) were beneficial. However, viability of the cells was increasingly maintained for lower energy input levels. Therefore, if preservation of viability is targeted, several consecutive treatments with lower energy input levels may be beneficial.

In summary, PEF treatment can be considered a promising building block for future sustainable food production. The technology has the potential to contribute to exploit and optimize microbial fermentation processes, ultimately leading to higher yields and purity of extracts.

Oral Session 18: Waste Utilization

Co-Chairs:

Ozan Ciftci

Kiruba Krishnaswamy

Developing an integrated green biorefinery for harnessing a high-stability and high-bioaccessibility lycopene product from tomato waste

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ABSTRACT

Tomato processing industry generates large amounts of waste that contain lycopene, but lycopene extraction requires use of hazardous and toxic solvents. Moreover, lycopene degrades in the presence of light and oxygen. Hence, there is a need for clean methods to isolate lycopene from tomato waste and then convert it into a stable form. Therefore, the objective of this study was to develop an integrated green process to separate and enrich lycopene from tomato wastes and then to convert it to a high-value lycopene formulation.

An integrated inline extraction-reaction-particle formation process based on supercritical carbon dioxide (SC-CO2) was developed. Tomato waste was extracted by SC-CO2 and the lycopene was separated from the oil in a packed bed enzyme reactor using. Then, the separated lycopene was converted into free-flowing lipid powder in the particle formation system using SC-CO2. The maximum lycopene yield was obtained at 80 °C/50 MPa and 70/30 peel/seeds ratio based on mathematical modeling using mass conservation law. The lycopene yield had a direct relationship with external mass transfer coefficient. In the bioreactor, lower ethanol flow rate and increased enzyme bed length significantly increased separation of lycopene (800 mg/100 g) ($p<0.05$). Approximately 90% of the triacylglycerols in the extract were converted into ethyl ester form. Free-flowing powder lycopene was generated via loading the separated lycopene into hollow solid lipid microparticles in the particle formation unit. Stability of the lycopene particles increased 4 folds during one-month storage at room temperature (24 °C).

A novel integrated extraction-reaction-particle formation process to separate a bioactive from a waste, then purify and convert it into a high-value food product was developed. The process does not use toxic chemicals and solvents, minimizes waste generation, and maximizes utilization of bioactives from agricultural products. This is a first step to developing integrated green supercritical fluid biorefineries.

Seeding circular economy for upcycling greek yogurt acid whey

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ABSTRACT

Acid whey (AW), a byproduct of Greek yogurt production, presents notable environmental disposal challenges because of its high biological oxygen demand. This research investigates employing millet (underutilized, climate-resilient ancient grains) as a neutralizing and encapsulating agent for acid whey, through spray drying process. The major goal of this project is to explore the potential of acid whey, a byproduct from Greek Yogurt industry, as a sustainable source for the development of a novel whitening agent that can replace titanium dioxide (TiO2) in food products. The search for TiO2 alternatives in the food industry has gained momentum, propelled by safety concerns and changes in regulatory landscapes. Although TiO2 has been the choice of whitening pigment for its capability to enhance the aesthetic quality of food products, its acceptance among consumers has waned. This development targets the dual objectives of utilizing acid whey—and offering an eco-friendly alternative to titanium dioxide as a whitening agent in foods.

Results indicated that Acid Whey Millet (AWM) powders exhibited superior whiteness, as shown by higher L* values compared to traditional TiO2 and other millet-based formulations. The powders were water-soluble, with particle sizes ranging from 1.18 ± 0.02 to 1.42 ± 0.14 µm. Millet addition enhanced the glass transition temperature and improved the shape and morphology of the powders. AWM powders also showed significantly increased antioxidant activity. Chemical analysis confirmed high levels of lactose, essential minerals (P, K, Ca, Zn, and Cu), and antioxidants, demonstrating millet's efficacy as a spray-drying agent for AW and the potential of AWM as a functional ingredient in food applications. This study highlights the feasibility of using millet to transform AW into a valuable food ingredient, creating a circular economy system and offering an eco-friendly alternative to TiO2 while addressing waste disposal issues.

Encapsulation of Vitamin B12 with soymeal as a wall material and studying its in-vitro release profile and application in various nutritional products

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ABSTRACT

In the past few years, the human diet trend has shifted towards plant-based foods, with an emphasis on foods that are nutrient-dense and high in fiber, protein, vitamins, and minerals. This trend is being driven by increasing awareness of the health advantages of a plant-based diet. Soybean is one of the most abundant sources of protein, oil, carbohydrates, and other essential ingredients. The soy-oil industry accounts for more than 80% of total soybean production. Soymeal is a significant byproduct of the soy-oil manufacturing industry with a high nutritional profile. Soymeal is abundant in protein, carbohydrates, and some fatty acids, which makes it a suitable wall material to entrap bioactive components such as vitamins. In the present study, 5% soymeal was combined with 5% maltodextrin (MD) and 5% gum Arabic (GA) to encapsulate the vitamin B12 inside the protective layer to prevent its degradation with changes in environmental conditions. Spray drying technology is used for encapsulating vitamin B12 by generating micron-sized powder particles. Collected microcapsules are used to analyze physiochemical characterization. In addition, the in-vitro release profile of vitamin B12 was also analyzed by creating a simulated digestion medium to study the targeted release of vitamin B12 inside the digestive system. Furthermore, encapsulated powder could be used for multiple nutritional applications such as sports supplements, fortified food products, and nutraceutical products.

Comprehensive utilization of olive byproducts

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ABSTRACT

The California olive industry generates significant amounts of byproducts, including olive pomace, during olive oil production. Currently, olive pomace is underutilized as low-value cattle feed, posing economic and environmental challenges. This research aims to improve the profitability and sustainability of the olive industry through a biorefinery approach to valorize olive pomace. The objectives are to 1) extract phenolic compounds as value-added antioxidants, 2) produce biogas via anaerobic digestion of dephenolized pomace, 3) convert olive pit and digestion residue into biochar for wastewater treatment and soil amendment, and 4) assess economic feasibility and environmental impact through techno-economic analysis (TEA) and life cycle assessment (LCA). Preliminary results demonstrated successful extraction of high-value phenolics from olive byproduct, enhanced biogas production from dephenolized pomace, and effective conversion of waste to biochar for environmental applications. The proposed biorefinery scheme shows promise in improving economic viability and sustainability of the olive industry. This research is highly relevant to food and agriculture as it showcases innovative processing strategies to convert agricultural waste into value-added products sequentially. Implementing such circular bioeconomy approaches in the food industry can significantly enhance profitability, minimize waste, and promote sustainable practices. The findings provide valuable insights for olive processors and food engineers to adopt integrated, eco-friendly solutions for byproduct valorization.

Develop highly fermentable insoluble dietary fibers from oat husks

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ABSTRACT

Oat husks, as residual byproducts of oat processing, present low value and environmental challenges. These lignocellulosic residues are rich in cellulose, hemicellulose, and lignin, offering potential to be used as dietary fibers. However, oat husks, like most lignocellulosic materials, have poor functionality and gut fermentability. This study aims to evaluate the effectiveness of subcritical water process to modify the chemical and structural properties of insoluble dietary fiber (IDF) in oat husks. IDFs from oat husks were separated using a wet fraction process. Subcritical water treatment was employed to modify IDFs. Varied processing parameters were strategically employed to modulate the chemical and structural characteristics of IDFs. In specific, the IDFs were mixed with different chemicals (water, 2% citric acid) and subjected to distinct temperatures (130, 160, and 190 °C) with 1 hour duration. The modified IDFs were characterized by microstructures and surface chemistries for screening. Increasing the temperature from 130 to 190 °C reduced hemicellulose content from 19.4% to 0.1% and reduced the particle size of IDFs. In addition, in-vitro fermentation was conducted to investigate the fermentability of modified IDFs. Quantitative analysis of short-chain fatty acids, including acetic acid, propionic acid, and butyric acid, produced during fermentation was performed. Total SCFAs of modified IDFs after 6-hour fermentation did not differ from those of unmodified oat husks. However, after 48-hour fermentation, total SCFAs of modified IDFs increased by 2 folds, and demonstrated slow fermentability, which is potentially beneficial for preventing certain intestinal ailments, e.g., bloating. The observed alterations in chemical and structural properties and enhanced fermentability suggest that subcritical water treatment has a potential to maximize the utilization of food byproducts and reduce environmental impact.

Oral Session 19: Value added foods

Co-Chairs:

Soojin Jun

Srinivas Janaswamy

Valorization of agricultural biomass: towards developing eco-friendly films to address plastic perils

Srinivas Janaswamy

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ABSTRACT

Plastic, a byproduct of non-renewable petroleum resources, has become a daily necessity since its invention a century ago. It is portable, durable, lightweight, and a "friend" of human civilization. It is available for further innovation and utility. However, its intrinsic ability to remain dormant (roughly 700-1000 years) to degrade, as well as humans inability or unwillingness to effectively manage its end-of-life, is causing the perilous plastic debris. Despite ongoing recycling, two-thirds of this waste accumulates in landfills or is scattered in the natural environment. It disintegrates gradually into microplastics and nanoplastics and unfolds a multifaceted global problem. These tiny particles not only cripple the lives of millions of species on the Earth but also contaminate waters and retard the growth and yield of crops. They can enter the human gut via food, igniting health problems. Although a complete plastic ban is difficult to envision or enact in every sector of its use, replacing it in food packages seems an excellent starting point to mitigate environmental damage and improve human health. To this end, cellulosic residue from agricultural products, processing byproducts, and non-tree-based plant biomass aids in formulating biodegradable films. Such a cost-effective and environmentally sustainable plastic-replacement solution will benefit current and future generations and offer a unique value-added proposition for the agriculture industry and farmers to use agriculture byproducts to increase the profitability of their operations.

Ultrasound assisted sequential extraction of water and alkali soluble proteins from 8 Irish grown faba bean varieties

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ABSTRACT

Introduction: Faba bean (Vicia faba), also known as field, broad, fava, or tic bean, is a high-protein crop well-suited to the Irish climate. In Ireland, this crop exhibits relatively high yields, ranging from 6-8t/ha for winter varieties and 4.5-7.5t/ha for spring varieties. This research aims to identify Irish-grown faba bean varieties suitable for protein isolation and explore their potential for developing high-moisture meat alternatives.

Method: Four spring (Cartouche, Fanfare, Lynx, Tiffany) and four winter (Augusta, Irena, Tundra, Vespa) faba bean varieties were cultivated and harvested in Teagasc Oak Park, Ireland. Protein isolation from faba beans was carried out through isoelectric pH shift method using both conventional and ultrasound-assisted extraction (UAE) techniques. Water-soluble (albumins) and alkali-soluble (glutelin) fractions were sequentially isolated from all Irish-grown faba bean varieties.

Results: Irish-grown faba bean varieties proved to be well-suited for processing and protein isolation. UAE yielded higher extraction yields compared to conventional method, although the isolated proteins had slightly lower purity. Across all varieties and isolation methods, the recovery of water-soluble fractions ranged from 30.29 to 59.92%, significantly higher than the alkali-soluble fractions, which ranged from 6.60 to 26.95%. The study revealed that the fraction with the highest protein content was the albumin fraction. Albumins are structural and enzymatic proteins, forming complex linkages with carbohydrates, lipids, and nucleic acids which is a pre-requisite for any protein based material to be suitable for high moisture extrusion process.

Conclusion: UAE proves to be an efficient extraction method considering lower extraction time and higher extraction yield. Additionally, the suitability of derived protein fractions for meat alternative development is under investigation.

Next-generation dairy foods: unlocking the potential of nutrient-dense dairy by-products

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ABSTRACT

Milk is a rich source of bioactive compounds and nutrients critical for human health. A key component of milk, the milk fat globule membrane (MFGM), acts as a vehicle for delivering biologically active molecules in the gastrointestinal tract. MFGM consists of approximately 60% proteins (such as glycoproteins) and 40% lipids (such as phospholipids), offering a range of functions including supporting brain development, modulating the immune system, providing antimicrobial properties, and promoting the growth of beneficial gut bacteria.

The dairy industry generates various by-products rich in valuable bioactive compounds, yet they are often underutilized. One such by-product is whey protein phospholipid concentrate (WPPC), produced during the manufacture of whey protein isolate. Our recent study revealed that WPPC contains bioactive glycoproteins and phospholipids, with MFGM proteins making up 23% of the total protein content and phospholipids constituting 20% of the total fatty acid pool.

The future of dairy foods lies in harnessing the potential of nutrient-dense dairy by-products. To improve human health and foster a sustainable food supply chain, we are refining methods to extract these components in their purest form for comprehensive analysis. I will share case studies demonstrating how dairy streams can be valorized, focusing on their prebiotic and nutritional advantages. Through these innovative approaches, we aim to maximize the nutritional value of bioactive compounds found in underutilized by-products like WPPC. This strategy not only enhances human health but also aligns with the broader goal of achieving a more sustainable and resilient food supply chain.

Supercritical/subcritical CO_2 as green extraction technology for the retrieval of value-added biocompounds from apple pomace

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ABSTRACT

One third of the food that is produced in the world is lost or goes to waste according to the Food and Agricultural Organization of the United Nations (FAO). In this sense the 2030 Agenda for Sustainable Development reveals the global understanding of this problem having as a target the reduction of food losses along the production and supply chains. Apple pomace, a heterogeneous mixture of peels/seeds/pulp, is handled as a waste by the juice industry. Nevertheless, this is a source of bioactive compounds such as ursolic acid (UA) (3β-hydroxy-urs-12-en-28-oic acid) and polyphenols (PP). Conventional extraction methods depend on solvents that can lead to environmental drawbacks such as air and water pollution. Additionally, these are time-consuming, and require multistep. Conversely, supercritical extraction has demonstrated to be a feasible nonconventional extraction method. The present work explores operational parameters such as pressure, static time, dynamic time, temperature, particle size, pretreatment, and co-solvent during the supercritical/subcritical extraction of UA and PP from apple pomace. Results exhibited a correlation of the extraction conditions on the yields of UA and polyphenols. The maximum extraction yield of UA (6,117.2 µg/g) was achieved at the highest evaluated levels of temperature (60 °C), particle size (>250 µm), and co-solvent ethanol (25% w/w). Phloridzin and epicatechin were the PP of highest content with 531.4 and 288.3 µg/g, respectively. As a result, supercritical extraction is intensely related to the effect of variables on diffusion and solubility. This can be further explored to design ecofriendly processes to produce value added biomolecules from renewable sources.

Exergo-economic Performance of Moderate Electric Field Extraction of Oleuropein

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ABSTRACT

The extraction of bioactive compounds from plants is an essential step in the pharmaceutical, chemical, and food industries. In extraction processes, it is generally aimed to destroy the tissue matrix and transfer the desired component to the external environment. In this study, performance evaluations of moderate electric field extraction (MEF-E using 30 V/cm with square or sine waves at 1, 1000, and 2000 Hz) and conventional extraction for oleuropein were performed. The solvent and leaves mixture volume was determined as the control volume, and the components entering and exiting the system boundaries and the changes occurring at the system boundaries were considered. In both wave types, it was determined that as the frequency increased, the amount of energy used (Einlet) and energy lost (Qloss) in the MEF-E process decreased ($p<0.05$), whereas the energy efficiency (ηEnergy) increased ($p<0.05$). Lower Einlet values ($p<0.05$) and higher ηEnergy values ($p<0.05$) were obtained using the sine wave type at constant frequencies. According to exergy analyses, the destroyed exergy value (Xdestruction) decreased as the frequency increased in both wave types ($p<0.05$). This shows that the useful energy changes depending on the frequency applied. In addition, in both wave types, the highest exergy efficiency (ηExergy) values were obtained in 2000 Hz applications ($p<0.05$). The unit exergy cost of the obtained extract (cextract) was not affected by the frequency value applied in the square wave type ($p>0.05$), but the lowest cost value was obtained at 2000 Hz in the sine wave type ($p<0.05$). The significant effect of the wave type-frequency interaction on the obtained cextract was determined. In future studies, it is recommended that the downstream processes of oleuropein from the obtained extract be examined to provide more information for comparing MEF-E with the conventional extraction process.
Keywords: Moderate electric field, Extraction, Exergo-economic, Oleuropein

Oral Session 20: Advances in Cold Plasma

Co-Chairs:

Deepti Salvi

Roopesh Syamaladevi

Cold plasma technologies to enhance food safety, quality, and functionality

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ABSTRACT

Cold plasma is a flexible, innovative, nonthermal food processing technology. It has been shown to be an effective sanitizing process on a range of food commodities against pathogenic bacteria, viruses, fungi, and parasites. The field of cold plasma processing is evolving rapidly worldwide, with applications and technical advances being made in a number of different areas. This presentation will briefly introduce cold plasma - what it is and how it works - before exploring the latest developments in the field. Applications for food safety, quality and shelf-life, and food functionality will be presented and discussed. Systems covered will include corona discharge, dielectric barrier discharge, and plasma jets. Also, plasma activated water and mist will be explained and the latest research summarized.

Plasma activated water bubble technology for the inactivation of bacterial biofilms

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ABSTRACT

Plasma activated water (PAW) has shown potential in reducing microbial biofilms. Recent research has focused on the enhancement of mass transfer efficiency and the dissolution of the plasma reactive species from the gas-to-liquid phase using underwater plasma bubbles. The first part of this abstract focused on the evaluation of the effectiveness of plasma activated water bubbles (PAWB) recirculated in a closed polyvinyl chloride (PVC) water pipeline under different flow regimes against the mixed-species biofilms. *Salmonella* Typhimurium ATCC 13311 and *Aeromonas australiensis* 03-09 biofilms were grown on the inner surfaces of the PVC pipes. The PAWB were recirculated inside the pipeline at different flow rates, corresponding to Reynold's number of 1000, 2500, and 4000. Higher biofilm inactivation was observed when PAWB was used for recirculation compared to distilled water. In addition to flow regimes, volume of PAWB circulated, the concentration of the major reactive oxygen and nitrogen species (RONS), and treatment time influenced the biofilm inactivation. It is important to understand the hydrodynamic parameters along with types and concentrations of RONS for designing an effective disinfection protocol using PAWB.

The second part focuses on the development of novel PAW ultrafine bubble (PAW-UFB) technology by integrating water ultrafine bubbles (UFB) with plasma. The biofilm inactivation efficacy of PAW-UFB was evaluated by treating biofilms of *S. enterica* and *A. australiensis* on stainless steel coupons. Selected properties of PAW-UFB and concentrations of RONS were measured, and their stability during storage for 7 days was evaluated. The results indicate that the RONS were more stable when generated using PAW-UFB compared to distilled water UFB. Moreover, the PAW-UFB treatment demonstrated promising results in the inactivation of mixed species biofilms. This study highlights the potential of PAW, especially when combined with UFB technology, as a novel and efficient method for biofilm control and food safety applications.

Microbial decontamination of black pepper - cold plasma processing as a minimal processing method

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ABSTRACT

Microbial contamination in spices is a major food safety concern. Traditional decontamination methods, such as heat or chemicals, can affect quality. Cold Plasma (CP) is experimented as a non-thermal, effective way to decontaminate spices with minimum quality losses. This research study evaluates the potential of CP as a minimal processing method targeting black pepper seeds and powder. Gliding Arc Plasma Discharge (GAPD) and a radio frequency-powered Low-Pressure Cold Plasma system (LPCP) were used. LPCP treatment was carried out using Argon gas-fed at 220 cm^3/min at 0.03 mbar. GAPD remote treatment of 15 min, (15 kV and 50 Hz) for black pepper seeds, revealed a percentage reduction of 73% and 93% of aerobic bacteria, yeasts, and molds, respectively. The reduction of aerobic bacteria, yeasts, and molds in black pepper seeds was 90% and 100% after 20 min at 250 W. In black pepper powder, 20 min treatment was sufficient to remove 88% of aerobic bacteria while totally eliminating the yeasts and molds. LPCP treatment to black pepper powders led to significant moisture and volatile oil losses. Piperine content degraded with time in both GAPD and LPCP. SEM images showed changes in black pepper seed surfaces after CP treatments. Surface etching of seeds due to reactive species generated in plasma can penetrate sub-micron levels of seed's surface. It can provide channels to evacuate piperine and volatiles near epicarp, which carries antibacterial properties to the surface. It can offer a protective antimicrobial barrier for the re-growth of microbes on the black pepper seeds' surface, leading to CP as a minimal processing technology. Experiments led to a new rotary reactor, improving treatment efficiency and reducing processing time, aligned with GAP and GMP standards for minimal processing. Scalability, cost, and regulations for integrating cold plasma in black pepper processing are needed in a timely manner.

Enhancing food safety and quality through cold plasma technology: applications in wheat processing

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ABSTRACT

Cold plasma technology (CPT) has emerged as a promising tool for enhancing food safety and quality, particularly in wheat processing. This talk will cover three significant studies conducted in our lab, showcasing the potential of cold plasma in pathogen reduction and enzyme inactivation, while maintaining the quality of wheat-based products.

The first study investigated the synergistic effects of plasma-activated water (PAW) and mild heating on *E. coli* inactivation during wheat tempering. Wheat grains inoculated with *E. coli* were tempered with PAW and heated to 55°C, achieving a 5-log reduction within 6h, compared to 12h with heating and deionized water. The combination of PAW and mild heating proved more effective than individual treatments, without compromising flour quality, including yield, physicochemical properties, dough rheology, and bread characteristics. This hurdle approach can be integrated into wheat milling to improve food safety.

In the second study, a CP-based hurdle approach was utilized for *Salmonella* control in pizza dough. Organic wheat flour inoculated with *Salmonella* was treated with atmospheric CP at 21 kV for 6 minutes, resulting in a 2.08-log CFU/g reduction. Additionally, using PAW in the dough formulation and subsequent in-package CPT further reduced the *Salmonella* load by 0.87-log CFU/g and 0.94-log CFU/g, respectively. The combined interventions achieved a total reduction of 3.91-log CFU/g, demonstrating the efficacy of CPT in enhancing the microbiological safety of pizza dough.

The third study focused on inactivating lipase and lipoxygenase in whole wheat flour using atmospheric CP and steam treatments. CP treatment at 25 kV for 6 minutes resulted in 97.5% and 100% inactivation of lipase and lipoxygenase, respectively, with minimal impact on flour's particle size, density, color, and proximate composition.

These studies collectively highlight the versatility and effectiveness of CPT in improving the safety and quality of wheat-based products, offering a viable alternative to conventional treatments.

The second part focuses on the development of novel PAW ultrafine bubble (PAW-UFB) technology by integrating water ultrafine bubbles (UFB) with plasma. The biofilm inactivation efficacy of PAW-UFB was evaluated by treating biofilms of *S. enterica* and *A. australiensis* on stainless steel coupons. Selected properties of PAW-UFB and concentrations of RONS were measured, and their stability during storage for 7 days was evaluated. The results indicate that the RONS were more stable when generated using PAW-UFB compared to distilled water UFB. Moreover, the PAW-UFB treatment demonstrated promising results in the inactivation of mixed species biofilms. This study highlights the potential of PAW, especially when combined with UFB technology, as a novel and efficient method for biofilm control and food safety applications.

Cold plasma and plasma activated water for sanitizing food and food contact surfaces

Deepti Salvi

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ABSTRACT

Cold atmospheric pressure plasma (CAPP) is a novel non-thermal technology that has gained attention in food and agricultural applications. Plasma, the fourth state of matter, offers a good alternative to conventional disinfection methods due to the generation of a mixture of reactive species that are effective in the destruction of microorganisms. Plasma-activated water (PAW) is generated by exposing water to plasma in the presence of air at atmospheric pressure. The reactive oxygen and nitrogen species (RONS) in PAW have been shown to inactivate microbes.

This talk will cover applications of cold plasma and PAW on inactivation of bateria as well as biofilms on various biotic and abiotic surfaces. To determine the inactivation efficiency of plasma and PAW against attached bacteria and single or mixed-species biofilms of different ages on sample biotic and abiotic surfaces were studied. The results were compared with controls and conventional chlorine-based sanitizers. Industry relevant conditions including strongly attached bacteria, mature biofilms, and presence of organic matter was studied. Concentration of reactive species was quantified as a function of treatment time. Plasma and PAW treatments showed comparable inactivation with traditional sanitizers.

Overall plasma technologies show promise not only at clean lab conditions but at simulated industrial conditions.

Oral Session 21: Cellular Agriculture and Precision Fermentation

Co-Chairs:

Nitin Nitin

Reza Ovissipour

Biomanufacturing future foods: cell-based meat production via serum-free media innovation with plant, microbial, and insect proteins

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ABSTRACT

The scaling up and commercialization of cultivated meat encounter various challenges, encompassing media formulations, serum-free media development, scaffold development, and bioreactor design and application. Despite substantial endeavors in formulating serum-free media utilizing proteins, peptides, and amino acids, a knowledge gap persists regarding the influence of protein extractions and bioprocessing on cell performance. Our preliminary experiments have shown that proteins and peptides exhibit both pro and anti-proliferative properties, contingent upon factors such as structure, molecular weight, degree of hydrolysis (peptide size), and concentrations in the media.

The primary objective of this study is to assess how various protein sources—ranging from plants, microbes, to insects—and different protein extraction methods, encompassing fermentation, enzymatic, and chemical processes, influence the performance, metabolism, and techno-economic aspects of bovine cells within the formulation. Enzymatic hydrolysis utilized commercially available microbial-based enzymes, fermentation processes involved gut-microbial communities isolated from adult fish, and chemical extraction relied on the pH shifting method for intact protein extraction.

Our research uncovered that proteins, gut-assisted fermented peptides, and enzymatically extracted peptides significantly bolstered cell performance in serum-free media at relatively low concentrations (0.001 to 0.1 mg/mL). However, at higher concentrations (1 to 10 mg/mL), they exhibited anti-proliferative properties. Moreover, enzymatic hydrolysis and gut biome-assisted fermentation contributed to enhancing peptide properties, further improving cell performance. Notably, the protein source played a pivotal role, with those containing higher albumin content demonstrating significantly enhanced cell performance compared to both serum-containing media and commercially available serum-free media. Additionally, our analysis of fresh and spent media regarding cell metabolites revealed that certain formulations with specific proteins augmented cell metabolism.

Cultivated meat: A bird's eye view

Claire Bomkamp

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ABSTRACT

Within the past decade, the concept of cultivating meat from animal cells has gone from little more than an idea to a rapidly growing industry and field of academic study. Today, a select few companies are offering small bites of cultivated meat in just a few restaurants around the world. While this represents a monumental technical achievement, much more is needed for cultivated meat to live up to its promise of producing the meat we love without the negative externalities of conventional production. For that, we need to be able to find cultivated meat everywhere, from fine dining to fast food to the neighborhood grocery store. What's required to get us from here to there? This talk will cover some of The Good Food Institute's efforts to create a "road map" that can provide direction to the scientists and innovators who will ultimately make the technical breakthroughs needed to push cultivated meat into the mainstream. By conducting life cycle and techno-economic assessments, we've begun to better understand what variables are the most important "levers" to press to make cultivated meat as sustainable and affordable as possible. By conducting surveys of the cultivated meat industry, we now better understand companies' challenges related to cell lines, bioprocessing, and omega-3 ingredients and can more confidently predict bottlenecks and make decisions about what technical challenges need to be prioritized. Our learnings from these and other projects have uncovered specific needs that allow us to make data-driven recommendations to others in the cultivated meat ecosystem and to offer research grant opportunities that are closely aligned with the needs of the industry.

Life cycle assessment of Beefy-9 and Beefy-R serum-free culture media for cell-cultivated beef production

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ABSTRACT

Sustainable production of cell-cultivated meat requires the use of sustainably produced nutrients. Culture media, which provides the necessary nutrients for cell proliferation and differentiation is a major contributor to the environmental impacts of cultivated meat production. Beefy-R and Beefy-9 are experimentally validated, serum-free cell culture media designed for bovine myoblast culture. While both media include basal media, ascorbic acid, sodium selenite, recombinant proteins, and growth factors, Beefy 9 and Beefy-R contain recombinant albumin and rapeseed protein isolates (RPI) to replace fetal bovine serum (FBS), respectively. FBS is problematic due to animal sourcing, ethical concerns, and high cost. While these culture media do not include animal-sourced components, their environmental impacts have not yet been investigated. In this study, life cycle assessment (LCA) was performed to estimate the environmental burdens of Beefy-9 and Beefy-R culture media production and identify hotspots for optimization. Uncertainty was assessed through sensitivity and scenario analyses, as well as Monte Carlo simulation. Our results demonstrate that Beefy-R has significantly lower environmental impacts compared to Beefy-9 in 11 out of 18 evaluated impact categories. For instance, the global warming potential (GWP) for Beefy-R and Beefy-9 production are 0.08 and 0.39 kgCO_2eq per liter, respectively. In Beefy-R, despite the absence of recombinant albumin, recombinant proteins and growth factors were the primary hotspot, leading to 41%, 5.9%, and 12% of GWP, land use, and water consumption for the formulation, respectively. This study confirms that RPI can be a more sustainable substitute for recombinant albumin in bovine myoblast serum-free media formulations. Additional research is required to identify low-impact alternatives for other recombinant proteins and growth factors in culture media.

Plant biomaterial scaffolds for cellular agriculture

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ABSTRACT

One of the key elements in cellular agriculture is to develop cost-effective and edible scaffold compositions to support cell attachment, proliferation, and differentiation. In addition, these scaffold compositions can also provide unique mechanical properties mimicking the texture of meat products. The research presentation will describe the top-down and bottom-up approaches for developing scaffolds for cellular agriculture applications using plant-based biomaterials. For the bottom-up approach, the material compositions for scaffolds will include plant proteins and lipids. The results will describe the role of structural and compositional properties in supporting cell attachment, proliferation, and differentiation of model cell lines for cultivated meat applications. The presentation will also describe the role of mechanical properties and surface compositions of individual and composite materials for cell attachment. For developing 3D structures of these compositions, the presentation will discuss the potential of 3D printing technology to create 3D scaffolds and characterize cell growth on these scaffolds.

For the top-down approach, the presentation will share the results of plant biomaterial decellularization and a vacuum-assisted seeding technology to develop an integration of cellular biomass with existing plant structures. The results will characterize the loading efficiency and the penetration depth of cellular biomass. Overall, the presentation will describe the innovations and the potential of plant-based scaffolds for cellular agriculture with specific applications for cultivated meat.

Nutritional profile, anti-nutritional factors, and digestibility of proteins in non-conventional leaf protein sources

Soumya Ranjan Purohit

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ABSTRACT

Leaf Protein Concentrates (LPC) have intrigued researchers for a considerable period of time and continue to grab their attention as a non-conventional protein source. With the growing population and increasing awareness towards efficient resource utilization, LPCs have a potential to gain popularity as a novel source of protein. This review summarizes the various methods of LPC concentration or precipitation and also notes their nutritional quality, anti-nutritional factors, and digestibility, that have been explored so far for various leaf sources. Though there are a number of advantages that can be derived from fractionation of leaf proteins, challenges pertaining to the process are vivid. Hence, an attempt to review and conduct experimental exercise related to advantages and challenges have been made in this work. The scope of utilization of LPC is vast but before diving into commercial utilization, it is of utmost importance that the safety and efficiency of these protein sources are well investigated. The key findings are issues like, lack of sulfur containing amino acids and minerals in LPC which makes the source not very balanced; non-conventional protein concentration method like fermentation as green and efficient means of protein concentration; importance of leaf drying for reduced cyanogenic potential, etc. Moreover, the yield of bamboo LPC from different precipitation methods tested in the present study revealed that, the acid precipitated one had the highest yield of 60.4 mg/g dry matter followed by fermentation, high-temperature precipitation and finally low temperature precipitation. For the crude protein percentage content in the LPCs, acid precipitation again exhibited the highest value of 39.55% followed by fermentation, high-temperature precipitation and then low-temperature precipitation. The acid precipitated LPC was thus further evaluated for its Osborne fraction composition. The results revealed that the LPC contained highest percentage of Glutelins in it, followed by Prolamins, Albumins, and Globulins. The application of LPC as feed and food has thus been highlighted and possible approach towards solving the challenges regarding LPC has been put forward as an idea in this article.

Oral Session 22: Advances in Food and Tissue Preservation

Co-Chairs:

Valerie S. McGraw

Juzhong Tan

Freezing of Living Cells and Tissues: A great challenge for science and technology

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ABSTRACT

Low temperature has been utilized to keep living cells, tissues, and organs dormant but potential alive (i.e., cryopreservation) for tremendous scientific and biomedical applications, including biobanking, cellular/gene therapy, tissue engineering, regenerative medicine, stem-cell/organ transplantation, artificial organs, new drug development, agriculture, food storage, and conservation of endangered species. However, there is a critical contradiction between the concept of cryopreservation and the experimental findings that the living cells and tissues can be killed by the cryopreservation process itself. Contrary to popular belief, the challenge to cells/tissues during the cryopreservation is not their ability to endure storage at cryogenic temperatures (below -180 ℃); rather it is "the lethality" of heat-mass transfer process coupled with phase transitions within an intermediate zone of low temperature (-15 to -130 ℃) that a cell must traverse twice, once during cooling and once during warming. The central theme of this presentation is to report the speaker's research work on: (1) fundamental mechanisms of cryoinjury and cryoprotection, (2) micro-heat-mass transfer and its great impact on cell survival during the cryopreservation processes; and (3) development of optimal and novel technology for the cryopreservation to prevent the cryoinjury and to ensure the survival of living biomaterials.

Postharvest washing using plasma microbubble to inactivate *Escherichia coli* on fresh berries and in wash water

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ABSTRACT

In this study, the use of plasma microbubbles as a novel approach to mitigate cross-contamination in postharvest washing of blueberries and strawberries was explored.

A rod-to-mesh dielectric barrier discharge reactor and a rob-to-cramp jet reactor were used to ionize compressed air to gas plasma, and the gas plasma was injected into a 5 L container with water through microbubble diffusers to obtain plasma microbubbles (PMB). The flow rate was modulated to 0.5, 3, or 5 cm^3/s, and the voltage of the power supply was 100, 150, or 200 V with a fixed frequency of 1000 Hz.

Strawberries and blueberries were spot inoculated with *E. coli* TVS355, and they were suspended in the wash water with PMB or air bubble (control) with agitation for 5, 10, or 20 min. The CFUs of *E. coli* on the berries and the wash water were enumerated on agar with 80 mg/L rifampicin. The number of *E. coli* on the berry surfaces before washing was 1.9×10^7/berry. After the washing, a reduction of 0.7 log CFU/berry was achieved with air bubbles and the number of *E. coli* in wash water was 5.6×10^3/ml. For the washing with PMB, reductions of 2.8 to 4.8 log CFU/berry were achieved on the surfaces of berries, and the number of *E. coli* in wash water between below the detection limit to 1.7×10^2/ml. Generally, with a moderate flow rate (1cm^3/s) and higher voltage, more *E. coli* was inactivated both in the wash water and on the surface of berries. With PMB generated by the rob-to-cramp jet reactor, more *E. coli* were inactivated.

The PMB-based washing system can be potentially employed by the fresh produce industry as a chlorine-free approach to inactivate food pathogens on produce surfaces and mitigate the risk of cross-contamination through wash water.

Evaluation of synergistic bactericidal activity of nanobubbles and peracetic acid and the underlying mechanism

Aprajeeta Jha[1], Rohan V. Tikekar[1] and Jose-Luis Izursa[2]

Department of Nutrition and Food Science[1]

Department of Environmental Science & Technology[2]

University of Maryland, College Park, MD, USA

ABSTRACT

Regulatory agencies recommend treatment of irrigation water with antimicrobial agents to successfully mitigate microbial risk. Nanobubbles (NBs) are stable, high surface area bubbles which upon physical rupture can produce antimicrobial activity. We aim to a) evaluate combined impact of bulk nanobubbles and peracetic acid (PAA) on inactivation *Escherichia coli* TVS 353 and *Listeria innocua* b) understand inactivation kinetics and c) explore the mechanism of microbial inactivation. To the three flasks each containing distilled water (control), PAA solution (4 ppm, S) and NB sparged water with PAA solution (4ppm, NS); 1 ml of *E. coli* TVS 353 and *L. innocua* was inoculated. Samples were drawn at the interval of 1 min for 6 minutes and immediately transferred into neutralizer solution (0.28g/ml sodium metabisulfite) for further serial dilution and bacterial enumeration. Sub-lethally treated bacteria were subjected to study a) membrane damage using propidium iodide assay b) membrane fluidity analysis by DPH assay and c) metabolic activity using resazurin assay. The significant increase (N=5; $p<0.05$) in bacterial inactivation was triggered by the combined effect of NBs and sanitizer leading up to approximately 1 log additional inactivation after 6 minutes of treatment. The average D-values (decimal reduction time) for *E.coli* TVS 353 sanitized in PAA solution with and without NBs were 135±12 s and 180±15 s, respectively and for *L. innocua*, these values were 120±5 s (PAA with NBs) and 170±13 s (PAA without NBs) at confidence level of 95%. Both microorganisms followed Weibull kinetic model for inactivation with a characteristic shoulder. Though sublethal treatment produced no significant damage to cell membrane, but a significant increase in fluorescence polarization of DPH was observed in both *E.coli* (16.33 ± 2.41%) and *L.innocua* (8.12±1.39%) confirming impairment of membrane mobility. Additionally, there was a synergistic effect of NBs and sanitizer on the metabolic rates of *L.innocua* and *E.coli* TVS 353.

Isochoric impregnation of calcium to enhance the quality of postharvest blueberries

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ABSTRACT

The availability of fresh food is often limited by rapid postharvest microbial and physicochemical degradation, which shortens shelf life and contributes to food waste. Isochoric (constant-volume) freezing is a pressurized technique that preserves foods at subfreezing temperatures without formation of ice inside the food product itself. Ice instead nucleates in a separate area of a rigid chamber, generating hydrostatic pressure, which can promote infusion of bioactive compounds into the solid food matrix. Owing to the ability of calcium to cross-link pectin, the infusion of calcium into fruits and vegetables via isochoric impregnation is a promising means to structurally fortify pectin-rich foods and extend shelf life. Here, we investigate isochoric impregnation of calcium into blueberries and assess the effects of calcium infusion on physicochemical, structural, and microbial properties.

To this end, we carried out 1-, 3-, 5-, and 7-day isochoric impregnation treatments at –0.5 °C (25 MPa), wherein blueberries are immersed in blueberry juice/$CaCl_2$ solution, followed by post-isochoric refrigeration (5 weeks, 4 °C), and assessed the quality of isochorically-impregnated blueberries relative to fresh and conventionally refrigerated (5 weeks, 4 °C) blueberries. Impregnation treatments resulted in a ten-fold increase in calcium content, as measured by total reflection x-ray fluorescence, relative to that of fresh blueberries, with no significant difference in calcium levels between 1- and 7-day treatments. In all quality parameters, calcium impregnation demonstrated a positive or neutral effect on blueberries post-refrigerated storage. Notably, calcium-infused blueberries did not experience any significant mass loss or pH change, increased in anthocyanin content, and showed better retention of antioxidants relative to conventionally refrigerated samples. Overall, these findings provide insight into the multifaceted role of isochoric treatments in food preservation and demonstrate that calcium impregnation is a promising route to extend the shelf life of sensitive agricultural products.

Assessing the impact of isochoric freezing as a preservation method on the quality attributes of orange juice

Sumeyye Atci[a], Valerie S. McGraw[a, b], Gary Takeoka[a], Vivian C.H. Vu[a], Tara McHugh[a], Boris Rubinsky[b], Cristina Bilbao-Sainz[a]

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ABSTRACT

Isochoric freezing (IF) is a novel food preservation method that maintains food products at subfreezing temperatures without freezing, eliminating the detrimental effects of ice formation. This study aimed to enhance the nutritional value and physical properties of fresh-squeezed orange juice (OJ) using IF as an alternative to traditional frozen storage or thermal pasteurization. OJ samples underwent conventional freezing (CF) and IF for 7 days, followed by thawing and analysis. Additionally, OJ samples were stored at 4°C for an additional 7 days after CF and IF treatments.

The samples were subjected to IF at −5°C, −10°C, and −15°C for 7 days. CF OJ samples were frozen at −18°C for 7 days. Thermal treatment of OJ was conducted at 72°C for 20 seconds. We assessed the microbiological and physicochemical attributes of both CF and IF OJ before and after storage, and compared them with fresh OJ, fresh OJ stored for 7 days at 4°C, heat-treated OJ, and heat-treated OJ stored for 7 days at 4°C.

Results showed that yeast and mold counts increased in fresh and CF OJ after storage at 4°C, while IF OJ remained below detection limits. IF (−15°C/143 MPa) OJ exhibited less color difference compared to heat-treated and CF OJ. Pectin methylesterase (PME) activity increased by 150% after 7-day IF, while heat treatment inactivated 42% of PME. IF (−15°C/143 MPa) OJ showed reduced pulp sedimentation, addressing a common issue in the juice industry. Ascorbic acid (AA) levels were significantly higher in IF (−15°C/143 MPa) OJ compared to fresh and CF OJ after storage. These findings suggest that IF offers a promising method for preserving OJ quality and enhancing its nutritional content.

Oral Session 23: Advances in Food Technologies Part I

Co-Chairs:

Gönül Z. Kaletunç

Rohan V. Tikekar

Innovative technology to make plant-based meat price & quality competitive with animal meat

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ABSTRACT

In this study, the use of plasma microbubbles as a novel approach to mitigate cross-contamination in postharvest washing of blueberries and strawberries was explored.

A rod-to-mesh dielectric barrier discharge reactor and a rob-to-cramp jet reactor were used to ionize compressed air to gas plasma, and the gas plasma was injected into a 5 L container with water through microbubble diffusers to obtain plasma microbubbles (PMB). The flow rate was modulated to 0.5, 3, or 5 cm^3/s, and the voltage of the power supply was 100, 150, or 200 V with a fixed frequency of 1000 Hz.

Strawberries and blueberries were spot inoculated with *E. coli* TVS355, and they were suspended in the wash water with PMB or air bubble (control) with agitation for 5, 10, or 20 min. The CFUs of *E. coli* on the berries and the wash water were enumerated on agar with 80 mg/L rifampicin. The number of *E. coli* on the berry surfaces before washing was 1.9×10^7/berry. After the washing, a reduction of 0.7 log CFU/berry was achieved with air bubbles and the number of *E. coli* in wash water was 5.6×10^3/ml. For the washing with PMB, reductions of 2.8 to 4.8 log CFU/berry were achieved on the surfaces of berries, and the number of *E. coli* in wash water between below the detection limit to 1.7×10^2/ml. Generally, with a moderate flow rate (1cm^3/s) and higher voltage, more *E. coli* was inactivated both in the wash water and on the surface of berries. With PMB generated by the rob-to-cramp jet reactor, more *E. coli* were inactivated.

The PMB-based washing system can be potentially employed by the fresh produce industry as a chlorine-free approach to inactivate food pathogens on produce surfaces and mitigate the risk of cross-contamination through wash water.

Development and characterization of nutrition bars produced by ultrasonic compression

Aprajeeta Jha[1], Rohan V. Tikekar[1] and Jose-Luis Izursa[2]

Department of Nutrition and Food Science[1]

Department of Environmental Science & Technology[2]

University of Maryland, College Park, MD, USA

ABSTRACT

Regulatory agencies recommend treatment of irrigation water with antimicrobial agents to successfully mitigate microbial risk. Nanobubbles (NBs) are stable, high surface area bubbles which upon physical rupture can produce antimicrobial activity. We aim to a) evaluate combined impact of bulk nanobubbles and peracetic acid (PAA) on inactivation *Escherichia coli* TVS 353 and *Listeria innocua* b) understand inactivation kinetics and c) explore the mechanism of microbial inactivation. To the three flasks each containing distilled water (control), PAA solution (4 ppm, S) and NB sparged water with PAA solution (4ppm, NS); 1 ml of *E. coli* TVS 353 and *L. innocua* was inoculated. Samples were drawn at the interval of 1 min for 6 minutes and immediately transferred into neutralizer solution (0.28g/ml sodium metabisulfite) for further serial dilution and bacterial enumeration. Sub-lethally treated bacteria were subjected to study a) membrane damage using propidium iodide assay b) membrane fluidity analysis by DPH assay and c) metabolic activity using resazurin assay. The significant increase ($N=5$; $p<0.05$) in bacterial inactivation was triggered by the combined effect of NBs and sanitizer leading up to approximately 1 log additional inactivation after 6 minutes of treatment. The average D-values (decimal reduction time) for *E.coli* TVS 353 sanitized in PAA solution with and without NBs were 135±12 s and 180±15 s, respectively and for *L. innocua*, these values were 120±5 s (PAA with NBs) and 170±13 s (PAA without NBs) at confidence level of 95%. Both microorganisms followed Weibull kinetic model for inactivation with a characteristic shoulder. Though sublethal treatment produced no significant damage to cell membrane, but a significant increase in fluorescence polarization of DPH was observed in both *E.coli* (16.33 ± 2.41%) and *L.innocua* (8.12±1.39%) confirming impairment of membrane mobility. Additionally, there was a synergistic effect of NBs and sanitizer on the metabolic rates of *L.innocua* and *E.coli* TVS 353.

Investigation into survival of natural microbiome in emulsion and other food matrices during simulated gastric digestion

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ABSTRACT

The availability of fresh food is often limited by rapid postharvest microbial and physicochemical degradation, which shortens shelf life and contributes to food waste. Isochoric (constant-volume) freezing is a pressurized technique that preserves foods at subfreezing temperatures without formation of ice inside the food product itself. Ice instead nucleates in a separate area of a rigid chamber, generating hydrostatic pressure, which can promote infusion of bioactive compounds into the solid food matrix. Owing to the ability of calcium to cross-link pectin, the infusion of calcium into fruits and vegetables via isochoric impregnation is a promising means to structurally fortify pectin-rich foods and extend shelf life. Here, we investigate isochoric impregnation of calcium into blueberries and assess the effects of calcium infusion on physicochemical, structural, and microbial properties.

To this end, we carried out 1-, 3-, 5-, and 7-day isochoric impregnation treatments at –0.5 °C (25 MPa), wherein blueberries are immersed in blueberry juice/$CaCl_2$ solution, followed by post-isochoric refrigeration (5 weeks, 4 °C), and assessed the quality of isochorically-impregnated blueberries relative to fresh and conventionally refrigerated (5 weeks, 4 °C) blueberries. Impregnation treatments resulted in a ten-fold increase in calcium content, as measured by total reflection x-ray fluorescence, relative to that of fresh blueberries, with no significant difference in calcium levels between 1- and 7-day treatments. In all quality parameters, calcium impregnation demonstrated a positive or neutral effect on blueberries post-refrigerated storage. Notably, calcium-infused blueberries did not experience any significant mass loss or pH change, increased in anthocyanin content, and showed better retention of antioxidants relative to conventionally refrigerated samples. Overall, these findings provide insight into the multifaceted role of isochoric treatments in food preservation and demonstrate that calcium impregnation is a promising route to extend the shelf life of sensitive agricultural products.

Development and validation of an improved model for listeria monocytogenes growth prediction in RTE meats as a function of temperature, pH, water activity, nitrite, & three organic acids

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ABSTRACT

Delicatessen meats are reported to be the leading vehicle of foodborne listeriosis outbreaks with a high fatality. Predictive models are valuable and cost-effective tools to assess and manage public health risk. The objective of this study was to develop and validate a secondary model based on literature food matrices data for predicting the growth of Listeria monocytogenes in processed meat products. The model included the effect of seven environmental parameters including temperature, pH, water activity, nitrite, acetate, lactate, and propionate. Listeria growth curves in food matrices (beef, pork, and poultry) were collected from ComBase and research publications. The four-parameter logistic model with delay was used as primary model to estimate the growth parameters (No, Nmax, tlag, µmax). The growth rates data was randomly divided into two sets, about 355 curves were used for model development and 115 curves for model validation. A gamma concept based cardinal parameter model was developed and performance was evaluated using RMSE, Bf, Af, and relative errors within acceptable simulation zone (ASZ). The developed model had an acceptable Bf of 1.06, Af of 1.17. and ASZ score of 74%. The model with interaction effect was found to perform better than model without interaction term. The goodness-of-fit parameter of the secondary model includes R2 = 0.913 and RMSE = 0.06 ln (CFU/g)/h for the developed model. The study also showed that simultaneous modeling approach is useful to develop models from limited and disparate datasets. The results of our study provide useful insights into the need for development and validation of predictive models in real food matrices rather than laboratory media alone. The developed model may be used to quantify the Listeria growth as observed in naturally contaminated ready-to-eat meat products. This model may be helpful for food industries to optimize the food formulation, reduce input of preservatives and its cost, and timely decision making to enhance the food safety.

Utilization of microwave dielectric microscopy for assessing compositional and technological quality of beef patties

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ABSTRACT

Monitoring the quality of value-added meat products is a challenging task to ensure the desired nutrients and sensorial by consumers and promote traceability in the meat industry. In this study, a microwave dielectric spectroscopy was feasibly investigates as an offline sensing system for beef patties. The benchtop system that works in the transmission mode (300 kHz to 3 GHz) comprised a parameters test set device coupled with a network analyzer, and the studied model system was beef patties that was formulated through six fat ratios (5-30%), two mincing levels (coarse, fine), and three muscles (round, brisket, and chuck steak), which resulted in testing 360 samples. Critical quality attributes included Water Holding Capacity (WHC), moisture, protein and fat contents. Predictive models were developed using Partial Least Squares Regression (PLSR) and 4-fold cross validation was utilized to conclude the optimal calibration models that was then applied on a separate test set. Results obtained for the test set showed correlation coefficient(Root Mean Square Error of Prediction) or r(RMSEP) values of 84.07%(3.15%) for moisture, 86.45%(3.87%) for fat, 69.98%(1.82%) for protein, and 52.12%(11.68%) for WHC. This study presented a feasible application of microwave dielectric technology as a rapid quality assurance methodology for ensuring transparency and resilient traceability of processed meats.

Oral Session 24: Advances in Food Technologies II

Co-Chairs:

Naveen Kumar Navani

Ningjian Liang

A novel heat-stable nano-in-micro platform as a delivery vehicle for probiotics, bioactives and micronutrients

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ABSTRACT

In the post covid-19 scenario, research and commercialization of antioxidant rich, pathogen mitigating, nutrient dense functional foods with ability to boost immunity has received a huge surge. This prompted us to develop GRAS-status food-grade polymers, hydrocolloids, and probiotics to protect probiotic bacteria. The challenge is to deliver a comprehensive system containing probiotics, prebiotics, micronutrients, and other bioactives, ensuring a consistent supply of health-promoting and immunostimulatory agents, thus reducing the need for multiple tablets or suspensions in daily routines. We propose a nano-in-micro heat-stable platform (NIMPOD) for oral delivery. NIMPOD aims to deliver selected health-promoting supplements in a single dose, providing health benefits and ensuring safe delivery and specific release in the gut milieu. NIMPOD is based on a layer-layer-layer fluorescently tagged polyelectrolytes (chitosan, carboxymethyl cellulose) encapsulating two functional moieties- probiotic bacteria and yeast (*Lactobacillus paracasei* and *Kluyveromyces marxianus*), and nanoliposomes containing taurine, folic acid, vitamins B12, D3, and iron. These separate entities were ultimately encapsulated in two different coats, a zein-pectin core-shell and tannic acid-Eudragit coat. NIMPOD was characterized using Dynamic Light Scattering (DLS), Fourier Transform Infrared Spectroscopy (FTIR), and Field Emission Scanning Electron Microscopy (FESEM). Supplement release under simulated gastrointestinal conditions and probiotic colonization were confirmed *in vivo* using a *C. elegans* worm model. Interestingly, results showed that worms exposed to this formulation lived longer, indicating an enhanced lifespan. To validate the immunomodulatory role of probiotics, qPCR demonstrated decreased expression of inflammatory cytokines such as TNFα and IL-12 upon exposure to the pathogen *Salmonella enteritidis*. Probiotic adhesion to intestinal cells was confirmed using the Caco-2 cell line, showing decreased adhesion of the pathogen *Salmonella typhi*. In summary, NIMPOD is expected to be an everyday go-to solution, also beneficial for conditions like leaky gut and associated metabolic disorders such as inflammatory bowel syndrome, colitis, and dysbiosis.

Extraction of proteins, lipids, chrolorophylls, total carotenoids and total phenolic compounds from *C. vulgaris* employing conventional and novel extraction techniques

Shaba Noore [1,2], Brijesh K. Tiwari [1], Janith Wanigasekara [3,4], Kate McKeever [5], Raquel Cama-Moncunill [6], Eugene Dillon [7,8], Gerard Cagney [7,8], James. F. Curtin [3,4] and Colm O'Donnell [2]

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ABSTRACT

In this study, conventional (soaking, stirring, shaking) and novel (microwave-assisted extraction-MAE, pulsed electric field-assisted extraction-PEFAE, ultrasound-assisted extraction-UAE) techniques were evaluated for extracting proteins, lipids, chlorophylls, total carotenoids, and total phenolic compounds(TPCs) from *Chlorella vulgaris*. The highest yields of protein (16.26 ± 0.60 g/100 g DW *C. vulgaris*) and lipid (5.25 ± 0.11 g/100 g DW *C. vulgaris*) were obtained with UAE (20 kHz, 4 °C, 10 min). While, the most efficient chlorophyll a (13.27 ± 0.73 mg/100 g DW *C. vulgaris*), chlorophyll b (9.69 ± 0.25 mg/100 g DW *C. vulgaris*), carotenoid (2.54 ± 0.18 mg/100 g DW *C. vulgaris*), and TPCs (20.84 ± 0.35 mg GA/100 g DW *C. vulgaris*) extractions were achieved with UAE (20 kHz, 4 °C, 5 min). Similarly, antioxidant activities were highest with UAE (5 min): Total antioxidant activity (2.13 ± 0.01 μg/mL), DPPH (64.74 ± 0.01 %), and FRAP (216.42 ± 4.70 μmol Trolox/L). Mass spectrometry identified 21 health-benefiting proteins (5-83 kDa), and fatty acid analysis revealed presence of ω-3 (C20:3n3c and C20:5n3c) and ω-6 (C18:2n6c, C22:2n6c, and C22:2n6c) fatty acids in crude *C. vulgaris* extracts. Cytotoxicity analysis on colorectal adenocarcinoma cells indicated safety below 80 μg/mL for food, nutraceutical, and pharmaceutical applications, warranting further research on its potential as an anticancer extract. Overall UAE treatment demonstrated promising technique for extracting proteins, lipids, and bioactive compounds from *C. vulgaris*, displaying promising antioxidant properties and safe cytotoxicity levels.

Life-cycle assessment and cost analysis of different non-thermal food preservation technologies: case study of orange juice production

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ABSTRACT

Significant improvements are needed in food and beverage industry to accelerate the industrial decarbonization process. As one of the largest energy consumption sectors, food industry is accountable for approximately one-third of total greenhouse gas (GHG) emissions globally. Alternative energy-saving technologies such as non-thermal food processes are explored to overcome this challenge. However, a direct cost and environmental impact comparison among different non-thermal food processes are limited due to the early-stage of these emerging food technologies. This study aims to compare industrial sustainability by performing an *ex-ante* life-cycle assessment (LCA) and technoeconomic analysis (TEA) of four non-thermal food technologies: high pressure processing (HPP), pulsed electric field, cold plasma, and ultraviolet using orange juice production as a representative case. Our results show that relative to conventional thermal pasteurization, selling prices of orange juice from these non-thermal food preservation technologies are slightly higher with HPP being the most expensive, and the cradle-to-gate GHG emissions from these non-thermal processes are comparable or lower than conventional thermal process. Additionally, LCA results also indicate that large GHG contributors in orange juice production are orange plantation and juice packaging. The outcome of this study provides insights into both economic and environmental sustainability of different non-thermal food technologies and indicates the hotspots and barriers for future commercialization of these non-thermal processes.

A model-based study on the sustainability of local food chains

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ABSTRACT

Current food manufacturing trends based on decentralised and/or localised systems are driven by the need to increase sustainability and resilience in our food chains. The idea behind this is that shorter food distribution routes would significantly contribute to reduce energy demand and GHG emissions associated to food chains, as well as to avoid major disruptions, guaranteeing food supplies. However, there are scarce studies that show how these new production scenarios might unfold – this works aims at filling that gap.

In this context, we have developed a modelling tool for the design and evaluation of food distribution routes, focusing on comparative assessment of decentralised vs. centralised systems. Based on this, we have studied how food supply chains might look for different scales of production – e.g., from food incubators to fully centralised systems based on a single food plant. We have used bread and ice cream as exemplars, and the UK as case study.

Considering different food manufacturing configurations (i.e., from a cloud of small local production sites to single-plant fully centralised systems) as input, the proposed modelling tool was used to find (i) the optimal number and/or location for each facility/plant (ii) the routing and network path that minimises costs and GHG emissions.

Results show how environmental criteria become more significant with increasing sizes of the distribution route, while costs do not show such strong dependence. When combine with available analogous information (cost, GHG emissions) from the processing stage, we can identify those scenarios where distributed networks become a realistic alternative, with shorter distribution networks counteracting higher processing costs resulting from losing economies-of-scale.

This work presents a robust and simple tool that will help food manufacturers/stakeholders in the complex decision between centralised vs decentralised food manufacturing systems, supporting decision-making and strategic planning across the food supply chain.

Oral Session 25: High Pressure Processing

Co-Chairs:

Marcello Cristianini

Bala Balasubramaniam

Pressure coupled to pH-shifting on the protein structure and techno-functional properties of sesame protein isolate (*Sesamum indicum L.*)

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ABSTRACT

Sesame isolate protein is a promising ingredient for the food industry, contributing to a circular economy, as it can be generated from by-products industrial. However, its techno-functional properties limits its application in food products. In this study, changes in structural (Surface hydrophobicity index and Fourier transform infrared spectroscopy (FTIR)) and techno-functional properties (Water and oil holding capacity, emulsifying activity, emulsion stability index and solubility) of Sesame Protein Isolate (SPI) were evaluated after processing by High Hydrostatic Pressure (HHP) at pressures of 200, 400, and 600 MPa for 10 minutes (25°C) at different pH (4.5, 7.0 and 11.0). HHP caused changes in the secondary structure of SPI mainly when processed at 400 and 600 MPa at pH 4.5 and at 200, 400 and 600 MPa at pH 11.0. Regarding surface hydrophobicity (Ho) showed a 157% increase in when compared to the unprocessed sample. Processing carried out at pH 4.5 and 7.0 caused an increase of 63% and 80%, respectively, in its solubility when analyzed at pH 2.0. Processes at 200 MPa had a greater influence on the emulsifying activity index at pH 4.5, 7.0 and 11.0, increasing by 132%, 115% and 17% respectively. The water holding capacity increased by 23% of samples processed at 600 MPa at pH 4.5 and at 200 MPa at pH 7.0. HHP can modify plant-based protein structures imparting their techno-functional properties, improving its application in the food industry as an ingredient.

Effect of ultra high pressure homogenization in reconstituted infant milk formula fortified with lactoferrin and α-lactalbumin: physicochemical, retention and microbial studies

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ABSTRACT

Ultra High Pressure Homogenization (UHPH) is an emerging technology that applies pressure up to 400 MPa and induces turbulence, high shear, cavitation, and temperature increase during treatment. It is a continuous process and improves the techno-functional and microbial quality of food matrices For the first time, effect of UHPH (50–250 MPa at 25 °C) was investigated on reconstituted Infant Milk Formula (IMF) fortified with Lactoferrin (LF) and α-Lactalbumin (α-Lac). Particle size, viscosity and solubility were investigated after UHPH. The retention of LF and α-Lac was also performed. IMF was inoculated with both gram-positive (Staphylococcus aureus, ATCC 29213) and gram-negative (Escherichia coli, ATCC 8739), and microbial inactivation (log reduction) was enumerated. Average particle size and viscosity were decreased up to 150 MPa treatment and increased after this range while the opposite trend was observed for the solubility of treated samples. The significant retention ($p > 0.05$) of both LF and α-Lac was found as > 90 % among all the conditions applied. However, severe impact of UHPH was observed on β-Lg as it showed only 71.4, 53.8 and 40.2% retention after 150, 200 and 250 MPa treatment, respectively. The UHPH-treated samples showed a low inactivation of S. aureus among all treated samples. However, a very high level of microbial inactivation (under the detection limit) of inoculated E. coli was observed at and over 150 MPa treatments. Therefore, owing to the substantial denaturation of β-Lg ($p < 0.05$), UHPH has the potential to develop a hypoallergenic liquid IMF since β-Lg is considered as the major allergen present in cow milk which is, interestingly, absent in human milk. This pioneering study further recommends the application of UHPH at ≥ 150 MPa to retain heat-sensitive bioactive ingredients and guides the researchers and manufacturers to design new baby foods including items for special use.

Impact of thermal, high-pressure, and ultra-shear pasteurization technologies on beetroot juice metabolites using an untargeted Nuclear Magnetic Resonance spectroscopy

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ABSTRACT

The impact of three food pasteurization technologies, namely thermal, high-pressure, and ultra-shear processing, on the metabolites of beetroot juice was evaluated using a processomics approach with NMR as an analytical technique.

Two batches of beetroots acquired from different local grocery stores were used for this study. Beetroot juice obtained from these batches was subjected to high-pressure processing (HPP) at 600 MPa and 25 °C for 5 minutes, ultra-shear technology processing (UST) at 400 MPa and 30 °C, and thermal processing (TP) at 96 °C for 12 minutes.

Principal component analysis (PCA) for the two batches indicated that both extrinsic factors such as processing parameters (temperature, pressure, shear, holding time) and intrinsic factors such as the origin of the beetroots from different stores influenced the PCA plot. When the influence of intrinsic parameters was minimized by studying a single batch processed by TP, HPP, and UST, distinct clusters for different processing methods were formed, indicating that processing influenced the metabolites. While processing is not the main factor determining the final composition, as indicated by PCA with different batches, supervised techniques like OPLS-DA and random forest (RF) demonstrated that processing does impact the beetroot juice metabolome. Seven metabolites (leucine, alanine, valine, glutamine, gamma-aminobutyric acid, fructose, and glucose) were identified as potential process-induced biomarkers.

Non-enzymatic degradation kinetics at hyperbaric storage conditions: the direct and indirect multifactorial impact of pressure on polyphenol degradation

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ABSTRACT

Pressure can influence the kinetics of non-enzymatic reactions in foods, a topic not widely studied. According to transition state theory, the volume change from the ground-state complex to the activated state ($\Delta V^{\#}$) determines whether the reaction rate increases, decreases, or remains unaffected under pressure. This becomes particularly significant under conditions of prolonged pressure exposure such as in hyperbaric storage (HS). HS, an emerging food preservation method, applies moderate hydrostatic pressure with an upside over traditional refrigeration due to the lower energetic cost and ability to ensure microbial safety. However, the impact of pressure on the kinetics could affect ingredient stability, notably of polyphenols, which are crucial for the sensory and health-promoting qualities of foods. While even for thermal-processing a comprehensive structure-dependent understanding of non-enzymatic polyphenol deterioration is missing, it is much less studied for pressure-based technologies. Our study focused on 10 polyphenols, covering several flavonoid subgroups (catechins, anthocyanins, flavonols) selected to differ in major structural features such as the number and location of hydroxyl group, the presence of gallate group, and the type and size of the attached sugar. Their degradation in common and baroresistant buffers (to avoid pressure-induced pH shifts) were studied for extended times and mild pressures (<200 MPa) at accelerated pH conditions to simulate HS and minimize non-isobaric and non-isothermal effects interfering with $\Delta V^{\#}$ calculation. In baroresistant buffers, a linear relationship between polyphenol degradation rates (k) and applied pressure was observed, allowing $\Delta V^{\#}$ calculation. Despite the significant structural variety and major differences in k within the subgroups, no significant structure-dependent effect of pressure on $\Delta V^{\#}$ was observed, which is suggestive of a similar mechanism by which pressure accelerates the degradation. These findings not only highlight the potential impact of HS on the quality of polyphenol-rich foods but also enhance our understanding of pressure effects on reaction kinetics.

Oral Session 26: Food Systems Modeling

Co-Chairs:

Sungil Ferreira

Snehasis Chakraborty

Atomization to curing: mathematical insights into microencapsulation

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ABSTRACT

Leveraging recent advances in mathematical modeling, this study enhances particle engineering for microencapsulation via spray drying and complex coacervation. We present three instances where modeling process conditions elucidated different microencapsulation methods. Initially, we assessed the impact of non-dimensional numbers (Weber and Ohnesorge) on carotenoid-rich oil encapsulation using a chickpea protein/pectin blend through spray drying. Subsequently, these non-dimensional numbers (Weber and Ohnesorge) were used as a basis to model particle size in complex coacervation using a dual-fluid nozzle. Lastly, a shell and tube heat exchanger system gauged shear rate and temperature effects on microcapsule cooling/curing post-coacervation. Biopolymer properties were determined such as superficial tension, rheologic behavior and density. Encapsulation efficiency and yield data were gathered using gravimetric and spectrophotometric techniques. Particle size and morphology were ascertained via optical microscopy, while in vitro digestion employed simulated gastric conditions. Non-linear modeling was conducted with Minitab. Across all scenarios, we successfully modeled the response variable (encapsulation efficiency, particle size and morphology, gastric resistance, intestinal core release) based on process conditions. The study highlights the impact of air shear caused by atomization during spray drying, and temperature gradients during capsule curing/cooling of the complex coacervated capsules, which proved to be important variables since they directly affected the final properties of microcapsules produced. These factors critically influence the final microcapsule properties, paving the way for predictive modeling of microcapsule behavior, crucial for bespoke applications in food, pharmaceutical, and agricultural sectors. *** Application of turmeric and propolis extract for smart and active sheets based on potato starch obtained using extrusion technology.

Quantifying the temporal variability of dry roasters by season and location in roaster

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ABSTRACT

Dry roaster validations have been challenged by anecdotal evidence of temporal variability that has not yet been quantified or documented in the literature. It has been suggested that not all locations in a dry roaster are heated equally, and thus will not provide consistent microbial inactivation as a result. The purpose of this study was to document the temperatures in the middle of a bed of peanuts in a flat-bed continuous dry roaster. Forty-eight sensors were placed in a grid pattern inside the roaster (6 bars with 8 sensors spanning the width of each bar) and continuously collected data for one calendar year. The data was filtered to only include those values where peanuts were inside the roaster (>140°C) which reduced the data set to ~10 million values. Data values were tagged with the month they were collected and their location in the roaster by bar and position on the bar. A three-way ANOVA was performed in R on each of three random samples consisting of 10,000 data points per month and revealed significant differences ($P < 0.001$) in temperature data for both location measures, month, and crosses of the three factors for all three data sets. Peanuts processed in the summer months experienced hotter overall roaster temperatures than those processed in the winter months which could result in underprocessing if the process is validated during warmer months. Further analysis of the data will include estimation of *Salmonella* inactivation on the peanuts to determine if the temperature differences observed have practically significant result on food safety outcomes. The results of this study can inform dry roaster validation studies and critical factors related to dry roasting of nut and seed products.

Cold plasma induced inactivation kinetics of peroxidase in whole wheat flour

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ABSTRACT

Peroxidase, also known as POD (EC 1.11.1.7), found in whole wheat flour (WWF), facilitates the oxidation of various substrates when hydrogen peroxide is present. This enzyme is crucial in the bleaching of carotenoids and can contribute to undesired alterations to color and flavor in WWF. There is research on dry and microwave heating employed to inactivate POD in wheat flour; however, there is a risk of compromised functionality of the wheat flour. This research employs atmospheric cold plasma (voltage: 5-25 kV; exposure time: 1-10 min) and steam treatments (at 100°C for 1 to 6 min), to inactivate POD in WWF. Cold plasma exposure at 25 kV/10 min and steam treatment (100°C/6 min) resulted in a 99% reduction in POD activity in WWF. Upon employing the nth-order kinetic model, POD's inactivation order (n) during cold plasma treatment was 1.15. The cold plasma-induced inactivation rate constant varied from 1.5-43.9×10-2 min-1 when the voltage changed from 5 to 25 kV, whereas the steam-induced inactivation rate was 52.1×10-2 min-1. This study presents, for the first time, the sensitivity of POD inactivation (SV = 164.2 V) - the alteration in Vrms needed to initiate a change in the k-value of the enzyme. The optical emission spectra of cold plasma-treated air revealed characteristic band heads at λ = 328-426 nm, 314 nm, and 739-778 nm, confirming the presence of reactive nitrogen species (RNS), hydroxyl radicals, and reactive oxygen species (ROS), respectively. Both cold plasma and steam treatments induced changes in the secondary structure of enzymes, promoting a more random coil configuration. Notably, the cold plasma treatment at 25 kV/10 min had no discernible effect on the flour's particle size, density, color profile, or proximate composition. This underscores the potential of atmospheric plasma treatment to regulate POD activity in WWF, consequently bolstering its stability during storage.

Modeling & simulation efforts in academia and food industry

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ABSTRACT

Multiphysics modeling and simulation can help investigate real-world physical interactions. Multiphysics simulation reduces the need for testing and physical prototyping, thereby accelerating product and process design and optimization. Over the decades, the application of mathematical modeling in food process and product design has increased significantly. Multiphysics modeling has guided process and product engineers through the complex labyrinth of food innovation. These modeling exercises have also led to new products, processes, and efficient solutions to complex problems related to food processing, package design, and food formulations. This presentation will explore the academic and industry efforts in reshaping food product, process, and package design. The applications of materials science, along with the complexities of multiphysics and multiscale modeling, will be discussed. The presentation will also examine the latest developments and modeling strategies that advance the application of multiphysics modeling in the food industry and inspire the next generation of food scientists and engineers. The predictive power of modeling to create a sustainable, nourishing, and delicious future will be highlighted.

Poster Session 1: Processing

Development of an eco-efficient integrated continuous extraction-reaction process using supercritical carbon dioxide for value-added processing of tomato processing waste

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ABSTRACT

The tomato processing industry generates large amounts of waste that contain lycopene, but lycopene extraction requires the use of hazardous and toxic solvents. Hence, there is a need for clean methods to harness lycopene from tomato waste. An integrated inline continuous extraction-reaction process based on supercritical carbon dioxide (SC-CO2) to extract and concentrate bioactive from wastes was developed.

Tomato waste was extracted by SC-CO2 and the extract + SC-CO2 mixture entered an inline packed bed bioreactor packed with immobilized lipase (Novozym 435). In the bioreactor, the lycopene-containing oil-rich extract and ethanol was put into an alcoholysis reaction by pumping ethanol into the bioreactor to convert triacylglycerols (oil) into fatty acid ethyl esters (FAEE) to further separate lycopene from the extract. A higher CO2 flow rate (2.0 L/min) and pressure (50 MPa) significantly increased the lycopene content of the extraction-reaction product ($p<0.05$). A higher reaction temperature (60 °C), lower CO2 flow rate (0.25 L/min), and moderate ethanol flow rate (0.05 mL/min) significantly increased the reaction conversion ($p<0.05$). The highest FAEE mass fraction achieved was 78.2%, which was performed at 60 °C, 0.25 L/min CO2 flow rate, 50 MPa, 8 h, 0.05 mL/min ethanol flow rate, and two bioreactors where 873.85 mg/100g of lycopene content was obtained. At a lower temperature (40 °C) and pressure (10 MPa), the separation efficiency of the produced FAEE and lycopene is improved. The final lycopene content (2507.75 mg/100g) increased nearly 3 folds after the enrichment process.

This novel process does not use toxic chemicals and solvents, minimizes waste generation, and maximizes the utilization of bioactive fromagricultural products. This is a first step to developing integrated green supercritical fluid biorefineries. Therefore, the objective of this study was to engineer a novel, integrated, green process to extract and enrich lycopene from tomato processing waste.

Microbial inactivation in cold-filled acid foods

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ABSTRACT

Introduction: Acid-resistant foodborne pathogens have led to numerous outbreaks in acid foods having pH values below 4.0, thus raising concerns about the safety of these products. Commercial sterility of 5-log reduction highly resistant Listeria species in shelf-stable foods with pH less than 4.6 is commonly achieved through hot-filling, but cold-fill-hold processes possess promising potential if microbial safety and stability is ensured.

Purpose: Determine the time required for a 5-log reduction in Listeria innocua in commercially prepared apple and orange juices and raw extracted apple and orange juices.

Methods: Store-bought commercially sterile apple and orange juices, as well as raw extracted apple and orange juice were independently inoculated with Listeria innocua and kept at ambient temperature (25°C) to determine the holding times needed to achieve a 5-log reduction in Listeria innocua. Trials were performed in triplicate followed by microbial count determination at sampling times. Samples were enumerated every 2 days up to 8 days.

Results: A cold-fill-hold process provided a 90% (1-log) reduction in L. innocua in the samples at 25°C, with a hold time of 3.30 days for commercially prepared apple juice (R2=0.34) as compared to a hold time of 2.13 days for raw extracted apple juice (R2=0.81). For commercially prepared orange juice, a 1-log reduction was observed in 4.20 days (R2=0.73) whereas for fresh orange juice, it was observed in 2.11 days (R2=0.82). For the four juices, greater than 5-log reductions of pathogenic bacteria were estimated at 16.5, 10.7, 21.0, and 10.6 days after inoculation, respectively.

Significance: Future work will include evaluation of conditions to provide a 5-log reduction on pathogenic Escherichia coli O157:H7, Salmonella enterica, and Listeria monocytogenes with a formal shelf-life analysis for cold-fill-hold process to be selected as a thermal processing alternative.

Improving heating uniformity in radio frequency heating by dynamically adjusting electrode pap and investigating density

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ABSTRACT

Objective:

In the field of radio frequency heating, a critical obstacle lies in achieving uniform heat distribution. This research investigates addressing this challenge by focusing in dynamic electrode gap adjustment and sample density. Corn flour serves as our chosen food sample, aiming to optimize the overall heating process.

Method:

The RF heating rate and heating uniformity of corn flour were evaluated using a 27.12 MHz, 6 KW RF oven (COMBI 6-S, Strayfield International, Wokingham, UK) equipped with parallel-plate electrodes (L:83 cm and W: 40 cm). Fixed electrode gaps ranging from 7 to 15 cm and dynamic electrode gaps of 7→11→15 cm, 9→12→15 cm, and 10→12→14 cm, each with different time intervals, were selected for the experiments. Consistently, 200 g of corn flour was utilized for each trial, maintaining a package height of 4.5 cm. To investigate the impact of density, samples with densities of 0.6, 0.7, 0.8, and 0.85 gr/cm3 were chosen for testing.

Results:

A substantial improvement in heating uniformity and rate was observed by dynamically adjusting the electrode gap. The most favorable outcome was associated with the dynamic electrode gap sequence of 9→12→15, resulting in a decrease in the uniformity index from 0.085 to 0.053, signifying an enhancement in heating uniformity. Regarding the impact of density, optimal heating uniformity was achieved with the sample possessing the highest density of 0.85. Despite the lower heating rate attributed to the higher mass content requiring more heating, the superior heating uniformity at higher density can be attributed to the reduction in air gaps, acting as insulators within the sample.

Design and development of a refractive window drying System coupled with vacuum: Production of bioactive fruit powders

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ABSTRACT

Hybrid technologies have been studied to obtain both technologies' benefits and improve the quality and efficiency of the drying process in terms of time and energy used. Researchers have studied the effect of coupling refractance window (RW) technology with infrared, ultrasound, and solar energy; however, there are no studies of refractance window coupled with vacuum (RWV). This study aimed to develop a hybrid drying system, using a refractance window coupled with vacuum, to obtain apple pomace powder and evaluate its bioactive compounds. The developed RWV system comprises a thermoregulated bath, vacuum chamber, steam trap, pressure regulator, and vacuum pump. It was compared (RW) and freeze-drying (FD). Apple pomace samples (3 mm thick) were dried using RW at 65, 75, and 85ºC under atmospheric pressure and VRW at the same temperatures, under vacuum pressure of 0.15, 0.25, and 0.45 bar. The drying time, water activity, moisture, particle size distribution, total soluble solids, color, polyphenol content, antioxidant activity, and dietary fiber of the final product were measured.

The results showed that VRW reduced drying times by 17 to 25% compared to RW at a vacuum pressure of 0.45 bar. RW and VRW obtained similar results for water activity, moisture, particle size distribution, and total soluble solids. The Color analysis showed significant differences ($p<0.05$) between freeze-drying and RW and RWV. The RWV treatment at 85ºC and 0.45 bar obtained the slightest color difference ($\Delta E=3.1\pm0.1$). The highest content of polyphenols and antioxidant activity was obtained with the RWV process at 65ºC and 0.45 bar, obtaining 5.84±0.29 mg GAE/gbs and 50.0±1.30 µmol TE/gbs, respectively, the dietary fiber content at these same conditions was 43.8 g/100g, with 32.4 g insoluble fiber and 11.4 g soluble fiber. Results suggested that RWV drying can be explored as a potential technique for drying fruits in a shorter time, with better retention of bioactive compounds and quality.

Enhancing bioactive extraction from cold brew spent coffee grounds: Optimizing time-temperature combinations for nutritious energy bar production

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ABSTRACT

Objectives: This research aims to optimize the extraction of bioactive compounds from cold brew spent coffee grounds (SCGs) and utilize them in the production of nutritious energy bars.

The primary objective is to develop a sustainable method for extracting bioactive compounds from SCGs that maximizes yield and maintains their nutritional value. Additionally, the study seeks to enhance the nutritional profile and flavor of energy bars by incorporating the extracted bioactive compounds, thereby contributing to the development of innovative and environmentally friendly food products.

Methods: The extraction process will utilize microwave-assisted extraction (MAE) with varying time-temperature combinations to determine the optimal conditions for extracting bioactive compounds from SCGs. Four different time intervals (10, 20, 30, and 40 minutes) and temperatures (100, 120, 140, and 160°C) will be tested, along with a 10-minute cooling time. Furthermore, 54% ethanol will be used as the solvent to ensure efficient extraction of bioactive compounds. High-Performance Liquid Chromatography (HPLC) will be employed to analyze and quantify the extracted bioactive compounds, such as caffeine and chlorogenic acid, by comparing them with standard compounds. This analytical technique will provide accurate measurements of the bioactive compound content in the extracted samples.

Results: The study is to identify the most effective time-temperature combinations for maximizing the extraction yield of bioactive compounds from Cold brew SCGs. By optimizing the extraction process, the research aims to achieve high yields of bioactive compounds while minimizing energy consumption and environmental impact. Additionally, the analysis using HPLC will enable the identification and quantification of bioactive compounds (caffeine, chlorogenic acid, trigonelline)present in the extracted samples. Furthermore, the study aims to formulate energy bars enriched with bioactive compounds extracted from SCGs, enhancing their nutritional content and flavor profile. These energy bars will offer consumers a convenient and sustainable snack option that promotes health and wellness.So far combinations of 20 mins and 120C have shown higher concentration of bioactives.Yet, to do more trials.Overall, this research represents a significant contribution to the food engineering profession and the food industry at large. By repurposing waste streams from coffee production and incorporating them into value-added products, the study demonstrates innovative solutions for sustainable food production.

Physical and chemical properties of pork loin (M. longissimus dorsi) during roasting in a temperature-controlled oven

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ABSTRACT

Cooking pork loin in electric ovens involves intense heat and mass transfer that favors simultaneous changes in its physical and chemical properties, particularly the formation of the characteristic brown crust. The oven conditions strongly impact the intensity and kinetics of those properties' appearance. Therefore, finely adjusted process conditions are crucial to control how the oven temperature influences the food's physical and chemical changes during roasting. For this purpose, a finely controlled cavity was built with thermocouples installed to measure walls and pork loin temperatures. The experimental system favored obtaining precise and reproducible experimental data during pork loin roasting at different processing temperatures (180, 200, and 220 °C). During roasting, the gradual protein denaturation, the reduction in water retention capacity, and the increase in the material elastic modulus with the temperature increasewere assessed. Itwas observed that the most significant sample structural changes occurred when the internal temperature ranged from 64 to 94 °C. Increasing oven temperature intensified mass losses, reducing juiciness and shrinking the roasted pork loin, which increased the shear force during cutting essays. Furthermore, the higher temperatures in the pork loin crust favored protein aggregation and the accumulation of browning compounds from Maillard reactions and lipid oxidation. Helpful correlations between roasting conditions and the changes in pork loin's physical properties were proposed and validated. These are crucial for the mathematical modeling and numerical simulation of pork loin roasting processes under different conditions. These numerical simulations are based on heat and mass transfer phenomena during roasting, which can determine cooking conditions and alternatives for improving oven operations and producing high-quality and safe roast pork loin.

Challenges of rapid baking in the case of flat breads and non-conventional baking

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ABSTRACT

The phenomena of swelling and destructuring of the starch granules that occur during conventional baking are strongly modified in the case of ultra-rapid baking like flat breads. As part of the European Flat Bread Mine project, we are studying in detail the impact of the heating rate on the wheat starch gelatinization process. Rapid baking modifies the conventional gelatinization process (swelling/dispersion), resulting in a sudden starch granule disruption / explosion resulting from a pressure rise within the internal zones of the granules. Recent investigations showed that a rapid baking yields a more pronounced leaching of amylose via radial channels of starch granules leading to a stronger amylose gel on the one hand, and on the other hand, to the partial dismantling of the branches of amylopectin into dextrins. The short chains dextrins appeared to form dextrins (from amylopectin)-lipid complexes. These phenomena have a strong effect on the texture, hardness and staling of flatbreads

Comparison of physico-chemical properties of air-classified navy bean protein-rich fractions: Whole versus hulled beans

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ABSTRACT

Consumer preferences for healthier, plant-based food products has led to increased interest in alternative protein sources, including pulses, which are rich in protein, carbohydrates, vitamins, and minerals. A more sustainable approach in protein extraction is through dry fractionation in combination with air classification. This method shows great potential for producing more functional protein ingredients and eliminates the expenditure of proteinaceous effluent treatment in traditional wet-fractionation methods. To adapt this technology in pulse-protein industry, further process optimization is needed for unexplored pulse sources. In this study, the influence of dehulling on the physicochemical properties of navy bean protein-rich fractions produced from dry fractionation and air classification was investigated. During air classification, different air classifier speed (4230, 5680, 7115 rpm) and secondary air opening (20, 40%) settings were performed. Dehulling of navy beans was done using a bench-top roller mill followed by a one-pass run in an air classifying mill to produce finer bean flours with desired particle size distribution (D90 is 38-40 µm). Fine navy bean flours with and without hull fractions were passed through a mini-split air-classifier to separate fine (protein-rich) and coarse fractions at the desired cut point of 20-22 µm. Results showed that protein content of air-classified protein-rich fractions ranged from 40 to 55% (w/w), which varied depending on the classifier speed and secondary air opening. The maximum protein recovery was about 73%. Extracted proteins showed significantly increased ($p < 0.05$) protein yield and total dietary fiber at increasing classifier wheel speed and decreasing secondary air opening. Dehulling prior to milling and air classification significantly increased ($p < 0.05$) the extraction, protein recovery yield, and purity; and improved color for the specific combination of air classification settings. Meanwhile, no significant impact ($p > 0.05$) of dehulling was observed on the composition of protein-rich fractions from navy bean flours.

Significance of tempering conditions on the *E. coli* load of milling fractions during lab-scale milling

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ABSTRACT

Enteric pathogen contamination of wheat flours is a major concern for the flour milling industry. The objective for this study was to determine the relevance of different tempering conditions (inoculation level, moisture, temperature, and time) on the E. coli load of wheat milling fractions.

Hard red winter (HRW) wheat grains were pre-dried and inoculated with non-pathogenic E. coli (ATCC 1427, 1429, 1430, and 1431) at 5.4 ± 0.2 (high inoculation), and 3.5 ± 0.1 (low inoculation) log CFU/g. The inoculated wheat grains (500 g) were then tempered under different moisture (15 and 17%), temperature (25, 35, and 45o C), and time (6, 12, and 18 h). Tempered grains were milled using lab-scale roller mill, and the E. coli load of milling fractions were analyzed. The E. coli load of the wheat grains was reduced by 0.0-3.3 log CFU/g after tempering, with greater reductions ($P < 0.05$) observed at high inoculation level, temperature (45o C, and tempering time (18 h). Lower ($P < 0.05$) E. coli loads were observed in wheat flour (break, sizing, reduction, and straight grade) and non-wheat flour fractions (bran, fine bran, and shorts) at low inoculation, higher temperature (45oC), and longer tempering time (12 and 18 h) conditions. E. coli counts ranged from 0.5-4.1 (non-wheat flour fractions), and 0.5-3.4 log CFU/g (wheat flour fractions). Inoculation level (9.2-51.49%), temperature (19.5-62.6%), and tempering time (10.2-30.4%) were the main contributors to the total variance observed in the load reductions, and E. coli load of milling fractions.

The results from this study will help in further understanding the role of the tempering step in the distribution of E. coli in the milling fractions and help in improving potential tempering intervention steps for reducing pathogen contamination during wheat milling.

Manufacture of ice cream by altering the whey protein-to-casein ratio

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ABSTRACT

Milk used for ice cream manufacture is often fortified with protein powders (e.g., whey protein concentrate, milk protein concentrate, and micellar casein concentrate) as part of the milk solids-not-fat components. Altering the whey protein-to-casein ratio (WP/CN) can be an important determinant of the overall quality of ice cream. The objective of this work is to evaluate the impact of milk protein fortification, specifically altered WP/CN, on the manufacture of ice cream. Non-fat dried milk, whey protein concentrate, and micellar casein concentrate were used to formulate a basic ice cream formulation (42.15 ± 0.75% total solids, 13.13 ± 0.55% total fat, and 4.55 ± 0.25% total protein) containing different was used to WP/CN, including 13/87, 20/80, 30/70, 50/50, and 70/30. Overall, ice cream mixes exhibited particle size distribution that spanned from 0.73 to 0.04 µm, regardless of the WP/CN. Additionally, the viscosity of all formulations decreased with increasing the shear rate, exhibiting a shear-thinning behavior. Increasing the amount of whey protein significantly reduced the viscosity of the mixes between 2- and 4-fold, depending on the shear rate and WP/CN. Ice creams formulated with a ratio of 50/50 exhibited relatively high values of hardness (76.53 ± 3.82 N) and onset of meltdown of 2514 s, whereas a ratio of 20/80 exhibited moderate hardness (57.41 ± 2.87 N) and onset meltdown values of 2376 s. The outcomes of the study provide relevant information for the manufacture of ice cream by changing the WP/CN.

Mapping of hygienic design standards, guidelines, and practices for equipment

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ABSTRACT

Adherence to hygienic design standards, guidelines, and practices is pivotal in ensuring the safety and quality of products in food, bioproducts, and pharmaceutical manufacturing. Despite the significance of such measures, a universal framework encompassing these standards remains elusive, posing challenges for newcomers in the field. In response, this study endeavors to map the landscape of hygienic design standards, guidelines, and practices across diverse manufacturing sectors within a unified framework.

Utilizing the ASME BPE 2019 as a foundational framework due to its comprehensive scope, the study systematically categorizes standards, guidelines, and practices from various organizations. Through a meticulous selection process, contributing organizations (e.g. 3-A SSI, EHEDG, ISO, ANSI/NSF, ASABE, PMMI, PIP, BEAG, ISPE) were identified based on their primary focus on standards, guidelines, and practices applicable across multiple manufacturing sectors.

Results indicate a predominance of standards, guidelines, and practices addressing general requirements and unit operations, with a limited subset extending to facility considerations. The ASME BPE 2019 emerges as a pivotal tool for mapping categories across disparate standards, guidelines, and practices facilitating clarity and enabling comparisons among industry practices.

In conclusion, this study offers a valuable resource for individuals navigating the complex landscape of hygienic design standards providing insights into the scope and coverage of existing standards, guidelines, and practices while advocating for a unified approach to ensure product safety and quality across diverse manufacturing sectors.

Optimization of radio frequency heating treatment for inactivating *Aspergillus* mold and securing quality and safety of hazelnut inshells for the long-term storage

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ABSTRACT

Justification: Mold contamination (especially from Aspergillus flavus) is a big concern for hazelnut industries, which not only can potentially produce toxic carcinogenic aflatoxin, but also accelerates rancidity of hazelnut. Radio frequency (RF) heating treatment tackles these issues as it can provide fast and volumetric heating for whole hazelnut inshells.

Objective: To optimize radio frequency heating conditions for inactivating Aspergillus molds and securing quality and safety of hazelnut inshells during the long-term storage.

Methods: Aspergillus oryzae was used as a surrogate of Aspergillus flavus in microbial study. The come-up time (CUT) for shell and kernel located at cold spot (center) in the single layer uninoculated inshell hazelnuts and temperature profiles of shell and kernel located at center and two corners were determined. Hazelnut was inoculated with Aspergillus oryzae suspension (104-6 CFU/g), and thermally treated at 55, 60 and 65 °C with different holding time (around 0 to 10 min). Samples without any heat treatment were used as a control. After treatment, samples were performed serial dilutions for plate counting (48-h at 29 °C) and lipid oxidation tests. The results were demonstrated by log reduction between treated samples (N) and control (N0) (log (N/N0). Data was collected in duplicates and analyzed using LSD (P<0.05).

Results: While kernel's temperature reached 70 °C (cold spot), shell's temperature was lower than 55 °C. Hence, mold population reduction of inoculated whole inshells was only 0.48 log CFU/g. For enhancing mold reduction, shell's temperature was aimed to increase up to 55, 60 and 65 °C with CUT of 14.48, 19.19 and 26.04 min, respectively. However, kernel's temperature were much higher ranges (74.0 to 112.2 °C) than shells. This could be concerned experiencing quality changes due to high temperature of kernels. Hence, mold inactivation temperature of shells needs to be comprehended with temperature profiles and lipid oxidation tests of kernels for optimizing RF pasteurization.

Vacuum microwave drying of concord grape pomace: Study of drying kinetics for the preservation of bioactive compounds

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ABSTRACT

Concord grapes (Vitis labrusca) are primarily used for juice production. Grape pomace is a main byproduct stream from the juicing process with significant mass, which is comprised of skin (~42% w/w), seeds (~22%), and stems (~25%) with 50-72% moisture content on wet basis. Pomace is often discarded as a waste, which leads to environmental acidification; however, it contains various bioactive compounds that may benefit human health. Microwave vacuum drying (MVD) uses dielectric heating aided with a vacuum to enhance the heat and moisture transfer, thus can achieve drying at a lower overall temperature compared to air drying (AD). The goal of this study was to model the drying kinetics and study the degradation of bioactive compounds during MVD and AD processes. Grape pomace obtained from a commercial juice processing plant was dried with a pilot scale MVD and AD and the drying kinetics were modeled using several empirical models. MVD was conducted at 1.5, 3, and 6W/g at 8kPa vacuum, and AD was conducted at 70°C and 5% RH. Changes in the total polyphenols and monomeric anthocyanins throughout the process were studied. Increase in the MVD power reduced the time required to remove ~25% weight from 30 minutes at 1.5W/g to 10 minutes at 6 W/g. Both drying conditions provided a shelf-stable finished product that was well below 0.4 water activity. 10 minutes at 1.5, 3, 6W/g reduced the pomace weight by 7.3, 15.9, 25.2% respectively. The Page model fitted the data well with the Radj2 = 0.977 - 0.989, which can be used to predict the drying progress. At a 25% weight reduction, samples exhibited an increase in polyphenol content by 81-87%. The results obtained in this study can help the processors to optimize drying parameters to best dry pomace to required levels, while preserving nutritional components.

Potential of radio frequency dried spent grains as a carrier for functional compounds from spent hops

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ABSTRACT

Spent grains and spent hops are the most substantial by-products in beer brewing. Relevant studies have shown the adsorption effect of dried spent grain or dried spent hops, however, most of them deal with heavy metals or dyes, which may cause secondary pollution. The objectives of this study were to apply radio frequency for drying of spent grains, then used it to adsorb the functional ingredients extracted from spent hops. By combining the energy-saving drying method with the physical properties and functional ingredients of the by-products, a novel compound functional food could be developed. Results showed that the water content of 1 Kg wet spent grains could be reduced to 5% in 15 min by radio frequency heating with a condition of 5 kW power and 13 cm electrode gap. The absorption ability of prenylflavonoids and hop bitter acids, the major functional components of spent hops, could be attained 90% with 3 minutes in a condition of spent grain dose was 0.1g/mL and working pH was 4. Modeling of adsorption isotherm and kinetics showed that the adsorption of prenylflavonoids and hop bitter acids on radio frequency dried spent grains could be best-fitted by the Shift-square Langmuir and Pseudo-second-order models, and the Qmax was evaluated as 67.11 mg/g. FTIR showed that the functional groups in spent grains such as O-H and C-O-C were possibly responsible for binding of prenylflavonoids and hop bitter acids.

In situ fabrication method of functional bacterial cellulose with enhanced productivity using statistical modeling

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ABSTRACT

It has long been understood that antimicrobial properties are one of the most essential functions in the field of food packaging. In this study, we applied a technique to functionalize bacterial cellulose (BC) with antimicrobial properties using an in-situ method. As a result of measuring the characteristics of BC produced by adding the hydrolyzate of this material to the fermentation medium of Acetobacter xylinum ATCC 11142 using plant-based biomass containing flavonoids, it was confirmed that it exhibits antibacterial activity. Since the low yield of bacterial cellulose has always been a problem, statistical modeling was applied to optimize the medium to solve this problem. The optimization was done by using the response surface methodology (RSM). In the RSM optimization study, a Box–Behnken design with three parameters was applied. In conclusion, statistical modeling can be used to optimize HS medium concentration and biomass additive concentration for maximum production of antibacterial bacterial cellulose. The antibacterial activity of BC suggests its potential application as an antibacterial food packaging.

Extraction of minerals from seaweed (*Mazzaella japonica*) using reciprocation agitation thermal processing

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ABSTRACT

To the best of our knowledge, this study is the first study proposing the agitation thermal processing as a potential method for extraction. Seaweed, as one of the fastest-growing plants on Earth, is abundant in major minerals, including potassium, sodium, magnesium, and calcium. Herein, reciprocating agitation thermal processing (RA-TP) was employed for extraction of minerals from Mazzaella japonica, a red seaweed commonly found around Vancouver Island. RA-TP with water as a solvent was used while controlling extraction parameters including reciprocation frequency (0, 1, 2 Hz), temperature (232, 250, 268 °F), and cook time (5, 15, 25 minutes). Reciprocating at 2 Hz significantly lowered the average heating rate index (fh) to 433 seconds compared to 1 Hz (544 seconds) and 0 Hz (584 seconds) ($p < 0.05$). Processing at 2 Hz-232°F had the significantly lowest fh of 385 seconds ($p < 0.05$), 40% lower than the highest fh of 646 seconds at 0 Hz-268°F. The mineral contents were determined using inductively coupled plasma optical emission spectroscopy. Extraction at 268 °F significantly increased calcium, magnesium and sodium, but not potassium content. Potassium extraction ranged from 10.75 g/kg (0-232-25) to 14.96 g/kg (2-268-5) but was not significantly affected by retort conditions ($p > 0.05$). The Na/K ratio was significantly affected by temperature and the interaction of frequency and cook time. Response surface methodology optimized the retort conditions at 2 Hz, 268°F, and 5 minutes by maximizing magnesium content to 8.13 g/kg, maximizing calcium content to 3.83 g/kg, and minimizing Na/K ratio to 1.71. The results could contribute to adoption of agitation retorting as a potential method for extraction of minerals from seaweed and other sources. Such a method would result in sterilized seaweed, which could then be used for food production, while the can liquid could be dehydrated as a mineral sources.

Effect of high-pressure processing on the secondary structures of sesame isolate protein (*Sesamum indicum L.)*

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ABSTRACT

Plant-based proteins have limited application in processed foods due to their poor technofunctional properties. High pressure processing can induce structural changes in proteins improving its functionalities. Sesame isolate protein (SPI) from oil extraction by-product (cake) was processed by High Pressure Processing – HPP (200, 400 and 600 MPa; 10 minutes; 25°C), at pH acidic (4.5), neutral (7.0) and alkaline (11.0). The Fourier Transform Infrared Spectroscopy (FTIR) was performed to evaluate changes in secondary structures of the SPI. It was observed that the β-sheets structures are predominant in SPI. After processing by HHP the samples processed at pH 4.5 (400 and 600 MPa) and 11.0 (200,400 and 600 MPa) it was noted that pressure had a greater influence on the random coil structures, decreasing the content of β- turns, when compared with the respective controls (unprocessed sample). At pH 7.0 (processing) at pressures of 200 and 600MPa, a decrease in β-sheets and an increase in β-turns, and under the 400 MPa there was a reduction in both structures, but with the more significant appearance of α-helix.

Convective and infrared drying of banana: kinetics, color and water activity

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ABSTRACT

Bananas contain a high moisture content, which makes them quite perishable. Therefore, fruit processing can be an alternative. Drying can be used to preserve bananas, reduce transportation and storage costs, and produce products that cannot be obtained in any other way. This work aimed to study the drying kinetics of bananas using convective and infrared (IV) methods. The samples were dried at 60 °C in a fixed bed dryer with an air velocity of 2 m/s (convective drying) and in equipment under heating with 3 infrared lamps of 250 W each (IV drying). To adjust the experimental drying data, six empirical models were used (Page, Simple exponential, Two-term exponential, Wang and Singh, Henderson and Pabis, and Logarithm). The effective diffusivity was calculated using the Fick diffusional model. The banana samples were also evaluated for color and water activity. IV drying resulted in higher drying rates than convective drying. The logarithm model obtained the best fit to the experimental data on banana convective drying, while for IV drying, the model that best fit was that of Wang and Singh. The effective diffusivity values were in the order of 10-10 m2/s. Regarding quality analysis, the water activity of the dried samples by both methods was 0.56, indicating its stability. For color, there was a reduction in the L* and b* parameters and an increase in a* for the convective drying samples. The samples dried by IR showed a reduction in L* and an increase in the a* and b* parameters. The greatest difference in color compared to the fresh sample (ΔE) was found in the convective dried bananas.

Sensors help uncover value-added ingredients in waste streams from breweries

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ABSTRACT

Introduction: Brewers' spent grain (BSG), accounting for 85% of breweries waste, is an excellent source of dietary fibers and proteins. There is a growing interest in exploring BSG as a food ingredient. It is essential to determine the composition of BSG to get desired nutritional profile. Conventional wet chemistry methods are time consuming, labor intensive, and costly. We investigated the application of a new generation of handheld near-infrared (NIR) devices for quantifying macronutrients in BSG.

Hypothesis: The unique NIR vibrational overtones and combination bands of molecules that makeup foods combined with pattern recognition algorithms can provide rapid quantitative information of macronutrients in BSG, representing an alternative to conventional wet chemistry methods.

Methods: BSG samples were obtained from 11 local breweries. The proteins, carbohydrates, and lipids in the samples were determined using reference wet chemistry methods. Samples were scanned by a handheld Near Infrared (NIR) device operating in the 1350 to 2500 nm region. Absorbance spectra were analyzed by regression (Partial least squares, PLS) algorithms for developing predictive models.

Results: BSG components obtained from reference methods agreed with previously reported results. Calibration models were developed for proteins, lipids, and carbohydrates. In 10s scans, models predicted the BSG components with standard error of cross-validation (SECV) <0.5 and correlation coefficient of validation (rval) >0.95. These results indicate that NIR spectroscopy can provide fast and reliable results for estimating BSG composition within a few seconds.

Conclusions: An accurate measurement of composition is essential for nutrition labels. The NIR spectroscopic method was easy to use for rapid quantification of nutrients without any need of sample preparation or operator training. The NIR spectroscopy can be easily implemented in plants for real-time analysis of by-products of the food industry providing sustainable added value and low-cost alternative to ingredients that otherwise would become waste.

Extraction of anthocyanins from purple sweet potatoes via co-solvent modified supercritical carbon dioxide

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ABSTRACT

Purple sweet potatoes (PSP) are recognized as a valuable source of anthocyanins, renowned for their health-promoting properties. This study investigated the use of supercritical carbon dioxide (SC-CO2) technology as a green and sustainable method to extract anthocyanins from PSP, systematically exploring various extraction parameters to optimize total phenolic content (TPC), anthocyanin content (ANC), and antioxidant activity (AA) of the extracts. SC-CO2 extractions (i.e., temperatures of 35-50 °C, 10%-30% (w/w) co-solvent concentrations, and pressures of 30-40 MPa) were investigated and optimized. The SC-CO2 extractions were carried out using a 60% ethanol-water (v/v) mixture as a co-solvent for 3 h. Moreover, conventional solvent extraction methods were performed using ethanol and methanol. The solvent-to sample ratio was set between 15:1 (v/w) and 45:1 (v/w), with the temperature ranging from 35 °C to 50 °C, and an extraction time of 60 min. The research findings indicated that SC-CO2 extraction at 30 MPa, 35 °C, and 20% co-solvent concentration provided the highest TPC (339.8±6.1 mg/g), ANC (136.0±5.0 mg/100g), and AA (ABTS (7.3±0.2 mg/g Trolox equivalent), DPPH (18.2±0.4 mg/g), and FRAP (1398.6±3.5 mg/100g)). Moreover, structural characterization demonstrated that SC-CO2 extraction under optimized conditions facilitated the extraction of anthocyanins due to a more porous structure. In conclusion, this study highlights the potential of SC-CO2 technology as an eco-friendly and efficient approach for extracting anthocyanins from PSP to develop health-promoting functional foods.

Selective extraction of waxes from bioethanol production side-stream via supercritical carbon dioxide: Thermal characterization and modeling

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ABSTRACT

Bioethanol production heavily relies on agricultural products, primarily corn and sorghum, which are rich in starch. However, the conversion process creates a lipid slurry side stream typically wasted or used as animal feed. This slurry is rich in valuable high-melting point waxes. However, the isolation ofwaxes fromother lipids presents several challenges, including clogging during filtration, the presence of equally soluble lipids, and the use of toxic solvents. Thus, this study aims to develop a green process that utilizes supercritical carbon dioxide (SC-CO2) to fractionate lipids to selectively obtain commercial wax equivalents and construct a predictive model for the melting curves of the purified waxes for industrial use. To optimize the processing conditions for selective wax separation, a response surface design with three factors was employed: pressure (8-40 MPa), temperature (35-75°C), and time (2-6h). The oils and waxes extracted were characterized using GC and DSC. The melting profiles of the waxes were modeled using Functional Data Analysis (FDA) to determine the specific conditions yielding waxes with melting patterns matching industrial waxes. Under optimized conditions (40 MPa, 75°C, and 6 h), 92% (w/w) of crude oil was extracted, resulting in high-purity wax powders. Furthermore, functional principal components analysis on the B-spline model revealed that the DSC curve of the high-purity wax was comparable to that of commercial carnauba and candelilla waxes. Moreover, after being treated with 40 MPa at 55°C for 6 h, the resulting wax melted similarly to beeswax. Wax coatings are widely utilized in the food industry for their exceptional ability to create a barrier against moisture and enhance the shelf life of food products. Overall, a food-grade fractionation method was employed to sustainably valorize an agro-industrial side product to generate high-value waxes for the food industry, providing a sustainable alternative source for waxes while reducing waste.

Inactivation of *Enterococcus faecium* NRRL B-2354 on different material surfaces used in food industry employing superheated steam.

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ABSTRACT

Traditional sanitation in dry food manufacturing plant is challenging as moisture residue can harbor microbial contamination. Superheated steam (SHS) is produced when water is heated to temperatures beyond boiling point (125-400°C) and doesn't lead to condensation on surfaces. There are limited studies available on sanitation efficacy of SHS on different surfaces. This study was conducted to understand the efficacy of SHS as a tool to inactivate Enterococcus faecium NRRL B-2354 on different surfaces (stainless steel, concrete, plywood, leather, Polytetrafluoroethylene (PTFE), silicon rubber, cotton, and cardboard) commonly used in food industry. The surfaces were either spot inoculated or coated with representative food matrix (baby formula) and treated with SHS at 150°C for the process time (come-up time + treatment time) of 3 mins. We also studied the impact of prolonged SHS treatment on the roughness of selected surfaces (stainless steel, plywood, and silicone rubber) by treating them at 150°C for 5 mins once a week over 8 weeks. Spot inoculated surfaces showed a higher microbial inactivation (range- 9.2±0.9 to 10.7±0.7 log reduction/coupon) whereas, surfaces with inoculum coated with baby formula had lower inactivation (range- 7.8±0.4 to 9.6±0.4 log reduction/coupon). Higher microbial inactivation was observed when surfaces had high thermal inertia, low hydrophobicity, and roughness. Prolonged exposure of SHS on surfaces did not change the surface roughness ($p<0.005$).

Impact of combined laser and ultrasound treatments on the germination and nutritional quality of broccoli, radish, and kale seeds

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ABSTRACT

In this study, we investigated the effects of laser, ultrasound, and combined laser-ultrasound treatments on the germination and nutritional properties of broccoli, radish, and kale seeds. After treatment, the seeds were germinated for five days. The germination rates increased by 13%, 11%, and 10% for kale, radish, and broccoli seeds respectively when exposed to combined laser and ultrasound. Correspondingly, the average sprout length for these seeds increased by 32.61%, 28.30%, and 14.04%.

The sprouts from treated seeds demonstrated significantly enhanced protein solubility, emulsion activity, and foaming and water/oil absorption capacities. Total phenolic content (TPC) and DPPH radical scavenging activity were also significantly higher in sprouts compared to untreated seeds. The highest TPC was observed in sprouts treated with the combined method, with TPC values showing a dramatic increase from seed to sprout. Specifically, the DPPH activity increased from 3.02 to 7.19 µmol TE/g d.w for broccoli, 3.18 to 6.95 µmol TE/g d.w for radish, and 5.68 to 9.89 µmol TE/g d.w for kale.

Additionally, sprouts treated with the combined method showed the highest total flavonoid content (TFC), with kale sprouts reaching 73.6 mg/g d.w, followed by radish and broccoli at 64.5 mg/g and 58.9 mg/g d.w, respectively. These values were nearly double those of the untreated seeds. Color analysis revealed that the highest lightness (L*) values were observed in sprouts subjected to the hybrid treatment, with average L* values of 53.4 for broccoli, 63.2 for radish, and 56.2 for kale.

Overall, the use of laser and ultrasound treatments significantly enhances the germination, nutritional value, and potential application of sprouts in functional foods, demonstrating a promising method to improve the edibility and health benefits of germinated seeds.

Chicken myofibrillar proteins: Enhancement of functional and physicochemical properties during vacuum microwave thawing and high-intensity ultrasound

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ABSTRACT

This study had dual objectives: firstly, to evaluate changes in the physicochemical and textural properties of chicken samples under vacuum microwave thawing method, and secondly, to investigate the potential of ultrasound treatments in enhancing the functional properties of myofibrillar proteins extracted from chicken breast. The vacuum microwave thawing process reduced cooking and thawing losses in chicken samples and enhanced the emulsifying and foaming properties of myofibrillar proteins, thereby improving their functional attributes. Additionally, the vacuum microwave thawing process significantly altered particle size distribution and turbidity in the myofibrillar proteins. On the other hand, the study findings revealed that extending the duration of ultrasound treatments positively affected the water-holding capacity, solubility, foaming, and emulsifying properties of myofibrillar proteins. Moreover, these treatments resulted in decreased particle size distribution and improved rheological behavior of the proteins when compared to the control sample.

Guided-Ultrasound-Enhanced-Evaporation (GUEE): Reducing energy consumption during falling film evaporation

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ABSTRACT

The manufacture of food powders is an energy-intense process, where the mother liquid is evaporated to remove 60-80% of the water prior to drying. Industrially, falling film evaporators (FFE) are the most suitable means of evaporate (pre-concentrate) large volumes of the mother liquid. In FFE, the evaporation occurs within the surface of a thin film of the mother liquid flowing down over a heating surface. Evaporation of liquid foods has been identified as one of the most carbon-intensive process in the food industry. In this study, the design of FFE by guiding ultrasound waves through the length of the heating surfaces (evaporation tubes) was undertaken to take advantage of the unique features of guided ultrasonic waves. Unlike conventional ultrasound (bulk waves), guided ultrasound can be propagated over long distances (up to 50 meters), depending on the wave modes and frequencies used. Key design parameters are the effective length of the vertical tube, minimum flow rate to create a thin film, pressure-drop, and film thickness. To date, no research has been done on the use of guided ultrasound as for reducing the overall energy requirements during evaporation, warranting investigation on the impacts of unique guided ultrasound properties on FFE performance.

Spray-dried unripe acerola juice: an evaluation of the effect of different carriers on the product quality and stability

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ABSTRACT

Acerola (Malpighia emarginata) is a tropical fruit renowned for its high nutritional content and abundant vitamin C content. This fruit is highly perishable, and the dried pulp often faces challenges in retaining its properties due to environmental and processing factors. To address this, we investigated the impact of different drying carriers (maltodextrin (dextrose equivalent (DE) 5 and 2), arabic gum, modified starch, and soluble corn fiber (two commercial brands, Nutriose® FM06 and Promitor® 85N)) on moisture content, water activity, particle size, solubility, dispersion time, microstructure, glass transition temperature (Tg), color, and sorption isotherms of spray-dried green acerola juice.

The acerola powders showed an average water activity of 0.332 ± 0.009. Samples added with soluble corn fiber showed a significantly lower moisture content (<5 g/100g) compared to the other samples because of the lower viscosity and consequent lower droplet size and higher water diffusivity during drying. Also, the lower span value demonstrates higher homogeneity in samples dried with soluble corn fiber and maltodextrin compared to samples dried using arabic gum and modified starch. Solubility was affected by the carrier chain size and more complex structure; thus, samples dried with arabic gum and modified starch presented lower solubility (<80%), while the other samples presented solubility higher than 90%. The average Vitamin C content powder was 18.526 g/100g, with arabic gum allowing a significantly higher retention of this compound (19.1 g/100g). The analysis of the sorption isotherm revealed that acerola samples with maltodextrin had a lower equilibrium moisture value, in general all the powder exhibited a Type III behavior, typical for foods with high soluble solids content. In conclusion, samples with arabic gum, maltodextrin, and Promitor® 85N (in this order) showed superior performance across the studied parameters, particularly regarding the stability of the powder and the retention of vitamin C.

Minimization of microwave power reflection in the continuous-flow heating of mango puree by modeling the effect of the tuner stubs heights

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ABSTRACT

Continuous-flow microwave heating is an emerging technology that offers advantages for thermal processing of liquid foods. The objectives herein were to model the electromagnetic heating and study the influence of the tuning stubs in the processing of mango puree, which was pasteurized in a Lab25-UHT/HTST EMVH unit (MicroThermics, USA) at 90 °C and 1.2 L/min. The microwave heater model, simulation and geometry were developed using COMSOL Multiphysics 5.3. The geometry consists of the cavity, waveguide, applicator tube, puree and tuner stubs. To study the influence of the stubs in the absorption of electromagnetic power, a Monte Carlo optimization was applied for a total of 200 evaluations were the parameter S11 (return loss) was minimized changing the height of three tuning stubs considering mango puree at 40 °C (inlet temperature) using the physics for electromagnetism. The optimization provided a S11 of -36.2 dB (0.02 % power reflected); however, a change in height of less than 0.3 mm in each of the tuner stubs could increase the power reflected up to -25.8 %, showing the high sensitivity of the system. With the optimized stubs, the multiphysics model was simulated and validated considering electromagnetism, laminar fluid flow and heat transfer. For the processing conditions, the power reflected was 15.3 % mainly due to the change in dielectric properties with temperature, not considered in the optimization. The boundary condition for emitted power was adjusted to consider this reflection. The temperature difference at the outlet was still 1.5 °C because of scattering at entrances. Although the electromagnetic power absorbed by the fluid is highly influenced by the fluid dielectric properties and tuner stubs heights, the latter is seldom integrated in modeling studies and instead it is considered that all the emitted power at the entrance port is absorbed.

A phenomenological understanding of MEF assisted heating of heterogeneous food system

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ABSTRACT

The heating assisted by moderate electric fields (MEF) allows for a faster and more homogeneous compared to conventional heating, with potential benefits on final product quality and on process efficiency. The applicability of this technology is closely related to the characteristics of the food to be treated.

The aim of this study was to evaluate the heating behavior of a heterogeneous food system composed by a dispersant phase (mashed potatoes) and a disperse phase (chicken meatballs).

The analysis was carried out in a rectangular shaped MEF cell, equipped with stainless steel electrodes, fed by an AC generator, with potential difference up to 150 V.

Three formulations of the dispersant phase were prepared: one (A) having the same electrical conductivity of the meatballs; another (B) having the same volumetric heat capacity of the meatballs but electrical conductivity doubled; the last one (E), having electrical conductivity being the half of A one.

Tests were conducted applying fixed potential gradient, from 4 to 8 V/cm.

Different configurations were tested, particularly with one, two or three meatballs dispersed in the masked potatoes. When one or two meat balls were present in the system, also the effect of their relative position was evaluated. Heating test lasted 4 min and 30 s.

Results show that the heating patters are influenced by the position of the dispersed component. On the same line, meatballs heat up with similar rate than the mashed potatoes. Mashed potatoes laying between the electrodes, with no dispersed components between them, heat much faster. Large temperature differences are estimated in the dispersant phase, while in the meat balls the temperature gradient is less evident. When two meatballs are present, one of the two always exhibited a higher temperature gradient.

This study contributes to the understanding of MEF heating of foods, especially for solutions to be considered for ready-to-eat meals to be heated up in domestic appliances equipped with MEF system.

A comparative analysis of steam condensation, electric resistance, and induction heating heat exchangers

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ABSTRACT

This study presents a comprehensive comparison of three distinct heat exchange methods: steam condensation, electric resistance heating, and induction heating. Heat exchangers are vital components in various industrial processes, including power generation, chemical and food manufacturing, where efficient heat transfer is paramount. Each method offers unique advantages and limitations, influencing their suitability for different applications.

This process is widely employed in power plants and industrial heating systems due to its simplicity and high heat transfer coefficients. However, it requires a significant infrastructure for steam generation and may encounter challenges related to condensate management and energy efficiency.

Electric resistance heating involves passing an electric current through a resistive element, which generates heat through Joule heating, offering precise temperature control and rapid heating rates, making it suitable for applications requiring fine-tuned thermal management, such as semiconductor manufacturing and food processing. Nonetheless, electric resistance heating can be energy-intensive and may pose safety risks associated with high electrical currents.

Induction heating utilizes electromagnetic induction to induce eddy currents within a conductive material, producing heat through resistance. This technique offers rapid and localized heating without direct contact between the heating element and the material, minimizing contamination and enabling precise temperature control. Induction heating is commonly employed in metal fabrication and in general where uniform heating and high production rates are essential. However, it requires specialized equipment, and moreover magnetic steel is not suitable for direct food contact.

This comparative analysis examines key performance metrics, including heat transfer efficiency, energy consumption, operational flexibility, and cost-effectiveness, to evaluate the strengths and limitations of each heat exchange method. Furthermore, potential advancements and emerging technologies in heat exchanger design and implementation are discussed to address current challenges and optimize thermal management in food industrial applications.

Power-to-food: Advanced bioreactor design for controlled hydrogen fermentation

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ABSTRACT

Objective

The non-pathogenic bacteria Cupriavidus necator represents a novel and sustainable food protein source reaching protein contents of up to 75% in their dry matter. The chemolithoautotroph proliferates on H2 (electron donor), O2 (electron acceptor), and CO2 (carbon source). In this study, a lab-scale bioreactor setup was engineered that is safe for aerobic hydrogen fermentation and yields high biomass concentrations for single-cell protein harvest.

Methods

A semi-continuous fermentation system was designed to autotrophically cultivate hydrogenotrophic C. necator and monitor the process parameters. Potential explosion risks in the setup associated with the oxyhydrogen reaction were identified and counteracted by safety measures. Varying gas feed mixtures (H2, O2, CO2) and volumetric flow rates were operated and its impact on growth rate, biomass yield, and protein concentration was analyzed. The growth rate measured by optical density readings, biomass yield determined as change in dry weight over time, and protein concentration tested with the Dumas method were recorded as a function of the operated cultivation parameters.

Results

All components of the bioreactor and measuring probes were made from glass/PTFE (no metal-to-metal friction) or explosion proof/hydrogen-certified to eliminate any potential source of ignition. The accumulation of hydrogen in the peripheral atmosphere and headspace was prevented by installing the reactor in a fume hood and continuously flushing the headspace with pure nitrogen. A clear correlation between increased flow of the gases and higher growth rates and biomass yield was determined, respectively. The protein concentration was mainly affected by the O2/CO2 ratio in the gas feed, with the lowest level of 5% CO2 resulting in the highest protein concentrations. Operating the optimum fermentation conditions, the cultivation of hydrogenotrophic bacteria surpasses protein yields from other microorganisms used for SCP production (algae, yeast, etc.), which reveals the potential towards the production of sustainable food material.

Lipids, shear stress, and fibrous texturization of plant-based meat analogs produced by high moisture extrusion

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ABSTRACT

Sustainability concerns have promoted the development of plant-based meat analogs (PBMAs) with similar texture than that of animal meat. High Moisture Extrusion (HME) is a resource-efficient process, commonly used to industrially produce PBMAs. It facilitates the formation of fibrous structures (FST) like those of animal meat. In animal meat, fat confers tenderness, juiciness, and characteristic flavor, but the incorporation of lipids into HME tends to deter FST formation.

This work analyzed the impact of shear (mechanical stress) during pilot-scale extrusion in the final FST of soy protein concentrate-wheat gluten extrudates with added lipids. The factors of analysis were the lipid content of the formulation (F1:0% (control), F2:2% soybean oil, F3:2% soybean shortening), the number of high-shear (reverse) elements in the screw configuration (Low—0, medium– 1, high– 2 (control)), and the cooling die temperature (CDT) (70°C and 86°C (control)). The FST was characterized by the hardness, anisotropy index (AI), and surface profile parameters.

The results showed that the energy supplied to the material in the extruder (measured by the specific mechanical energy, SME), decreased with the addition of lipids, and increased with the number of reverse screw elements and the reduction of temperature in the cooling die. In general, the hardness and AI of the samples increased with SME (Hardness=2.75*SME, R2=0.96; AI=0.05*SME, R2=0.88). Confirming the importance of the lipid content and shear stress interaction, without reverse elements, the thermomechanical energy added was insufficient to form an extrudable structure when oil was present, whereas the control and shortening formulations did produce extrudates with suitable texture. Compared to the control parameter (AI=1.45±0.17), variations in shear increased the anisotropy, as the highest AI (1.84±0.15) was for F3, with one reverse element and CDT of 70°C; followed by F2 (AI of 1.79±0.15), with one reverse element and CDT of 86oC.

Integrated production by extrusion of biodegradable materials from cassava *(Manihot esculenta)*

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ABSTRACT

The present study is justified by the problem of the increase in environmental pollution caused by the use of plastics from fossil sources and the increase in organic waste from some food industries such as cassava. The objective of this research was the development of eco-friendly and biodegradable films using extrusion, a technique already present in the industry, with the integration of starch and cassava bagasse from the same batch as raw materials and determining the main properties of the films obtained. The raw materials, starch and bagasse, were characterized regarding their moisture (11.59 g/100 g w.b. and 6.75 g/100 g w.b., respectively), amylose content in starch (20.29 g/100 g d.b. and 22.93 g/100 g d.b., respectively), gelatinization temperature peaks (65.9 – 68.6 °C and 67.6 – 71.4 °C, respectively), crystallinity, particle size distribution and morphology by scanning electron microscopy. Formulations with only starch (S100), only with bagasse (B100), and a reciprocal ratio of 2:1 (S100-B50 and S50-B100), 1.5:1 (S100-B67 and S67-B100) and 1:1 (S100-B100) were tested, using water and glycerol as plasticizers. Using a twin-screw extruder (speed of 80 rpm; temperature profile: 60-75-90-100-110-100-95-90 °C and 90 °C in the film die zone), films were obtained with physical properties like moisture (12.53 – 15.65 g/100 g of film, w.b.) solubility (46% – 71%), hydrophilicity (27° – 50°, water contact angle) and thickness (0.876 – 1.269 mm) influenced by the interaction between fiber and starch and with high opacity values (greater than 0.965). Finally, the tensile strength values are greater than 1.5 MPa and with values up to 2.59 MPa (for S100 and S100-B67) and with elasticity values varying between 42 –82%; these mechanical results can be considered a landmark within food engineering and industry as they proved to be higher to most studies previously carried out under the same conditions for cassava starch extrusion.

Convective drying and shrinking effects on papaya slices

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ABSTRACT

This study evaluated the drying, shrinkage and vapor sorption behavior of papaya slices. Fruits (Carica papaya var. Sunrise) were peeled, seeds were removed and slices of 6 mm height were cut, followed by drying in a convective air-dryer, at 50 or 60 °C, 20 % RH and airflow of 4 m/s. The shrinkage was followed by capturing images every 30 min, using an optic microscope attached to the dryer. The moisture sorption isotherms were obtained using a vapor sorption analyzer, applying 25 °C, air flow of 120 mL/min and the water activity range from 0.1 to 0.9. As expected, papaya is a hygroscopic-porous matrix and had a considerable shrinkage at both temperatures. At 50 °C, the slice was reduced to 46.0 % of its original area, while at 60 °C, this reduction was 26.5 %. This could indicate that case-hardening occurs at a higher temperature, decreasing the shrinkage. Drying rates were calculated considering shrinkage and plotted against moisture content. From these curves, differences in the drying rate behavior were observed at 50 and 60 °C. In both cases, the constant drying rate was not observed. For 50 °C, two falling rate periods can be observed, while only one falling rate period was observed for 60 °C. This could indicate that at 60 °C, the drying rate is only controlled by moisture diffusion from the interior to the surface, while at 50 °C, vaporization occurs at the interior and has to diffuse to the surface. As for the moisture sorption isotherm, hysteresis was observed, which is typical for hygroscopic solids. GAB model provided a good fit (R^2=0.98) and monolayer moisture predicted using the model (0.106 g/g d.b.) is similar to those found in the literature.

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Extruded High Moisture Meat Analog (HMMA) fiber qualities are dictated by the product temperature gradient at the cooling die entrance

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ABSTRACT

Establishing cooling die scale-up criteria and optimized cooling die operation paradigms is essential to improve the economic viability of extruded High Moisture Meat Analogs (HMMA). This work aims to demonstrate how the heat transfer rate and subsequent product cooling gradient in the die dictate sample quality and are thus key HMMA scale-up criteria.

Wheat protein isolate at 45% moisture was extruded using 2 throughput rates (2.7 and 4.5 kg/hr), 2 cooling dies (tall/narrow and short/wide), and 4 die media inlet temperatures (36, 48, 60, and 72 °C). The Anisotropy Index (AI) was quantified using directional cutting tests, and die inlet pressure was monitored. Dimensionless correlations were developed to understand the convective heat transfer rates associated with the cooling process.

The AI had a positive relationship with die height ($p < 0.05$), and trends in die inlet pressure confirmed that higher applied shear rates and cooling media temperatures enhance slip-flow in the die. The calculated energy balance implied that enhanced sample anisotropy is associated with more exothermic in-situ phase changes ($p < 0.05$). The aspect ratio (height/width) of the cooling die channel was a parameter required to reconcile the dimensionless Nusselt versus Graetz heat transfer correlation that was developed.

This cumulatively implies that developing meat-like fibrousness in HMMA requires the correct amount of shear deformation of the extruded melt to take place before the product solidifies in the cooling die. Minimizing the cross-sectional temperature gradient through increased product thickness and wall temperature are thus key quality control criteria. Proof of concept experiments that maximized the die inlet section temperature showed this to be the case, with enhanced AI ($p < 0.05$) being found as the product temperature gradient in this section was correspondingly minimized. Industry can apply these findings directly to scaling up and optimizing their extruded HMMA cooling dies.

Edible mushroom's spoilage kinetics: linking structure to extent and rate of deterioration

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ABSTRACT

Understanding the role of structure in the degradation kinetics of physical and chemical attributes is essential to fully comprehend a food matrix and its potential deterioration during processing and storage. Mushrooms are a commodity in high demand, encompassing numerous species and types, all with short shelf lives and attributes easily altered during storage and processing. Hence, they constitute an adequate target to identify a link between internal structure, and physical and chemical deterioration. Four kinds of mushrooms (White-WM, cremini-CM, oyster-OM, and shiitake-SM) were purchased locally and stored at 12°C, RH=92%. Overall appearance and colour parameters were assessed using image analysis. Mechanical properties were evaluated using a UTM. Specimens at different storage time intervals were also fixated (10% formalin), chemically dehydrated (25 to 100% ethanol), and dried using a critical point dryer (Autosamdri®-931, Tousimis). Micro-computed tomographs (micro-CT) of the dry specimens were collected at the BMIT-BM 05B1-1 line (Canadian Light Source Synchrotron, SK, Canada). Micro-CT reconstructions were obtained with the UFO-KIT software (https://ufo.kit.edu/dis/index.php/software/) and microstructural differences, porosity and tortuosity, were estimated using Avizo (Thermofisher Scientific, MA, USA). WM exhibited the highest overall colour difference (~30 AU) and reduction in mechanical properties, followed by OM, SM, and CM. Regardless of the mushroom type, the gills' appearance and microstructure deteriorated faster than any other part, which could be attributed to their high surface-volume ratio. The OM's shorter shelf life correlates with its higher porosity (OM=0.81±0.01, SM=0.67±0.01, WM=0.65±0.04, CM=0.53±0.12), while the stability of CM colour and mechanical properties during storage was related to its lower porosity. This study presents valuable insights into relationships between structure, biochemical reactions and shelf-life. It also provides information on the internal structure of food, which plays a vital role in mass and heat transfer phenomena.

Degradation kinetics and bioaccessibility of beta-carotene from potato crisp fried in beta-carotene fortified sunflower oil

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ABSTRACT

Beta-carotene, a precursor to vitamin A is a health promoting bioactive and readily available from vibrant coloured fruits and vegetables. Co-consumption with fat/oils can enhance the absorption of beta-carotene in human body. This paper reports on the thermal degradation kinetics of 0.02% beta-carotene dissolved in sunflower oil at temperatures encountered during deep fat frying (160-220 ̊C). A network-based model for isomerisation and chemical degradation at these elevated temperatures is proposed, and the rate constant for each reaction in the network is reported. The results from the thermal degradation studies showed that even after heating for 30 min at 180̊C, 75-80% of the Beta-carotene remained in the sunflower oil, demonstrating the potential use of Beta-carotene fortified oils for frying. To assess the bioaccessibility of Beta-carotene, a human study was carried out in which 10 healthy volunteers (five males and five females) were fed potato crips (50g) which had been fried in Beta-carotene enriched sunflower oil at 180̊C for 2.5 min. Blood samples were collected prior to and every 1.5 h over a 7.5 h period post consumption, and beta-carotene concentrations in plasma were determined by LC-MS. The amount of crisp fed to each volunteer contained on average 5 mg of Beta-carotene, which corresponds to half the daily requirements of vitamin A. Relative to the fasting (baseline) sample, a significant increase ($p<0.05$) was observed in plasma beta-carotene concentration at 7.5 h post consumption of the potato crisps (0.21±0.11 µg/ml vs 0.45±0.17 µg/ml; $p=0.003$). Thus, it can be concluded that Beta-carotene is fairly stable and bioaccessible even after exposure to temperatures used during deep-fat frying. The co-consumption with fats/oils could have the potential to meet the dietary requirements of vitamin A and reduce vitamin A deficiency worldwide.

Keywords: Beta-carotene; Stability; Bio-accessibility; Degradation; Sunflower oil.

Poster Session 2: Modeling

Machine learning for calculating microbial survival curves during thermal processing from data obtained under constant conditions with come-up times

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ABSTRACT

Objective: Microbial survival models are indispensable in food processing calculations and control, ensuring compliance with stringent food safety and quality standards. Quite a few primary survival models with secondary models have been proposed to describe different patterns of microbial survival data. This causes inconvenience in using these models. On the other hand, machine learning, as an emerging tool, has been successfully used in a wide variety of applications. The objective of this study is to apply machine learning models to predict microbial survival curves during thermal processing based on the data under constant conditions with a come-up time (CUT), which is defined as the time taken to reach the target constant temperature.

Method: Two machine learning (ML) approaches, Support Vector Regression (SVR) and Gaussian Process Regression (GPR), which employed various kernel functions to measure input vector similarity, were applied to fit simulated microbial survival curves with come-up time dynamics based on the Weibull model. To enhance model accuracy, Adaptive Boosting, a boosting technique utilized as an ensemble method in ML, was integrated into both original algorithms. Furthermore, an innovative algorithmwas developed to convert survival data with CUT to those under the ideal constant conditions (CUT = 0) which were used to train the ML models.

Results: After testing different types of kernels such as the radial basis function (RBF), polynomial, and sigmoid kernels, we observed that the RBF kernel outperformed the others in terms of fitting quality. However, its performance was still unsatisfactory. To address this, the Adaboost algorithm was applied, resulting in a remarkable decrease in Mean Squared Error (MSE) values by up to 400%. This significant improvement paved the way for calculating microbial survival curves during thermal processing, which closely mirrored the simulated curves. Both Support Vector Regression (SVR) and Gaussian Process Regression (GPR) demonstrated resilience to overfitting, while also producing smoother curves compared to alternative ML algorithms.

Nonetheless, it's worth noting that kernel-based methods may struggle when faced with new data that falls outside the range of trained features, potentially leading to a failure of fitting.

Measuring the thermal death kinetics of *Salmonella Enteritidis* and *Enterococcus faecium* in finish drying conditions at constant temperatures and humidities

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ABSTRACT

Introduction:

Finish drying involves high-temperature and low-humidity conditions. There is a significant gap in understanding the microbial inactivation effect during finish drying.

Objectives:

To develop an isothermal and constant-humidity method to measure the thermal death kinetics of microorganisms at relative humidities (RH) between 0 and 30% and temperatures between 100 and 140 °C. To obtain the thermal death kinetics data of Salmonella Enteritidis PT30 and Enterococcus faecium NRRL B-2354 (surrogate) under finish drying conditions.

Methods:

Silica gel beads were conditioned at 100 °C and RH between 0-25% until equilibration in an oven with dewpoint temperature controlled using a customized device. The moisture content and high-temperature (80-140 °C) water activity (aw) of the conditioned silica gel were measured. Subsequently, conditioned beads were added into thermal water activity cells for RH control during isothermal treatments. Thermal resistance of S. Enteritidis and E. faecium inoculated on sands were measured at temperatures ranging from100 to 140 °C and RH between 0% and 30%.

Results

The moisture content of silica gel demonstrated a linear relationship with aw at specific temperatures (e.g., 100 °C), with aw increasing linearly with temperature. This characteristic makes silica gel an effective RH controller. The D-value of S. Enteritidis was measured as 23.3 minutes at 100 °C and 12% RH, and 2.1 minutes at 120 °C and 14% RH. Similarly, the D-value of E. faecium was 39.3 minutes at 100 °C and 12% RH, and 3.2 minutes at 120 °C and 14% RH. The Z-values for S. Enteritidis and E. faecium were 19.2 °C and 18.4 °C, respectively. As this research continues, more data will be reported.

Optimization, characterization, and kinetics of cold pressed linseed oil extracted using novel freeze thaw pretreatment

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ABSTRACT

Traditional extraction methods often compromise the oxidative stability of oil, whereas advanced non-thermal techniques can be costly, demand expertise and complex for large-scale use. In response to this challenge our research aims to introduce a novel freeze-thaw (FT) pretreatment to enhance the yield and quality of cold-pressed linseed oil while maintaining its stability. Employing Taguchi orthogonal arrays for pre-screening factors and Box-Behnken Design with Response Surface Methodology to optimize FT conditions. This FT pretreatment significantly increased the oil yield by 1.5 times, improved the antioxidant properties as indicated by increases in phenolic compounds (13.6%), DPPH activity (20%), ABTS assay (11%) and total tocopherol content. Scanning Electron Microscopy revealed cellular disruptions that facilitate these enhancements. Thermal analysis revealed a significant increase of thermal conductivity, thermal diffusivity and decrease of specific heat in the optimized FT linseeds. Comprehensive physicochemical assessments of linseed oil showed FT treatment does not affect the fundamental attributes of oil, such as acidity, viscosity, and fatty acid composition, with the oil remaining rich in polyunsaturated fatty acids. The kinetic approach including activation energy, activation enthalpies and entropies were found to be non-significantly different, highlighting the process's ability to maintain oil stability due to low temperature processing. This optimized FT approach not only boosts yield and antioxidants but also preserves the stability of oil, that offers an easy solution for efficient production to meet up the global oil demand.

Real time quality assessment, fault detection and process optimization of rice milling using computer vision and artificial intelligence.

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ABSTRACT

Aim

This research work is to develop an artificial intelligence (AI)-based automated real-time approach to evaluate the quality of rice products produced during the rice milling process by extracting milled rice physical features for quality analysis. Due to the flow volume of milled rice during milling processes, real-time image processing of rice milling frequently produces indistinct segmentation and classifications, which reduces the accuracy of the image analysis. However, real-time analysis can be accomplished by utilizing AI, computer vision, and machine learning (ML) approaches.

Method

Computer vision and image processing techniques have had great success in the food and drink industry. These technologies are used to acquire real-time rice images; the acquired images will be converted to grayscale, labelled frames for processing and extracting numerical data from the images. AI techniques such as the Mask R-CNN and YoloV8 for instance segmentation are computer vision task used for object detection, image feature extraction, pixel-level segmentation, and grain classification. It assigns the same pixel values to all objects of the same class, capable of predicting bounding boxes and class probabilities directly from raw images in real-time. Numerical data generated are used to create real time closed loop for process optimization. This technique evaluates the real-time physical characteristics of the milled rice, such as the length, width, and colour.

Result

First-stage image processing, segmentation, and classification do not perform well under ideal operating conditions, but with AI and deep learning, real-time analysis results were satisfactory with 98% accuracy.

Conclusion

This research work will assist industries in evaluating the real-time physical characteristics of milled rice, such as the length, width, and color. This project is critical to running an optimal operation for the rice milling process. It will enhance the long-term viability of the milling process and boost its operational effectiveness.

Modeling the inactivation kinetics of *Salmonella typhimurium*, *E. coli*, and *Listeria monocytogenes* in model acidified solutions using high pressure processing

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ABSTRACT

High Pressure Processing (HPP) has emerged as a promising non-thermal technology for enhancing food safety by effectively reducing microbial populations. It is commonly used for processing refrigerated juices to achieve a 5-log reduction in pathogens and extend the shelf life. In this study, we investigated the inactivation kinetics of three major foodborne pathogens, Salmonella typhimurium, Escherichia coli, and Listeria monocytogenes, in model acidified solutions using HPP. The aim was to develop predictive models to better understand and optimize the HPP process parameters for ensuring microbial safety in fruit juices.

Inactivation kinetics of the pathogens were determined at various combinations of acid type, pH, pressure (500, 600 and 700 MPa) and time (1-5 minute) using a laboratory-scale HPP system. We anticipate our results will reveal significant reductions in pathogen populations with increasing pressure and time, demonstrating the efficacy of HPP in microbial control. Using these data, predictive mathematical models will be developed to estimate the microbial reduction under different processing conditions. The models will validated using experimental data to indicating their potential utility for optimizing HPP parameters in industrial scale. Overall, this study contributes to the advancement of food safety strategies by providing a comprehensive understanding of the inactivation kinetics of common foodborne pathogens in acid juices using HPP, facilitating the development of targeted interventions to ensure the microbiological safety of fruit juice products.

Digitalization and automation for food industry – Training challenges

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ABSTRACT

Food industry requires a significant training for sustainable processing with recent challenges on digitalization and automation for industry 4.0 and beyond. Considering the dominancy of SMEs in Europe`s food industry, this has become a significant challenge to fulfil. The aim of this presentation was to present how the project EQVEGAN (European Qualifications & Competences for the Vegan Food Industry – https://eqvegan.eu) started to overcome these challenges including the technology transfer.

The EQVEGAN project has been funded by the European Commission through the Sector Skills Alliance Program. The vegan food sector was specifically targeted due to the change of the food industry with the driving forces of the consumer changes with an increased share of production by this industry. The WPs of the project included to define the professional profiles and skills, design of innovative trainings, prepare work-based learning guidelines and implementation of quality assured trainings with certification and recognition.

EQVEGAN included 15 institutions from 11 countries and covered diverse profiles including VET providers from ISCED levels from 4 to 7, companies, industry associations, food industry professionals and of teachers and researchers with government agencies. The Alliance designed and offered innovative trainings to professionals and students in 7 languages (English, Croatian, Finnish, French, Polish, Portuguese and Turkish) and developed a skills portal to promote a European scheme for job profile certification for recognition by the industry.

While the food and drink industry are the largest manufacturing sector in Europe, comprised mainly with SMEs, it has the lower rank for innovation potential. It is also challenged by requirement of sustainable and innovative processing requirements. This background indicates the significance of the EQVEGAN with its possible extension to the whole food industry. This background also coincides well with the challenges of environmental-friendly food processing under the umbrella of the European Green Deal.

Computational modeling of curcumin release from yeast-based microcarriers patterned by 3D-printing

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ABSTRACT

Cell-based microcarriers, such as yeast microcarriers, have recently emerged as effective encapsulation systems for a wide range of bioactive compounds. A critical aspect of their use in designing new food products with improved bio-functionality is the ability to predict the release of the compounds encapsulated in yeast carriers. This study developed a computational model to predict the in vitro digestion release of curcumin-a representative bioactive compound–encapsulated in yeast microcarriers that were patterned into cubic shapes by 3D printing.

The release of curcumin was modeled as a mass transfer phenomenon coupled with reaction kinetics during the intestinal phase of digestion. Two reaction-diffusion equations represented the transport of bile salts from the digestive fluids to the interior of the cube, and the diffusion of the complex formed by curcumin and bile salts from the interior to the cube's surface. First order kinetics equations described the interactions of bile salts with both curcumin and other yeast components. The solutions were computed using finite element-based commercial software, with the curcumin concentration retained in the cube as the predicted variable.

To validate the model, a bioink was formulated by mixing yeast loaded with curcumin and a pectin solution. The bioink was then used to 3D print cubic shapes. 3D-printing enabled to mimic various distributions of bioactives found in nature, including a core-shell distribution where curcumin-loaded yeast was localized in the core of the cube, and a uniform distribution, where curcumin-loaded yeast was uniformly distributed throughout the cube.

The results demonstrated that the model exhibited excellent agreement with the experimental data for the core-shell distribution, and a moderate agreement for the uniform distribution. Consequently, the model can be used to conduct virtual experiments and simulate bioactive release across various geometries, initial concentrations, and localizations of compounds.

Rapid detection of yeasts in food: An AI-based approach using convolutional neural network and generative adversarial network

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ABSTRACT

Yeast has a key role in the food industry, either as a fermentative organism to make diversity of beneficial products or as a spoilage organism, depending on their species and the food context. Traditional yeast characterization methods generally take 5-7 days, resulting in reduced efficiency for food quality control. Furthermore, common culture-based methods require significant analysis to discriminate yeast species. This study aimed to develop an AI-based method capable of discriminating yeasts in foods within 6h.

This study used seven yeast species, such as Saccharomyces cerevisiae, Galactomyces candidus, Rhodotorula babjevae, Yarrowia lipolytica, Debaryomyces hansenii, Wickerhamomyces anomalus, and Candida albicans. Our experimental approach involved cultivating these yeasts on soft YPD agar for 6h for microcolony formation. The images of these microcolonies were captured with a bright-field microscope at 20X and subsequently used for training a deep convolutional neural network model.

A generative adversarial network (GAN) was integrated to generate synthetic images of D. hansenii and R. babjevae, thereby enriching the diversity of the training dataset. With the yeast discrimination model integrated with GAN, the recall for D. hansenii increased from 84.9% to 90.3% and the precision for R. babjevae increased from 81.7% to 88.5%, which led to an increase in mean precision and mean recall of detection from 96.0% to 96.5% and from 96.3% to 97.6%, across the selected species of yeast respectively.

To validate the practical applicability of the model, the model was tested on tomato and tomato juice. The results demonstrated that the integrated yeast discrimination model can distinguish yeasts in the presence of food debris with a mean precision > 95.2% and a mean recall > 93.9%. This study suggests the potential of yeast detection with advanced AI technologies, offering a promising solution for a rapid and an automated quality control analysis process in the food industry.

Comparing nutrient permeability in purified and native mucus using a dynamic mucus model

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ABSTRACT

The mucus is the first barrier against the entry of foreign substances into human body. In vitro permeability studies often use purified mucus to reduce impurities, but its barrier properties may differ from native mucus. Due to challenges in accessing the mucosal layer, studies usually employ static models, which may not fully replicate in vivo conditions. This study developed a mucus model to simulate dynamic secretion and turnover of mucus under the impact of gastrointestinal fluid as it flowed above that. The model comprised three layers: the bottom layer served as a reservoir for buffer solution, circulating to mimic submucosal fluid; the middle layer served as a mucus reservoir; the top layer served as channel for food flow, enabling mass transfer through mucus layer. The permeability of native and purified mucus was compared to address the knowledge gap concerning the biorelevance of purified mucus. The purified mucus was prepared by diluting the native porcine intestinal mucus with normal saline followed by centrifugation. The gallic acid was used as an example nutrient. For testing, 1 mL of mucus was loaded in the middle layer, and a 1g/L gallic acid solution was introduced to the top layer at a 1 mL/min flow rate, with a 2 mL/min buffer circulation in the bottom layer. The samples were collected every 15 minutes in a 240-min experiment. The mucus permeability coefficient was calculated using Fick's first law of diffusion based on the come-up time of the steady state and the corresponding gallic acid concentration in the bottom layer. The results showed that the purified mucus exhibited relatively higher permeability compared with the native mucus. Through the construction of the model, we successfully simulated the dynamic behaviors of mucus and food during digestion and the results indicated the importance of material selection in mucus permeability studies.

Inactivation kinetics of *Bacillus cereus* spores in peracetic acid for aseptic package sterilization

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ABSTRACT

Peracetic acid (PAA) is a key sterilizing agent for aseptic packaging material and equipment sterilization. It is critical for maintaining product safety across food and pharmaceutical industries. This study focuses on developing a method to estimate the effectiveness of PAA against *Bacillus cereus*, a surrogate organism chosen to test sterilization efficacy. Spores of *B. cereus* were exposed to PAA at concentrations and temperatures of 23, 35, 45, and 55 °C, reflecting a range of conditions to ensure the study's relevance to commercial food manufacturing applications. The log-linear and Weibull models were used to create inactivation models for PAA, analyzing its sporicidal activity at these conditions. Parameters were estimated at a reference temperature of 50 °C for both models. The log-linear model estimated D values at various PAA concentrations of 300, 1500, 2500, and 3500 ppm were 0.14, 0.04, 0.03, and 0.01 minutes, with z values of 32.65, 33.39, 35.02, and 27.38 °C, respectively. The Weibull model showed δ values with similar trends and z values of 31.89, 33.43, 35.02, and 25.29 °C for the same PAA concentrations. The models' precision was indicated by root mean square error (RMSE) values ranging from 0.66 to 0.80 log CFU/ml, with relative errors under 3%. The inactivation parameters of PAA against *Bacillus cereus* underscores the study's contribution to enhancing sterilization protocols' reliability and effectiveness for industrial applications.

Integrating machine learning and simulation for enhanced torrefaction process optimization: A Study on agri-food residues

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ABSTRACT

Converting waste materials into higher-value goods has become a prominent emphasis in the search for sustainable waste management solutions. This study aims at predicting and optimizing the torrefaction process on agri-food residues.

A simulation code was developed using the Aspen Plus® flowsheeting for torrefaction. The validation was conducted using experimental results that had been obtained with a lab-scale batch fluidized bed torrefier on industrial hazelnut wastes and cherry cake.

Various machine learning (ML) models, developed in Matlab and/or Python, (e.g., ANN, SVM, KNN and ANFIS) were trained using the simulation data from Aspen Plus®. Artificial data are used in the training phase of learning models, in all those cases where real data are limited or expensive to obtain. This enables exploration of a broad spectrum of scenarios and conditions, facilitating the creation of extreme cases to assess the robustness of the models. Then, they were used to predict the outcomes of torrefaction (mass and energy yield, flowrates of torgas and torrefied solids), which were further cross-verified with the experimental results. Ultimately, a further prediction work was carried out with the best-performing ML models: while keeping the same feedstocks, some relevant properties of them were varied (e.g., moisture content), or some unexplored operating conditions were adopted (e.g., changing the inert gas), which had not been tested experimentally.

Additionally, the test of the developed ML models will be extended to new feedstocks, e.g., some ones not considered by the authors so far or successfully investigated by others in the literature.

The integration of process simulation with ML will enable the optimization of process parameters to enhance both the yield and quality of the products. This work not only improves waste management methods but also demonstrates the potential of combining simulation technology and ML to optimize operations in sustainable waste valorization.

Modeling the inactivation kinetics of Bacillus cereus spores in solubilized fibroin solution

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ABSTRACT

Silk fibroin is emerging as a novel coating biomaterial for shelf-life extension of perishable foods. Silkworm cocoons, a typical source of fibroin, may be contaminated with *Bacillus* species. In this study, the inactivation of *Bacillus cereus* spores in solubilized fibroin solution was investigated in a continuous stirred-tank reactor at 85, 90, and 93°C. The fibroin solubilization process had a significant effect on spore inactivation, with reduction levels raging from 1.4 to 2.1 log CFU/mL after 60 min. Logarithmic reductions of *B. cereus* spores were modeled with four different approaches, including log-linear, Weibull, biphasic, and Geeraerd models. Inactivation curves were best represented by the Weibull model according to several statistical criteria (R^2> 0.97, adjusted R^2> 0.97, mean absolute error (E(%)) = 1.62%, and Akaike probability = 0.385). The Weibull model was then combined with two empirical secondary models that satisfactorily described the thermal inactivation of *Bacillus cereus* spores in solubilized fibroin solution (R^2 = 0.955, R^2_{adj} = 0.953, and E(%) = 2.43%). A kinetic diagram was developed to quantitatively determine the reduction of *B. cereus* spores within a time-temperature combination range that preserves the fibroin mechanical properties. The outcomes derived from this investigation will assist the food industry to design and develop appropriate thermal processes for the safe manufacturing of fibroin-based coating materials.

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Robust quality and safety prediction in a blink: A deep-learning based tool

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ABSTRACT

Numerical simulation is a convenient alternative to detailed experimentation for optimization and innovation in food manufacturing. Such simulation-based product/process design tools critically depend on fast and accurate simulations. Although simplified and empirical models offer fast results, their limited physical insight and narrow applicable range make them undesirable as a design and optimization tool. At the other extreme, physics-based complex food process simulations are unwieldy and slow for performing practical "what-if" scenarios, providing a major bottleneck in digital food manufacturing.

The tool is built using a surrogate neural network model that is trained using the simulation results from a multiphase and multicomponent porous media-based mechanistic model of fruit and vegetable drying. Temperature, moisture content, and deformation from the mechanistic model validated well against experimental data. The training data, generated from the mechanistic model using a suitable sampling tool covered six food materials to ensure great robustness. The neural network architecture is truly innovative using a hybrid of a memory-retaining network combined with a deep dense network. Finally, the surrogate model is combined with kinetic models to predict important safety and quality parameters.

The surrogate model can make near-instantaneous (4-6 seconds) predictions in sharp contrast to those from a mechanistic model (~6 hours), with comparable accuracy. Of the 40 test cases, 25% showed an RMSE value of less than 2oC in temperature and 0.1 in dry basis (db) moisture content, while the median error was 5oC in temperature and 0.2 in db moisture content when compared to the corresponding solution from the mechanistic model.

The versatile digital tool (a smartphone-based App) with its robustness and quick predictive capability can aid in everyday product and process quality/safety design through rapid estimation and optimization, reducing experimentation, shortening time-to-market, and providing avenues for novel changes. The tool, built on an open-source platform, can be a perfect launching pad for many exciting future innovations in intelligent design and optimization such as digital twins.

Microwave drying and frying of foods: Predicting the heat and mass transfer by solving multiscale transport equations coupled with Maxwell's equations of electromagnetism

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ABSTRACT

Consumption of fried foods is linked with obesity because of their high oil content and calorie density. Pore pressure (the effective pressure on pore walls) inside foods becomes negative during conventional frying. As a result, the porous food matrix loses its resistance to oil uptake and develops a 'suction' potential. Microwave application is expected to increase the pore pressure inside the food during frying and consequently restrict oil penetration. Conventional frying and microwave drying models were solved for potato cylinders as preliminary steps to solving the microwave frying model. The microwave drying model predictions for volume-averaged moisture content and temperature profiles at two locations (center and 2 mm from the surface) in the sample agreed well with the experimental results ($\%MAE < 7\%$). For the conventional frying model, the $\%MAE$ for moisture content, oil content, and temperature at the center were 5.86%, 22.41%, and 12.61%, respectively. The validated model improved our understanding of the frying and microwave heating mechanisms. During conventional frying, evaporation and gas expansion led to high pressures in the food matrix with a peak gauge pore pressure of 0.17 bar at the center of the sample. As frying progressed, the moisture loss from the food led to increasing magnitudes of capillary pressure, which caused the pore pressure to decrease. As a result, the food matrix became more susceptible to oil penetration. During microwave drying, heat concentration was predicted and experimentally observed at the center of the sample. A peak gauge pore pressure of 0.95 bar developed at the center due to the rapid volumetric heating nature of microwaves. This supports the application of microwaves to increase pressure development during frying. In the next step, the microwave frying model will be built by coupling the transport equations for frying with Maxwell's equations. The model will be solved to generate insights about the mechanisms involved in microwave frying. Model validation experiments will be conducted using a microwave fryer prototype.

Evaluation of multiscale mechanisms of ultrasound-assisted extraction from porous plant materials: Experiment and modeling on this intensified process

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ABSTRACT

Ultrasound-assisted extraction (UAE) is an intensified mass transfer process, which can utilize natural resources effectively, but still lacks detailed mechanisms for multiscale effects. This study investigates the mass transfer mechanisms of UAE combined with material's pore structure at multiscale. Porous material was prepared by roasting green coffee beans (GCB) at 120 °C (RCB120) and 180 °C (RCB180), and their UAE efficiency for phytochemicals (caffeine, trigonelline, chlorogenic acid, caffeic acid) were evaluated by experiment and modeling. Besides, the physicochemical properties, mass transfer kinetics, and multi-physical field simulation were studied. Results indicated that positive synergy effects on extraction existed between ultrasound and material's pore structure. Higher mass transfer coefficients of UAE (GCB 0.16 min^{-1}, RCB120 0.38 min^{-1}, RCB180 0.46 min^{-1}) was achieved with higher total porosity (4.47 %, 9.17 %, 13.52 %) and connected porosity (0 %, 3.79 %, 5.98 %). Moreover, simulation results revealed that micro acoustic streaming and pressure difference around particles were the main driving force for enhancing mass transfer, and the velocity (0.29–0.36 m/s) increased with power density (0.64–1.01 W/mL). The microscale model proved that increased yield from UAE-RCB was attributed to internal convection diffusion within particles. This study exploited a novel benefit of ultrasound on extraction and inspired its future application in non-thermal food processing.

Studying and modeling the meltdown behavior of frozen desserts

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ABSTRACT

The meltdown test is an efficient tool widely and commonly used to characterize structural changes in frozen desserts resulting from different ingredients and processing conditions. A number of factors influenced the meltdown of ice cream, including the fat content, type of hydrocolloids, freezing, overrun, and viscosity. The objective of this work is to evaluate the role of mix viscosity on the meltdown (weight vs time) and shape retention of ice cream. Ice creams formulated with 0, 0.3, and 0.45% of stabilizer blend (guar gum, locust bean gum, carrageenan, polysorbate 80, and mono- and diglycerides) were used to obtain three levels of mix viscosity, low-, med, and high-viscosity (0.63, 1.25, and 3.35 Pa s at 10 s-1 of shear rate, respectively). The meltdown was gravimetrically determined, where 40-60 g of ice-cream were placed on a suspended wire mesh (6 holes per cm). The temperature of the ice-cream and dripped weight were continuously recorded throughout the duration of the test. The meltdown test was conducted at room temperature. The onset of meltdown increased with increasing the mix viscosity, from 1758 ± 88, 1968 ± 98, to 3020 ± 151 s for low-, med-, and high-viscosity samples, respectively. On the other hand, the values of meltdown rate decreased with the viscosity from 0.0125 ± 0.001, 0.0096 ± 0.0001, and 0.0035 ± 0.0001 % s-1 for low-, med-, and high-viscosity samples, respectively. The shape retention of all samples exhibited a sigmoidal behavior, where the values were 56.47 ± 1.96, 68.57 ± 6.22, and 78.47 ± 6.32% for low-, med-, and high-viscosity samples, respectively.

Poster Session 3: Packaging

Effect of dual-mode modified atmosphere packaging on extension of shelf life for assorted fresh-cut fruits

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ABSTRACT

Fresh-cut fruits are perishable due to continuous physiological reactions and potential bacterial contamination. Nowadays, modified atmosphere technologies are used to inhibit the deterioration of fruits, however, those processes need a pre-mixed gas.

The purpose of this study was to develop a one-step dual-mode MAP process to extend the shelf life of fresh-cut fruits, which was achieved by nitrogen flush and passive modification. Assorted fresh-cut fruits were packed in LDPE and/or permeable materials (P-film), nitrogen flushed for 10-15 sec, and sealed. Samples were then placed at ambient temperature for atmosphere passively modified before storage at 5°C, followed by analysis of quality including gas composition, texture properties, color difference (ΔE), and total bacterial counts.

The results showed the oxygen contents after nitrogen flushing were determined 5%, and decreased to 3% after passive modification for 2 hr. The average respiration rates of the LDPE and P-film groups were 0.79±0.10 and 1.72±0.38 mL/kg/h, respectively.

In terms of quality index, the MAP samples showed the hardness was preserved at 80% and up of initial values at the end of storage, and the ΔE for cherry tomatoes, papaya, and guava were less than 5, indicating no visible difference, where guava slices showed brownness on the cutting surface in controls.

Additionally, the microbial counts in the controls were 4.05±0.68-6.60±0.77 log CFU/g, which was significantly higher than those in both MAP groups (LDPE 3.06±0.21-5.45±0.39 and P-film 2.65±0.43-4.53±0.10) storage at 5ºC for 168 h, where no significant difference in microbial counts between the MAP groups.

In summary, a simple dual-mode MAP developed in this study demonstrates effectiveness in slowing respiration and then extending the shelf life of fresh-cut fruits.

Keywords: dual-mode MAP, fresh-cut fruits, permeable film, respiration rate, color difference

Development and characterization of pullulan biofilms using the response surface method for protection of blueberry and its phenolic compounds

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ABSTRACT

Currently, the use of plastics in food protection represents a serious contamination problem. Given the need to reduce the use of plastics in the food industry, the focus of researchers and industries is on possible substitutes for conventional materials of petrochemical origin. Pullulan is a polymer widely studied today, individually or in combination with other components, due to its potential in the production of biodegradable and edible films for food protection. The present work exposes the possibility of obtaining plastic-like materials from pullulan. A study is carried out based on an experimental design to evaluate the characteristics of the films obtained according to the concentration of pullulan used and the pullulan/sorbitol ratio, with sorbitol being the plasticizing agent used. From the experimental design, the significant variables are determined and one of the films is optimized so that it has the same characteristics as a commercial polyethylene plastic. Finally, it was decided to test the effectiveness of the film by using it as a container for blueberries. Due to the ability to add active ingredients to the films, vitamin C is introduced as an oxidizing agent to evaluate its effectiveness. The optimization of the mechanical properties of the films resulted in values considerably higher than those reported in the literature. The application of pullulan films, alone and in combination with ascorbic acid, showed a significant reduction in fruit weight after 5 days of evaluation. The application of pullulan films, alone and in combination with ascorbic acid, showed a significant reduction in fruit weight after 5 days of evaluation.

Developing a market specific shelf life model for ‘Bing’ sweet cherry (*Prunus avium*) under Modified atmosphere packaging (MAP) throughout the supply chain

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ABSTRACT

Sweet cherry, known for its short lifespan and high sensitivity to temperature, faces numerous challenges during intercontinental shipments, demanding a tool for real-time shelf-life monitoring sensitive to temperature variations, crucial for all stakeholders involved. This study focuses on the 'Bing' cultivar, commonly exported from the USA.

Respiration rates, indicating O_2 consumption and CO_2 production, were determined at 0, 4, 8, and 13°C to derive model parameters for the Arrhenius equation (E_a (O_2) = 106 kJ/mol, E_a (CO_2) = 104 kJ/mol). Gas composition (O_2 and CO_2) under MAP was assessed via gas analyzer to validate mass balance estimations (R^2 =0.92). Shelf life estimation relied on color and firmness assessments. Color was quantified using hue spectra fingerprinting, while firmness was gauged using FirmTech, providing a firmness factor based on the stress-strain curve. Correlations between red saturation, green saturation, and firmness factor with gas composition were determined via partial least squares regression. An inverse function was derived from partial least squares model parameters, offering shelf-life predictions based on predefined endpoints. Validation was performed using retailer stated shelf life endpoints, assessing three temperature abuse scenarios: extreme, moderate, and none. The model was developed based on the change in color and firmness; hence, cherry with superior initial quality has a longer shelf-life.

During transportation, real-time temperature data serves as an input for the model, enabling estimation of the time required to reach predefined endpoints at the current temperature. Consequently, deviations from optimal temperatures may alter the time needed to reach these endpoints. This adaptable shelf-life model exhibits potential applicability across various fruits and products. Training the model parameters with relevant quality metrics and kinetic data enhances its efficacy and versatility for broader applications. To further improve the application, the model can be integrated with cloud computing to get the real time shelf life estimation.

Development of dual-function label for temperature indication and antibacterial activities

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ABSTRACT

Food safety and the cold chain are inseparable in the food industry, particularly, the cold chain ensures food products are at an appropriate temperature throughout transportation and storage, which prevents food spoilage and bacterial growth. However, once temperature abuse occurs, consumers usually are not aware of it. Therefore, the development of smart labels with dual functions of temperature-sensitive and antibacterial effects is necessary.

This study aimed to develop a dual-function label in smart packaging imparting critical temperature indication and antimicrobial activities. A thermochromic substance, crystal violet lactone, was mixed with a phenolic compound and fatty acids to prepare a thermo-sensitive indicator, in which thymol was used to serve as a co-solvent and antimicrobial agent. Smart functions were analyzed by melting properties, coloration, liquid movement, and antimicrobial activities.

The results demonstrated the reagent melted at 7ºC and converted from blue into azure color, indicating a visual response. The color difference (ΔE) between below and above 7ºC was > 5, particularly derived from a decrease of b* values, showing a visible difference. Following, the sensing reagent was immobilized on a filter paper to form a smart label, and subjected to temperature abuse tests. The distances of the melt reagent moving along the label were 3.5-7.0 and 5.0-8.5 cm from refrigeration to 10 and 25ºC for 10-30 min, respectively. The antimicrobial activities of the label containing 75 µL thymol against Salmonella and Listeria were obtained by the clear zones to be 2.70 and 2.10 cm, respectively.

In conclusion, the smart label prepared using crystal violet lactone, thymol, and fatty acids showed a visible difference at the temperature above the cold chain and duration, and also functioned to inhibit microbial growth.

Keywords: smart packaging, temperature-sensitive, antimicrobial, color difference, cold chain

Extrusion processed corn starch film reinforced with *ginkgo biloba* leaves-derived carbon nanodot for active food packaging applications

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ABSTRACT

This research hypothesized that application of Ginkgo biloba-derived CNDs in corn starch film can potentially enhance the antioxidant properties of the resulting composite, thus making it a compelling candidate for active food packaging applications. The main objectives of this research are 1) to develop extrusion-processed corn starch films reinforced with CNDs extracted from Ginkgo biloba leaves and 2) to evaluate various physicochemical properties 3) to assess functional properties by food application test to provide insights into their applicability in preserving food quality as active food packaging materials.

In this study, environmentally sustainable carbon nanodots (CNDs) were synthesized from *ginkgo biloba* leaves using a facile hydrothermal method. The green synthesized CNDs were characterized using high-resolution transmission electron microscopy (HR-TEM), which revealed that they had a diameter under 10 nm and were evenly dispersed. The CNDs were then incorporated into a corn starch (CS) matrix via an extrusion process to fabricate a CS/CNDs composite film for active food packaging applications. The effects of various CND concentrations on the physicochemical and functional properties of the CS/CNDs composite films were systematically investigated. The incorporation of CNDs into the CS film improved its mechanical, oxygen barrier, UV blocking properties, while also endowing it with antioxidant properties. Furthermore, the CS/CND composite film was used as an active packaging material for omega-3 oil, which is susceptible to rancidity and was found to significantly extend its shelf life due to the superior antioxidant activity of CND.

These findings suggest the developed CS/CNDs active composite film is a promising candidate for environmentally sustainable solutions for enhancing food shelf life and reducing food waste.

Development of antimicrobial biopad for enhancing storability of fresh strawberry packaged in clamshells

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ABSTRACT

Justification: Strawberries are prone to rapid spoilage due to factors such as microbial infestation, mechanical damage, or texture degradation. Foam pads commonly used for packaging are typically made from expanded polystyrene (EPS), characterized by low-density cell structures with high impact resistance and thermal insulation. Unfortunately, EPS is not biodegradable, posing environmental challenges. The environmental issues associated with petroleum-based foam pads could potentially be mitigated by biodegradable alternatives.

Objective: This study aimed to develop a nanocellulose-incorporated biopad with an enhanced porous-network and antimicrobial effect, and to evaluate its application in enhancing the quality of fresh strawberries during refrigerated storage.

Methods: Thermally insulated and hydrophobic biopads were fabricated using hydrogel and organogel Pickering emulsions incorporating nanocellulose. Various treatment factors were considered, including types of nanocellulose (cellulose nanocrystal/nanofiber), polysaccharides (methylcellulose, chitosan, and starch), and concentrations of nanocellulose (0.1-2%, wet basis). Each biopad was analyzed for physicochemical, mechanical properties, morphology, and antimicrobial activity. The quality changes in strawberries were assessed based on color, weight loss, appearance, firmness, and mold growth. Data were analyzed using ANOVA with Fisher's LSD test ($p<0.05$).

Results: The density of various biopads ranged from 0.05 to 0.5 g/cm3. Biopads exhibited water vapor absorption rates of approximately 14-27%, water absorption > 40%, fully soluble after 24-hour soaking, and water contact angles ranging from 42 - 66°. These results indicated that the biopads possessed hydrophilic surface properties, making them susceptible to water absorption and subsequent de-structuring, thus qualifying them as biocompatible and biodegradable pads. Morphology results demonstrated porous structures on the surface and cross-section of all biopads. In strawberry applications, the control group without biopads exhibited mold growth on a range of 5 - 24% strawberries, while the biopad-treated groups showed no mold growth for 2-week refrigerated storage. This study demonstrates the effectiveness of biopads for enhancing biodegradability, water or water vapor absorption, reducing density, and maintaining porous structure, thus enhancing qualities for fresh strawberries.

Biodegradable and light-activated antimicrobial materials for food preservation

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ABSTRACT

The increasing human population and the consequent increasing demand for food and energy has resulted in damage to both the environment and public health. Among the main factors negatively affecting the environment and human health are the continuous increment in plastic pollution and the ingestion of microplastics from the processing and packaging of foods, as well as microbial contamination. Some alternative methods to reduce the environmental and human health impact of food production are the concepts of Hurdle Technology and Antimicrobial Biodegradable Packaging. In Hurdle Technology, multiple agents are applied to food materials (sequentially or simultaneously) to induce changes that increase the shelf life and ensure the safety of the final product, while using a lower energy input without causing major quality losses. In this work, we prepared a blend of modified poly(lactic acid) and chitosan, and challenged it against Gram-positive and Gram negative bacteria, with and without additional hurdles. The results showed that this material was able to inactivate below the limit of detection (~ 5 logarithmic reductions) both types of bacteria in apple juice when accompanied with mild heat (50 °C) within 15 min. We also explored the possibility of using UV-A light as a hurdle, due to its ability to penetrate deep within samples (solid or liquid) and enhance the antimicrobial effect of cationic polymers. When exposed to UV-A irradiation, apple juice samples inoculated with Gram-positive bacteria achieved reduction below the limit of detection within 2 h. However, the exposure to UV-A light was less effective against Gram-negative bacteria, resulting in 2 – 4 logarithmic reductions. The antimicrobial blend also exhibited stability as it was confirmed through surface characterization analysis (microscopy techniques and infrared spectroscopy), which corroborated the preservation of chemical integrity (through the preservation of characteristic chemical groups) and absence of bacterial fouling.

Exploring the utilization of upcycled almond protein in extrusion processing to create nutritious direct expanded snacks

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ABSTRACT

This study aimed to understand the viability of upcycled ingredients from almond press-cake in direct expanded products using extrusion processing. The specific objectives included, to evaluate the impact of the inclusion of almond protein into rice flour for the development of extruded direct expanded snacks. To develop a profile of the proximate analysis of almond protein flour and observing its functional properties to better understand its viability as an ingredient. Understanding the interactions between the almond protein within rice flour through extrusion processing. The methods used in observing potential interactions in this study include proximate analysis (starch, ash, protein, fiber, fat), thermal properties (DSC), functional properties (WAI/WSI and Pasting Properties) and extrudate characteristics (Expansion ratio, WAI/WSI, Texture profile). We used a BRABENDER co-rotating twin-screw extruder with a die size of around 3.15 mm varying the treatment levels to three screw speeds (300, 400, 500rpm) , three moisture contents (18%, 20%, 22%), and three inclusion levels (5%, 15%, 25%). Looking at some preliminary data, visual changes to the surface structure and appearance were apparent for increasing inclusion of almond protein within the expanded products. Changes were seen in the air bubble structure, product color, and expansion ratio. Expansion ratio also coincided with the screw speed of the extruder, with increasing speeds leading to smaller average expansions. Some correlations may be drawn from screw speed and air bubble structure, as within inclusion levels, smaller air bubble formations were seen at higher screw speeds. Highest expansion readings occurred at 15% inclusion of protein, though with the variation of the other treatment parameters also showed the smallest expansion readings at the same inclusion level. Full study will include a Box-Behnken design to model the response to the process parameters to show what parameters will improve overall characteristics of almond direct expanded snacks.

Engineering packaging for a sustainable food chain

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ABSTRACT

There is high level of inadequate methods at all level of food supply in the global food industry. The inadequacies have led to vast wastages of food, hence there is need to curb the wastages that canlater have effect on natural resources, water resources and energy to avoid negative impact on the climate and the environment. There is need to engage multifaceted engineering packaging approaches for a sustainable food chain that will ensure active packaging, intelligent packaging, new packaging materials and sustainable packaging system.

Packaging can be regarded as indispensable components approach that can be applied to solve majorproblems of sustainable food consumption globally; this is about controlling the environmental impact of packed food. As earlier stated, scientific innovation will definitely solve the problem of food wastagesand eliminate diseases associated with ineffective food packaging.

The creative innovation will ensure packaged foods are free from food borne diseases and food chemicalpollution. This paper evaluates the key shortcomings that must be addressed by innovative food packaging so as to ensure safe natural environment that will preserve energy and sustain water resources. Certain solutions which include fabrication of microbial biodegradable chemical compounds/polymers from Agro food waste remnant appears a bright path to ensure a strong and innovative wastebased food packaging system.

Over the years, depletion in the petroleum reserves has brought about the emergence of biodegradable polymers as a proper replacement for traditional plastics; moreover, increase in the production of the traditional plastics has raised serious concern of environmental threat.

As a matter of fact, biodegradable polymers have proven to be biocompatible in nature which can as well be processed for other useful applications.

Therefore, this study will show case workable guiding framework for designing sustainable food packaging system that will not constitute danger to our present society and that will surely preserve natural water resources, because it will take the entire life cycle of food package into considerations with strong emphasis on complete prevention of food losses in the process of packaging design.

Various assessments methods will be deployed at different stages of the packaging design, in order to enhance the sustainability of the package. Every decision that will be made must be facilitated with methods that will be engaged per stage so as to allow for corrective measures through the cycle in the design process.

Basic performance appraisal of packaging innovations Food wastages can result to inimical environmental impacts, and ethical practice must be carried out majorly for food loss at homes. An examination conducted in West Africa quantified preventable food wastages over the entire food value chain at almost 180kg per person in a year. That is preventable food wastages, 35% of which originated at household level.

Many food losses reported, happened at the harvesting, storage, transportation, and processing stages are not preventable, which are without much environmental impact because such wastages can be used for feeding. Food wastages happening at homes and in many eateries are mostly preventable; furthermore, lost food materials do no find alternative use and are always completely lost. Other surveys have shown that 15%-20% household food losses can be traced to food packaging.

Therefore, new innovative packaging systems can lessen the environmental effect of food wastages so as to extend shelf-life in order to lower food loss in the process of distribution chain and at the household level.

Moreover, there is need for extension of secondary shelf life after package opening process, it should receive future research attention so as to further reduce food wastages at homes.

Nevertheless, to appraise the balance between technological innovation and environmental safety, the environmental effect of packaging innovations and food wastages must be scrutinized through the life-cycle assessment (LCA) methodology (including raw material extraction and processing, packaging manufacture, transport, and retail, and disposal of food and packaging, even at the household level) in addition to assessing the effect on food shelf -life or packaging features such as optical, physical, thermal, and mechanical properties.

Water demand in food manufacturing – usage and trends

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ABSTRACT

The food industry, a major water consumer, is facing significant environmental challenges (i.e., depletion of freshwater resources due to climate change) that are building up pressure on food security – as the global population is growing, both food and water demand for food production are expected to increase too. In this context, this work identifies water consumption hot spots in food manufacture processes, which will help to allocate resources more effectively and create a more sustainable food chain.

Water usage data was collected from literature and clustered by product and processing technique. Before analysis, data was transformed into standard units when needed/possible.

Findings show that the meat and dairy sectors are the most water intensive ones – water is systematically used to rinse/clean surfaces, pipework and vessels and thus guarantee hygienic standards; however, most cleaning-in-place (CIP) protocols are based on very conservative and outdated protocols, which could be significantly optimised. Similarly, literature reveals scope for further improvement of sterilisation and pasteurisation operations used in packed foods (e.g., pouches, cans, jars) - alternative preservation techniques, like microwaves or pulsed-electric-field (PEF) are being slowly introduced in the sector, so heat could be generated without using water/steam. Water is also a main component in the formulation of a number of food products, although in most cases is removed either by evaporation or sublimation, through drying or freeze-drying processes. Therefore, processing of dough-based products, as well as processing of powder foods and ingredients, constitute a major source of water consumption, too. Finally, this study has analysed water usage per location too, revealing those areas/countries more compromised by climate changes and draught.

The outcomes of this work constitute valuable information for the sector and policy makers that can help to re-evaluate current environmental and manufacturing strategies, increasing sustainability and security of food chains.

Application of turmeric and propolis extract for smart and active sheets based on potato starch obtained using extrusion technology

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ABSTRACT

Currently, there is interest in the improvement of biodegradable plastics for food storage. The objective of the present study was to evaluate the effects of turmeric and propolis extracts on the smart and active properties of potato starch-based sheets by extrusion. The moisture (11,25g/100 g of starch and 4,76 g/100 g of bagasse) and amylose content (21.56% amylose, 78.41% amylopectin) of potato starch and bagasse were characterized. Formulations with potato starch and bagasse (control film, CF), CF with turmeric (CF-T), CF with propolis extract (CF-PE), and CF with T and PE (CF-T-PE) using water and glycerol as plasticizers were processed in a twin-screw extruder (speed: 80 rpm. Temperature profile 60-75-90-100-110-110-100-95 °C and 95 °C in the film-die zone). Smart sheets were characterized by physical properties, such as moisture (17,76-20,43 g/100 g of film) solubility (18,94%-19,51%), and thickness (0.78-1.09 mm). In relation to mechanical properties, tensile strength test resulted in values up to 3.5 MPa (CF-T) and 3.28 MPa (CF-PE) and elasticity values between 71,42% (CF-T) and 84,28% (CF-PE). Regarding the smart properties, sheets with turmeric showed a significant color change on the *CIELab* scale when put into acidic (pH = 4) and basic (pH = 10) media with respect to neutral (pH = 7), using buffer solutions: ΔE=6.15 and ΔE=22.31 for CF-T, and ΔE=15.09 and ΔE=18.93 for CF-T-PE, while CF only presented ΔE=2.39 and ΔE=2.18, respectively. Likewise, the CF-T film showed the same change when the sheet was in contact with pork trials for three days. The disk assay with *E. coli* and *S. aureus* showed antimicrobial activity for S. aureus for all except CF; a halo was noticeable for CF-T (d=1 cm) and CF-PE (d=1.2 cm). In conclusion, sheets have proven to be smart and active in food applications.

Poster Session 4: Engineering Properties

Impact of acidification and calcium addition on the high-pressure and thermal gelation of pulse protein concentrates

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ABSTRACT

Driven by environmental, ethical, and health concerns, the demand for plant protein-based food products is increasing globally. Despite this demand, current market offerings fail to meet consumer expectations for high protein, ‘clean label’ alternatives. Pulse proteins offer a promising solution: they are readily available, cost-effective, and exhibit useful functionalities such as gelation, making them ideal candidates for optimization for use in semi-solid food applications such as yogurt, cheese, and meat alternatives. High pressure processing (HPP) has emerged as a ‘clean label’ method for inducing pulse protein gelation without compromising organoleptic and nutritional quality. To maximize the utility of this approach for food processors, this study investigates the effects of acidification (starting pH: unadjusted, 5.5, 4.5) and Ca^{2+} level (0, 10, 20, 30 mg Ca^{2+}/g protein) on the structure and texture of HPP- and heat-induced pulse (pea, faba, lentil) protein concentrate gels. Gels were evaluated by rheological, texture, and water holding capacity analyses. Both acidification and the type of processing had a significant impact on the resulting gels’ structure and texture. Heat-induced gels had comparable or greater water holding capacity and gel strength than HPP-induced counterparts, while HPP-induced gels were more cohesive than heat-induced gels. Acidification resulted in higher gel strength for both HPP- and heat-induced gels and increased hardness of HPP-induced gels. The effect of Ca^{2+} level depended on both acidification level and processing method. At unadjusted pH or pH 5.5, increasing Ca^{2+} addition reduced cohesiveness and hardness in heat-induced gels, but increased strength and hardness in HPP-induced gels. These findings can inform new food product formulation by offering a pathway to a range of gel characteristics achievable in pulse proteins through adjusting processing and formulation.

Structural and functional analysis of potato starch and protein blends for plant based-meat analog applications

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ABSTRACT

Plant-based meat analogs garner significant attention as sustainable and health-promoting alternatives to traditional meat. Despite mimicking the taste of meat, these analogs often lack the desired texture and flavor, impacting consumer acceptance. Recent studies have demonstrated that incorporating starch into proteins during high moisture extrusion enhances protein aggregation and texturization, imparting distinct thermal, rheological, and water-holding properties compared to their pure counterparts. This study aims to investigate the thermal, pasting, microscopic, and water-holding characteristics of potato starch, soy protein, whey protein, and their respective starch-protein blends.

Samples of potato starch (PS), soy protein (SP), whey protein (WP), and blends of Potato Starch-Soy Protein (PS-SP) and Potato Starch-Whey Protein (PS-WP) were prepared in 1:9 and 2:8 starch-to-protein ratios. Pasting properties were analyzed using a Discovery DH-3 rheometer equipped with a starch pasting cell, replicating RVA pasting analysis. The thermal profile included heating from 50°C to 95°C at 6.0°C/min, holding at 95°C for 5 minutes, cooling to 50°C, and holding for an additional 3 minutes. Potato starch exhibited a peak viscosity of 4.138 Pa.s at 61.61°C, while WP showed a peak viscosity of 0.092 Pa.s at 95.54°C. The 1:9 PS-WP blend demonstrated an increased peak viscosity of 0.123 Pa.s at 95.71°C and further increased for 2:8 PS-WP as compared to WP, with similar trends observed for PS-SP blends. Pasting profiles will be examined at 120°C and 140°C to simulate extrusion processes.

Differential scanning calorimetry (DSC) was used to understand the thermal properties of the samples. DSC indicated a gelatinization temperature of 59°C for potato starch, correlating with the pasting profile's peak viscosity. The water-holding capacities of proteins, starches, and blends were determined, revealing a decrease with higher starch content. Confocal Laser Scanning Microscopy (CLSM) was employed to analyze the microstructure and spatial distribution within the starch, protein, and starch-protein blends, providing further insights into their structural properties.

Exploring the mechanism of protein texturization: Role of additives (L-ascorbic Acid, azodicarbonamide, and hydrogen peroxide) in modifying the texture of high moisture meat analogs from wheat protein isolate

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ABSTRACT

The need for sustainable and high-quality meat analogs has driven the exploration of additives to improve the texture of plant-based proteins. Literature suggests that the formation of disulfide bridges is critical for the texturization of high moisture meat analogs (HMMAs). This study aimed to understand how chemical modifiers (ascorbic acid, azodicarbonamide, and hydrogen peroxide) affect disulfide linkages and subsequently influence the texturization of wheat protein isolate (WPI).

Extrusion was conducted on a co-rotating twin-screw system with a cooling die attachment. Temperatures were set to 50ºC, 50ºC, 140ºC, 140ºC, 140ºC starting from the feeding zone; the cooling die was set to 60°C. The total feed rate was 80 g/min. The modifying compounds were blended with wheat protein isolate at varying concentrations (0.1%, 0.5%, 1%, and 2% w/w), and were then extruded at two different input moisture levels (45% and 60% w.b).

The extrudates were analyzed for their textural, rheological properties, microstructure, and physicochemical characteristics. Besides that, analyses on protein solubility, hydrophobicity, protein structure, molecular weight, and disulfide and carbonyl groups were conducted to better understand the mechanism and protein folding dynamics during texturization.

Significant differences in the process parameters and the texture of the extrudates were observed in the presence of the modifiers. Specifically, azodicarbonamide and H_2O_2 decreased the hardness of the products under certain conditions by up to 80% and 35%, respectively. Addition of ascorbic acid, on the other hand, led to harder (20%) extrudates compared to the control. Specific mechanical energy was also reduced at 45% moisture content after the addition of 0.5% azodicarbonamide (by 20%), 2% ascorbic acid (by 29%), and 1% H_2O_2 (by 4%). Besides that, higher concentrations of modifiers generally improved color and elasticity in the products, which are essential for replicating the texture of meat.

This research adds to the existing knowledge of HMMA manufacturing by showcasing how chemical modifiers can manipulate textural properties through molecular interactions and structural modifications.

Investigating the stability of supercooled states under mechanical stress

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ABSTRACT

Supercooling technology, which allows foods to remain fresh below freezing points without ice formation, has been recognized as a promising solution to preservation challenges. However, the thermodynamic instability of supercooling behavior poses a significant challenge. In this study, we present findings on the stability of the supercooling protocol utilizing an oscillating magnetic field (OMF) condition that significantly enhances the stability against various macroscopic disturbances. Agar gels were exposed to varying degrees of rotational motion from 0 to 200 RPM under an OMF for 24 hrs within an open chest freezer using an orbital shaker. In addition, further stress testing was conducted employing a vibration table equipped with a stepping motor with a scotch yoke mechanism to account for lateral and longitudinal vibrations. The magnitude of vibrations and shocks were measured by using a 3-axis accelerometer. Each experimental setup involved testing 8 samples per trial with 5 repetitions per experimental condition. OMF-assisted supercooling (12mT, 5 Hz) maintained samples in supercooled states at -5 °C, thereby enhancing the stability against vibration induced by the orbital shaker, especially at speeds up to 200 RPM (equivalent to 5.052 ± 0.127 N obtained at a single axis. Notably, the probability of the samples treated with OMF remaining in the supercooled state was 96.25 ± 8%. However, this method did not significantly affect resistance to forces induced by the Scotch York mechanism. The peak force measured 6.004 ± 0.039 N, the probability of supercooling dropped to 22.62 ± 7%, and it decreased to 0%. This study highlights the potential of supercooling technology to preserve perishable foods within a simulated cold chain environment, even under mechanical stress. OMF-assisted supercooling can improve food safety and quality during transport and storage by managing vibration forces.

Characterizing and predicting the foaming properties of dairy ingredients using Hyperspectral Imaging technique

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ABSTRACT

Justification:

Milk protein isolates (MPI) and Whey protein isolates (WPI) are milk powders with a protein content of greater than 90%. These ingredients find diverse applications in various foods for their nutritional and functional benefits. Currently, there is an increasing demand for milk powder products to meet functional attributes including foaming properties. However, alteration of these ingredients via treatment with varying range of temperature, relative humidity and storage time might potentially change the functionality when reconstituted and used in various product applications. Conventional evaluation methods are time-consuming and destructive. Hyperspectral Imaging (HSI) system, combining imaging and spectroscopy, offers a rapid and non-destructive alternative to evaluate product characteristics.

Objective:

The ongoing study is aimed at utilizing hyperspectral imaging technique to characterize and predict the foaming properties of dairy ingredients in real-time.

Methods:

Functional properties such as foaming capacity and foam stability of MPI and WPI products were determined using standard analytical procedures. ANOVA was used to determine differences at a significant level of ($P<0.05$). Functional properties were characterized and predicted by correlating reference values from traditional methods with hyperspectral data of the same sample, utilizing a line scan camera mode of HSI within the wavelength range of 360-1100nm. Calibration models were then developed using HSI techniques coupled with multivariate statistical analysis to enable real-time prediction of desired functional properties.

Results:

The comparison between untreated and treated samples revealed a significant difference ($p < 0.05$) in both foaming capacity and foam stability of the protein solution. Across various combinations of temperature, storage time, and relative humidity, the foam activity and foam stability ranges for WPI and MPI were observed to be (23.92-123.45mL/g; 3.75-10.83%) and (280.09-543.21mL/g; 65.37-89.52%), respectively. The developed prediction model exhibited a decreased mean squared error (MSE) and improved coefficient of determination ($R^2 > 0.95$), indicating enhanced model accuracy and performance.

The application of radio-frequency cold plasma on modification of pea protein isolate

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ABSTRACT

Cold plasma is a sustainable and green technology that shows promising application to modify plant protein (PP) ingredients. Pea protein isolate (PPI) possesses unique attributes when compared to all other PP isolates; hence the demand for PPI as ingredients in the development of different food formulations by the food manufacturing industry is rising. However, the functionality challenges associated with the use of PPI as an ingredient in food formulations limit their use. One of the functionality challenges is low solubility. Hence, in this study, radio-frequency-generated plasma energy from a mixture of gasses (CO_2/ Ar) was used for the structural surface modification of PPI. To achieve the optimized process conditions of RFCP on the maximum solubility of PPI at two pH conditions (pH 3.4 and pH 7), a response surface methodology (RSM) design was used. Experimental conditions such as power levels (0, 60, and 120 W); time (10, 15, and 30 min), and flow rate (15, 25, and 35 sccm) were considered. The data obtained from the experimental design was fitted to a second-order polynomial equation. The results at pH 3.4 showed that at power level 67 W, time 14 min, and flow rate 23 sccm resulted in a max solubility, thereby increasing the solubility to 7.0% from 5.5% for the commercial PPI, essentially causing a percentage increase of 27.3%. Similarly, the results at pH 7 showed that power level 98 W; time 14 min; and flow rate 14 sccm resulted in a max solubility of 13.0% from 11.3 % which caused approx. a 15% increase. The current data shows that the RSM could be a useful mathematical tool to optimize and customize the solubility of PPI; however, the cost associated with cold plasma treatment should be justified for a meaningful change in protein functionality.

Comparative gel ability and emulsifying capacity analysis on 20 different soybean genotype varieties

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ABSTRACT

Soybeans, as a fundamental crop in global food production, exhibit diverse functional properties that are crucial for various food applications. Nevertheless, the substantial genetic diversity among soybean seed varieties cultivated in the United States significantly influences the molecular profile and functionality of soybean proteins. This diversity provides an excellent opportunity to explore and leverage the unique attributes of soybean proteins across various applications in the food and agricultural industries. In this research, we conducted a comparative analysis of gel-forming ability and emulsifying capacity across 20 distinct soybean genotypes. Each genotype underwent comprehensive characterization, including compositional analysis, protein profiling, and molecular characterization. Proteins were extracted using alkaline extraction and isoelectric precipitation, and then their gelation and emulsification properties were investigated. The rheological assessments showed varying gel elasticity and strength across genotypes. Some genotypes exhibited exceptional gel-forming ability, likely due to unique protein profiles, including distinct subunits of β-conglycinin. Additionally, different genotypes showed different levels of emulsion stability, and some genotypes were more effective at emulsifying. These findings underscore the significance of genetic diversity in shaping soybean protein functionality. By understanding these genetic variations, food engineers can optimize soy protein applications, enhancing sensory appeal and promoting sustainability. Ultimately, this research facilitates the development of innovative soy-based products through the precise selection of new soybean genotypes for food applications.

Impact of corn meal particle size on mechanical and physical properties of ultrasonically compacted nutrition bars

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ABSTRACT

Ultrasonic compression of cereal flours to produce nutrition bars is a novel technique during which a temperature rise leads to binding of particles. Therefore, less use of binders prevents undesirable textural changes during storage. Ultrasonic welding parameters and particle size affect the texture of bars. The study aimed to assess the effect of particle size on the physical and mechanical properties of bars by ultrasonic welding.

Corn meal (average particle size of 920 micron) was sieved to produce four particle size fractions designated as small, medium, large, and extra-large. They were hydrated to 22 percent moisture content and processed at ultrasonic weld energy of 2400J-3100J and percent weld amplitudes of 60-85. The temperature was measured with thermocouples placed inside the mold and force and energy development were monitored during the process and weld time was determined. Moisture loss and compaction during the process were calculated. Mechanical properties were determined by using three-point bend test and breaking strength was calculated for the bars made from each fraction.

Average particle sizes were 245, 530, 1030,1461 microns for small, medium, large and extra-large particles respectively. Temperatures inside the bars reached to 121 °C for extra-large particles and 130 °C for small particles at 60% amplitude and 2750J. The bars from extra-large particles had a fracture stress of 126.5 kPa while from small particles was 186.7 kPa. Compaction of bars from extra-large particles 25.2 and from small particles were 46.8 percent. Breaking strength and the compaction of bars were inversely proportional with average particle size at the same welding conditions.

Firmness of bars is correlated with the denseness of bars. The denseness of bars can be regulated by particle size. This information provides the opportunity to adjust the processing conditions to fabricate bars at varying firmness levels desired by consumers.

Mushroom protein nanoaggregates with enhanced functional properties: Combined treatments of ultrasonication with pH-shifting or transglutaminase cross-linking

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ABSTRACT

Edible mushrooms are a valuable protein source, rich in nutrients and low in calories. They contain beneficial bioactive compounds and are more economically and environmentally friendly than traditional livestock farming, requiring less land, water, and energy, and producing fewer greenhouse gases. However, the poor techno-functionality of mushroom proteins often limits their use in the food and beverage industry.

This study aims to explore an innovative approach, utilizing the combination of ultrasonication with pH-shifting or transglutaminase cross-linking, to modify the functional properties of mushroom protein.

Protein extraction from Turkey Tail (*Trametes versicolor*) powders was optimized using 9 solid/solvent ratios and two solvents (NaOH and phosphate buffered saline). The optimal condition (0.1 mol/L NaOH) was employed to produce mushroom protein powers (MP) using ultrasound-assisted extraction (20 kHz, 5 min), followed by freeze-drying. MP modification was performed by 6 treatments, including, control (MP), pH-shifting, ultrasound, TGase cross-linking, US and TGase cross-linking (USTC-MP), and pH-shifting + US. The functional, structural, and morphological properties of treated mushroom proteins were compared, including solubility, particle size, emulsifying properties, forming/gelling capabilities, oil/water absorption capacities, surface charge and hydrophobicity, SDS-PAGE, FTIR, circular dichroism, and SEM.

The pH-shifting + US was the most effective in reducing the sizes (61 nm) of soluble protein aggregates, enhancing protein solubility (74.48%), free sulfhydryl content (5.17 mmol/g), surface hydrophobicity (389.2), emulsion activity (83.46 m^2/g), and emulsion stability (44.76 min). On the other hand, TGase + US exhibited a higher oil absorption (2.09%), foaming capacity (123.1%), and foam stability (93.75%). Additionally, the minimum gelation concentration of TGase + US was the lowest among samples (15%). Moreover, the pH-shifting + US resulted with the highest denaturation temperature (92.7°C) and highest wavenumber (1638 cm^{-1}). In summary, the combination of pH-shifting and ultrasonication proved more effective in improving the emulsifying properties and functionality of mushroom proteins.

Formation of hollow solid lipid particles: next generation food ingredients

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ABSTRACT

The formation of hollow solid lipid particles using supercritical carbon dioxide (SC-CO_2) is a promising green technology to be used in the food industry as a bioactive carrier or fat replacer. The development of health- and wellness-promoting foods by incorporating bioactive compounds has become the priority of the food manufacturing industry. However, preserving the food quality and health benefits without having any damage to the nutritional value is challenging. Besides, effectively incorporating bioactive compounds into food formulations is challenging because they are lipophilic. Therefore, the main objective of this study was to develop novel bioactive carriers, or fat replacers simply and cleanly to form high stability and easy-to-use powder formulations.

Powder fish oil formulation and powder shortening alternatives were developed. Powder fish oil formulation was developed using natural waxes to protect omega-3 fatty acids, minimize degradation, and enhance oxidative stability. Results proved that the stability of fish oil increased significantly compared to crude fish oil. While omega-3 bioaccessibility was 6.1% it increased to 11.2%. In-vitro intestinal cell transportation of omega-3 fatty acids increased from 16.2 to 21.7%.

Alternative powder shortenings were produced using fully hydrogenated soybean oil and soybean oil. The effect of particle formation parameters on the particle characteristics and oxidative stability was investigated. It was found that after storing at 50 ºC for 4 weeks, the peroxide and anisidine values of the particles were still low enough according to regulations. The melting behavior of the particles showed that particles could fully melt during baking while keeping a solid state at room temperature, as desired. The performance of powder shortenings was evaluated in bakery products such as biscuits, puff pastry, and pie crust by evaluating textural properties, and internal structure. It was found that powder shortening alternatives can be used as fat replacers for bakery applications.

Development of 3D-printed probes for food texture analysis

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ABSTRACT

Food texture is a crucial sensory property and an important indicator of its acceptability in the consumer market. Consequently, the science of food texture continues to improve for different food systems and standards. The cost of each probe, made from stainless steel or acrylic resin, can range up to thousands of dollars and can add greatly to research costs. This has significantly limited food texture research to a few common tests. This research aims at utilizing 3D-printed texture probes for food texture analysis.

Cylindrical probes of diameters 5 mm, 7mm and 25 mm were 3D-printed using Fused deposition modeling (FDM) and Stereolithography (SLA) using polylactic acid and acrylic resin, respectively. These probes were used to perform penetration tests on soft products (mayonnaise, onion dip, sour cream, ketchup), firm products (apple, avocado, kiwi) and hard products (dark chocolate, milk chocolate and white chocolate). The probes were then compared with corresponding commercial probes.

Overall, the 3D-printed probes were successful in performing puncture tests of the samples, resulting in similar trends and values to that of the stainless-steel probe. For fresh produce and hard food products, there was no significant difference between the peak force measured by commercial probes and 3D-printed probes. For soft dips, FDM probes were closer to stainless steel probes while SLA probes were closer to commercial acrylic probes. The probe cost was significantly reduced for 3D-printed probes amounting to one-fifth and one-third of the cost of commercial probes for FDM and SLA printing respectively.

This research proves that 3D-printed probes may potentially replace commercial probes for food application. This is especially useful for smaller laboratories and has the potential to foster innovation in food texture analysis.

Rheological properties of Greek-style yogurt manufactured by hydrodynamic cavitation

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ABSTRACT

The fortification of the yogurt base by modifying the whey protein to casein ratio (WP/CN) is an important factor controlling the quality of Greek-style yoghurt. This work investigates the feasibility modifying the WP/CN ratio in combination with hydrodynamic cavitation during the manufacture of Greek-style yogurt. The feasibility was evaluated in terms acidification kinetics, syneresis, texture, microstructure, and rheological properties. The milk base was fortified to 15% dry matter to obtain different ratios of WP/CN (13/87, 20/80, 35/65, 50/50, and 65/35) by adding a predetermined amount of whey protein concentrate and micellar casein concentrate. A yogurt base fortified with non-fat dry milk was used as a control treatment. The highest hardness (3.51 ± 0.17 N) was observed in yoguerts formulated with a WP/CN ratio of 65/35. The minimum syneresis (14.95 ± 1.54%) was observed in the yogurts formulated with a WP/CN ratio of 65/35. Dynamic rheology showed an improved stability of the protein network in yogurts containing higher amount of whey protein, displaying a distinctive viscoelastic region and a behavior of weak gel. Images obtained though scanning electron microscopic displayed a grainy network made of caseins aggregates linked in clusters, forming a three-dimensional network of regular voids. The outcomes of this investigation suggest that quality characteristics of yogurt can be modulated by the whey protein content in combination of hydrodynamic cavitation.

Exploring the impact of ultrasound treatment on the drying kinetics and physicochemical properties of spirulina

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ABSTRACT

Spirulina, commonly used as a dehydrated powder in food, faces challenges regarding stability and sensory properties. Non-thermal technology can be explored to enhance the nutritional quality and sensory appeal of microalgae in food products, addressing issues associated with conventional methods such as high energy consumption and compound degradation. This study investigates the impact of a two-step process involving ultrasound pre-treatment and subsequent vacuum drying on the physicochemical properties of Spirulina biomass. The aim is to understand the effects of this combined process on volatile organic compounds, color, phycocyanin content, and in vitro digestibility of a commercial Spirulina. The samples were diluted and subjected to ultrasound pre-treatment at the power of 500 W at 25°C for different times (0, 5, 10, 20, 40 min). Subsequently, the samples were vacuum dried at 40°C and 80 mbar. Longer ultrasound treatment showed significantly reduced drying rates. The in vitro protein digestibility of untreated Spirulina control samples was 91.9%. Ultrasound and vacuum drying had a low impact on this parameter, ranging from 87.2% for a 40-minute treatment to 93.2% for a 5-minute treatment. Ultrasound/vacuum drying treatment demonstrated the ability to reduce the concentration of specific organic volatile compounds such as dodecane, 2,6,10-trimethyltetradecane, and hexadecane, 2,6,11,15-tetramethylhexadecane. D-Limonene, acetic acid, and pentadecane remained the three major volatile compounds found in all samples, with mean relative contents of 31.767%, 13.823%, and 12.010%, respectively. In conclusion, ultrasound/vacuum drying treatment decreased alkane aroma (from hydrocarbons) and increased fresh, green, fruity aroma from hexanal, from 2.524% (5 min) to 4.192% (10 min) and 3.781% (40 min), which positively impacts the odor of the final Spirulina product. These results underscore the potential of ultrasound/vacuum drying treatment as a method to enhance the sensory attributes of Spirulina.

Effect of UV-A dehydration on quality and structure of food products

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ABSTRACT

Food dehydration has been practiced since ancient times and remains a highly efficient method of food preservation. A diverse array of food dehydration techniques exists, each with its own benefits and drawbacks, yet many require exposing raw materials to high temperatures or high energy inputs. Therefore, we aim to utilize a new non-thermal form of dehydration with low energy requirements. Our study focuses on the investigating the effects of UV-A irradiation as a novel non-thermal dehydration technique on vegetable and animal-origin foods with the objective of expanding our understanding of how UV-A radiation impacts the physicochemical properties of these diverse food products. UV-A has the lowest energy intensity but also longer wavelength in the UV light range, resulting in deeper penetration into food samples, providing energy for water molecules to vaporize. In this research, we investigated the effect of UV-A light on retaining nutrients like vitamin C, β carotene, and retinol from food samples during dehydration.

Furthermore, to prove the ability to retain the color of food samples, we studied the degradative enzymatic activity of polyphenol oxidase which is responsible for enzymatic browning. The results showed that UV-A light was able to denature Polyphenol Oxidase and remove e moisture simultaneously, allowing the UV-A dehydrated samples to retain the color of the raw fruits. Furthermore, we investigated the antimicrobial effect of UV-A, on L. innocua and E. coli in sweet potato and were able to confirm that despite being a nonthermal process, it is able to reduce substantially the microbial population (~ 3 logarithmic cycles).

Lastly, we compared UV-A dehydrated beef jerky with cooking house beef jerky and the results showed brighter and better color retention in the UV-A dehydrated beef jerky and different surface chemistry compared to conventional cooked beef jerky.

X-ray micro tomography-based microstructural characterization and pore-scale modeling of antimicrobial gas flow in a bed of low moisture food

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ABSTRACT

Dried basil, a commonly used low-moisture herb, is known for its distinct aroma, flavor, and health benefits. However, pathogen contamination may occur on the surface of basil leaves which may lead to foodborne illnesses. Antimicrobial gases are passed through inter-leaf pore channels of food materials to reduce bacterial population and decontaminate the food. This study aims to develop a pore scale model to simulate the antimicrobial gas transport in the bed of basil leaves using image processing techniques and a computational fluid dynamics (CFD) method. The objectives of this work are to quantify the microstructural characteristics of the basil bed and obtain the gas pressure distribution, velocity field, and bed permeability. Basil leaves were placed in a petri dish and imaged using X-ray micro-computed tomography. The reconstruction process using XMReconstructor software was used to collect over 2000 high-resolution images of the channels formed in the basil bed at a voxel size of 10.5 μm. The microstructural characteristics of the bed were extracted by employing various image processing techniques such as volume rendering, filtering, watershed segmentation, and object separation. The 3D reconstructed image was converted to a surface mesh. Next, the geometry was created for the CFD simulations in a finite element software package (Comsol Multiphysics). The creeping flow, continuity, and Darcy's law equations were utilized to obtain the steady-state gas flow patterns through the bed. CFD analysis resulted in velocity distribution, pressure field, and permeability values for the bed. The results revealed that the bed had a porosity of 0.69 and a permeability of 1.82×10^{-9} m^2. Regions with zero velocity were detected. They included pore channels where the gas flow was blocked by the basil leaves due to the presence of blind channels. In these channels, gas cannot move, and thus, pathogen may not be subjected to the antimicrobial gas. Pressure profile, pore size, tortuosity, and pore network model characteristics were also obtained.

Utilzing small angle X-ray scattering to investigate the structural alterations in β-lactoglobulin, lectin proteins, and their mixtures induced by high-pressure processing technologies

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ABSTRACT

High pressure based technologies are gaining industrial attention due to increased consumer demand for minimally processed liquid foods formulated from dairy and plant proteins. This study evaluated the impact of different processing parameters (high pressure, shear forces, elevated temperature, and treatment time) on the structural integrity and conformational dynamics of representative dairy protein (β-lactoglobulin (BLG)), plant protein (pea lectin (PL)), and their blend.

The effects of high pressure and pressure-holding durations on protein samples were evaluated by treating the samples at 400 MPa and 25°C (High-pressure processing, HPP) with two distinct holding periods (0 and 5 minutes). Furthermore, the combined effect of high pressure and shear was investigated using 400 MPa-40°C ultra-shear treatments (UST). To gauge the thermal effects on the proteins, samples were treated at elevated temperatures (40°C and 65°C) before subsequent analysis. The conformations of the processed and unprocessed proteins were characterized using small-angle X-ray scattering (SAXS), a nanometer-scale, non-destructive structural characterization technology.

Among the proteins tested, PL is more resistant against HPP, UST, and heat treatment compared to BLG. Although the processed proteins remained folded, 5 min HPP treatment caused change of the secondary structures (molten or "swelling" globule) of BLG and the protein mixture, while UST treatment resulted in protein aggregation. Some protective effect of the proteins to each other against elevated temperature was also observed for the protein mixture. Overall, this study contributes to improving the understanding of how high pressure, shear, and temperature can affect proteins. The results of this study support the design of liquid protein foods based on animal, plant proteins and their mixtures with greater control of the functional properties, thus extending their utilization in food, nutraceutical, and bio-medical applications.

Ice recrystallization inhibition and ice shaping effect of kappa carrageenan in sucrose solution at long-term storage

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ABSTRACT

Polysaccharides are widely used to preserve the texture of frozen desserts like ice cream by inhibiting ice recrystallization. Despite recent significant advances in research, a clear comprehension of the ice recrystallization inhibition mechanism of polysaccharides remains elusive. Some previous studies hypothesized that the ice recrystallization inhibition originates from the interaction between polysaccharides and ice crystal surface and tried to correlate it with the ice crystal shape. In this work, we have developed a novel method for analyzing the shape change of ice crystals during storage to unravel the relationship between the recrystallization inhibition and ice crystal shape. The change in ice crystal shape was evaluated by the change in curvature distribution of ice crystals. This method depicts the ice crystal shapes as the distribution of curvatures at points on the ice crystal surfaces. The changes in distribution describe the changes in ice crystal shapes during storage appropriately. This method has been applied to evaluate the shape changes of ice crystals during the storage of sucrose solutions with and without kappa-carrageenan. The change in curvature distribution has clearly revealed the effect of the addition of kappa-carrageenan in sucrose solution on the suppression of growing rectangle ice crystals with flat surfaces during storage, which was obscured in the roundness changes, showing the potentiality of using the curvature distribution for evaluating the shape change of ice crystals during storage. Furthermore, the curvature distributions of ice crystals showed that ice crystals were rectangular with flat edges in the pure sucrose solution and were round or hexagonal in the sucrose/kappa-carrageenan solutions at longer storage time, where it exhibited significant recrystallization inhibition activity. These changes in shape suggest that there is a correlation between the shape change of ice crystals and the recrystallization inhibition activity of kappa-carrageenan.

3D-printed reusable hydroponic substrate for space and industrial plant cultivation

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ABSTRACT

Aim: Hydroponic cultivation is receiving increased attention due to its sustainable use of materials, space, and light. However, non-reusable substrates like rock wool or peat are still being used in the industry. This study aims to use modern manufacturing techniques, like additive manufacturing (AM), to enable 100% reusable substrates throughout the plant cycle. Easy root removal after harvesting, sterilization, and replanting opens the door for even more automation like Farmbot. Previous attempts at 3D-printing substrates have been unsuccessful because design for additive manufacturing (DfAM) has not been explored. This study aims to use the material's compliance and design resolution as a design strength.

Method: Biocompatible stereolithography (SLA) was used to prototype hydroponic growing containers with capillary action structures embedded in the seed holders. Frillice lettuce seeds (Lactuca sativa) were then planted in the pots. Physical, rapid prototyping was done to see the real-world effects of seed and plant interaction with the substrate. For example, some compliant gripping structures were either too loose, dropping the seed when planting, or too hard, preventing the seed from sprouting.

Results: Observations of the plant life cycle include seed sprouting, seedling, and root development. The compliant, capillary arms hold and transport water to the seed. Root development is made with additional arms below, which are angled towards the seeds for easy root removal. Air and light are also available for the seed/plant.

Conclusion: The presented design principles and methods can be used to develop optimized hydroponic plant substrates for different plants with no waste and a high degree of automatization. This system can also be used in space applications as the seed is held in place, getting water through capillary action. Further design iterations and horticultural design optimization are required to achieve a complete plant cycle with the current industry yield.

Poster Session 5: Nonthermal, Alternative Processing

The impact of cold plasma treatment on the gelation of nanocellulose

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ABSTRACT

Cellulose nanocrystals (CNC) have unique properties and nanoscale dimensions that make them attractive for various fields, particularly as food thickeners. CNC can form a hydrogel increasing the viscosity of the food. Past studies indicated that CNC can also form a gel in the human stomach, which may be useful in delaying gastric emptying and increasing satiety feeling. Cold plasma, the fourth state of matter, produces reactive species like reactive oxygen and nitrogen species (ROS and RNS), leading to surface modifications such as the introduction of functional groups when applied to materials.

This study aimed to investigate the effect of atmospheric cold plasma treatment on the gelation properties of cellulose nanocrystals. In the study, cold plasma was used to treat 8%(w/w) CNC with different ratios of feed gas and exposure time. The resultant CNC, CP-CNC, was investigated with pH level, particle size distribution, and zeta potential. CP-CNC was also examined by SEM for the microstructure and FTIR for its functional groups. Subsequently, CP-CNC induced gelation by different concentrations of Ca2+ ions, and then studied by rheometer in terms of dynamic modulus and its digestibility via a dynamic in vitro digestion model.

The results showed that cold plasma treatment was found to improve the gelation properties of nanocellulose effectively. After treatment with the ratio of O2/N2 a t 1:4 for 5 min, pH decreased to 2.1 ± 0.2 compared with the original sample of 6.2± 0.2. The zeta potential was still negative yet decreased to -19.56 ± 0.91 mV. The viscosity of CP-CNC decreased after 5 min treatment. The FTIR spectrum exhibited reduced peak intensity for the band 3600-3300 cm-1, as well as one new suspicious peak at 2256 cm-1. The viscoelastic properties increased significantly, triggered by the addition of Ca2+. CP-CNC was observed to delay gastric emptying compared with the untreated CNC.

This study demonstrates the potential of cold plasma treatment to enhance the functional properties of cellulose nanocrystals and provide new possibilities for their application as effective thickeners in food products.

UV-C light on controlling botrytis cinerea in postharvest blueberries

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ABSTRACT

Justification: Postharvest decay of fresh produce caused by plant pathogenic fungi results in numerous economic losses. Postharvest fungicides treatment is an important mean of decay control. With higher consumer demands for fresh, organic produce and with heightened awareness of safety and environment, new treatments with reduced chemical use to minimize produce decay losses is needed.

Objectives: This study aims to evaluate the effectiveness of UV-C for controlling Botrytis cinerea, a major decay-causing fungus that affect many specialty crops including blueberries.

Methods: An UV-C bench-top chamber was used for treatments with doses up to 0.57 Ws/cm2. An appropriate amount of B. cinerea spore suspension (4.9±0.2 log CFU/mL) was 1) transferred to PDA or blueberry surface and exposed to UV-C for evaluating spore inactivation, 2) treated by UV-C and then transferred to a 96-well plate with PDA for evaluating fungal growth inhibition (OD at 595 nm), and 3) treated by UV-C and then inoculated on the wounds of blueberries for evaluating colonization ability. The weight and pH of blueberries over storage (7 days) were measured.

Results: UV-C reduced spores on PDA by 2.5±0.2 log for 30 s (0.14 Ws/cm2) and 4.0±0.2 log for 120 s (0.57 Ws/cm2). The inactivation kinetics was fitted to Weibull model. UV-C treatment suppressed the growth of B. cinerea as shown in the growth curve over 96 h, with maximum inhibition of 50-72% depending on dosage. UV-C treated spores reduced colonization potential by >14 days inoculated on wounded blueberries, which could be due to spore inactivation and delayed germination and growth. The efficacy of UV-C was superior than 3% H2O2 in inactivating B. cinerea spores and natural microflora from blueberries, and the use of H2O2 with UV-C did not affect the overall efficacy. UV-C of the current doses did not significantly affect berry weight and pH over storage.

Gaseous ozone to improve the microbial safety of spices, seeds, and nuts

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ABSTRACT

Introduction: An increase in reported outbreaks associated with low-moisture foods (LMFs) highlights a need to investigate non-thermal gaseous technologies to increase their safety without compromising product quality.

Purpose: The objective of this study was to inactivate Salmonella spp. in different spices and nuts using gaseous ozone treatments and evaluate the suitability of Enterococcus faecium as a potential surrogate.

Methods: Four food products (basil leaves, black peppercorn, chia seeds, and walnuts) were inoculated with cocktails of Salmonella spp. and E. faecium and equilibrated to water activity (aw) of 0.55. Two-gram samples of inoculated foods were treated in a customized chamber with ozone concentrations of 900-930 ppm at relative humidity (RH) of 70-90% for time intervals of 1-5 h, followed by mild heating at 40°C/4h. Means from 3 batches were compared with JMP Pro (significance level of 5%). Survival data were used to fit 2 primary models (Log-Linear and Weibull) to evaluate the goodness of fit.

Results: At ozone concentration of 900-930 ppm and RH of 90%, the 5 h ozone treatment resulted in maximum log CFU/g reductions of 5.0±0.4 for basil, 2.5±0.2 for black pepper, 1.5±0.2 for walnuts, and 1.1±0.1 for chia seeds. There were no significant differences between 1 and 5 h ozone treatments for chia seeds or walnuts ($P<0.05$). Post-treatment mild heating at 40ºC for 4 h further inactivated Salmonella by 1-1.5 log CFU/g for black pepper and basil. E. faecium was a good surrogate for Salmonella in basil leaves. Based on lower R2 and RMSE values, the Weibull model provided better goodness of fit for all products.

Significance: Results of this study indicate some synergistic effects of ozone, relative humidity, and mild heating treatments to improve the microbial safety of spices and nuts during storage, though the food matrix may be a limiting factor.

Evaluating the thermal and nonthermal effects of cold plasma activated water in inactivation of *Salmonella Spp.* and *Enterococcus faecium*

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ABSTRACT

Introduction: Plasma-activated water (PAW) presents promising potential for sanitation and food pasteurization without thermally influencing the product quality due to its generation of reactive oxygen and nitrogen species. However, heat generation of PAW could cause a significant temperature increase, yet the contribution of thermal effects to microbial inactivation during PAW treatments remains understudied.

Objectives: This research aims to fill this gap by modeling the thermal death of bacteria in inoculated samples during both on-site and off-site PAW treatments, thereby distinguishing between thermal and nonthermal effects.

Methods: Specifically, autoclaved silica sand was inoculated with a cocktail of Salmonella spp. (S.Mbandaka 698538, S. Enteritidis PT30, and S. Tennessee K4643) or Enterococcus faecium (NRRLB-2354) and subjected to PAW treatment using various water types (tap and DI), plasma carrier gases (air and oxygen), treatment sites (onsite and off-site), and PAW generation time (5 to 30 min). Salmonella spp. is a pathogenic Gram-negative bacterium while E. faecium is a Grampositive bacterium which generally used as a surrogate of Salmonella in thermal process validation.

Results: Preliminary findings indicate a significant decrease in bacterial survival in both on-site and offsite PAW treatments. While onsite treatment at 200 V, 60 kHz, demonstrated a sharp microbial reduction (over 5 log) after 5 minutes, the temperature in PAW was found to reach above 60 °C suggesting a predominant thermal effect. Efforts are ongoing to identify the optimal conditions for improving the nonthermal effects of PAW treatment. As this research continues, more data will be reported.

Significance: This study aims to enhance process control and modeling strategies for the use of plasma technology in microbial inactivation, thereby improving food safety and uncovering new ways of controlling microbes in various industries with PAW treatment.

Evaluation of high pressure processing for microbial inactivation in concord grape juice concentrate

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ABSTRACT

Juice concentrates are commercially prepared by thermal evaporation. Nonthermal concentration processes using membranes, such as forward osmosis (FO), can retain heat-sensitive and bioactive components. Water removal aids juice preservation by lowering water activity (aw) and pH, but the levels achieved during FO concentration may not be sufficient to inactivate associated pathogen and spoilage microorganisms. This study identified nonthermal technologies to complement FO. We evaluated high pressure processing (HPP) to inactivate microorganisms in concentrated Concord grape juice. A 1 ml of each 5-strain cocktail mixture of Salmonella, L. monocytogenes, E. coli O157:H7, and Z. bailii was inoculated separately in 56 ml of Concord grape juice concentrate (54.7±1.1°Brix, pH of 2.8±1.1 and 0.88 aw). The samples were processed in triplicate at 600 MPa, 180 s, and 5°C using a commercial HPP unit. L. monocytogenes and E. coli were enumerated before and after processing, while Salmonella and Z. bailii were enumerated before and after processing and after 2 and 7 days of storage at 5°C. For pathogens, the results showed that after HPP, a >5-log reduction was achieved for L. monocytogenes and E. coli, but Salmonella only had a 4-log reduction. However, after 2 and 7 days of storage at 5°C, 5.4±0.9 and 7.6±0.4 log reductions on Salmonella were observed respectively. For Z. bailii, a <1 log reduction was measured for samples without HPP after 2 and 7 days. For the samples that were inoculated and subjected to HPP, a 2.1±0.1 log reduction was observed after processing with further reductions during refrigerated storage to 3.2±0.3 and 4.0±0.4 after 2 and 7 days, respectively. HPP was effective for pathogen inactivation in Concord grape juice concentrate with Salmonella showing higher resistance, requiring 7 days holding time after HPP to achieve >5-log reduction. HPP showed potential for decreasing typical spoilage yeast to extend the refrigerated shelf-life.

Thermostabilizing effect of high hydrostatic pressure on lactate oxidase

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ABSTRACT

High hydrostatic pressure (HHP) treatments are commonly utilized to inactivate undesirable enzymes in food processing. However, HHP can also stabilize certain enzymes, presenting new opportunities for high-pressure enzyme catalysis and biotechnological applications. In this study, we explored the impact of HHP on the kinetics of thermal inactivation of lactate oxidase (LOx) from Aerococcus viridans. Enzyme samples were incubated at 66 °C for durations ranging from 20 to 120 seconds under pressures from 0.1 MPa to 100 MPa. We observed a reduction in residual activity (RA) by 8.33% over 120 seconds at 0.1 MPa. Notably, the RA at 50 MPa was 54.55% higher than at 0.1 MPa after 20 seconds. Kinetic analysis, based on a pseudo first-order model, revealed inactivation rate constants of 1.44 min-1, 0.85 min-1, and 1.16 min-1 at 0.1 MPa, 50 MPa, and 100 MPa, respectively. The 50 MPa treatment demonstrated a significant thermostabilizing effect, whereas inactivation rates increased when the pressure increased to 100 MPa. These results indicate that HHP exerts a moderate thermostabilizing effect on LOx, with an optimal pressure treatment between 50 and 100 MPa.

Evaluation of cloud 320 and flavoset 5400L for Salmonella interventions in fresh poultry

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ABSTRACT

Objectives: The objective of this study is to assess the efficacy of Cloud 320 and Flavoset 5400L for the control of Salmonella in fresh chicken application.

Methods: Skinless chicken breast, weighing on average 100±3 g, were used for the study. The samples were spot inoculated with a two-strain cocktail of Salmonella Typhimurium and Salmonella Enteritidis at the 1 mL/100±3 g to achieve target inoculation level of 2-3 log CFU/g. The inoculum was then spread using a sterile L spreader and rested for one hour in biosafety cabinet for attachment. As per Table 1, the samples were then treated with Cloud smokes by spray application using airbrush and ground after 30 minutes. Treated ground chicken samples (~50 g) were air flushed with 70% nitrogen and 30% carbon dioxide and stored at 4°C for up to 30 days. At each sampling point, duplicate samples were homogenized and plated onto XLT4 agar selecting for Salmonella, and TSA for total aerobic plate count. Treatment effect was evaluated with one-way ANOVA in SAS JMP 17. Significance in this study is set at $P \leq 0.05$.

Results: All inoculated samples reached the target inoculum levels of 2-3 log CFU/g. The smoke solutions, Cloud 320 and Flavoset 5400L, showed cidal effects on Salmonella in ground chicken. On Day 0, 1.5% Cloud 320 significantly ($P \leq 0.05$) lowered the Salmonella levels from 2.80 log CFU/g in untreated samples to 1.85 log CFU/g whereas 2.0% Cloud 320 and 0.3-1.2% Cloud S-C100 provided 1.2-1.7 log reduction of Salmonella.

Significance: The spray application of Cloud 320 and Cloud S-C100 provide effective intervention strategy and clean label solution for Salmonella control in ground poultry applications.

Application oscillating magnetic field-based supercooling treatment on solid lipid nanoparticles

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ABSTRACT

Solid lipid nanoparticles (SLNs) are an effective delivery vehicle for bioactive compounds with limited bioavailability. However, SLNs are prone to physical instability, such as polymorphic transition (from α- to β′ or β-form) during cooling and storage. Supercooling technology utilizing oscillating magnetic fields (OMF) has been developed to preserve biomaterials at sub-zero temperatures without ice formation. This study aimed to apply OMF-based supercooling technology to formulate supercooled SLNs and assess their physicochemical properties, compared with control cooling protocols (freeze-thaw (-9°C), refrigeration (4°C), and room temperature (20°C)). SLNs were prepared by sonicating cocoa butter (5%) and soy lecithin (0.2%), followed by cooling for 24 h, according to the above protocols. Findings indicated that a 15 mT OMF at 5 Hz enabled supercooling of SLNs at -9°C while maintaining stable dispersion. In contrast, frozen-thawed SLNs exhibited distinct phase separation between lipids and aqueous phases, hindering physicochemical characterization. Particle sizes ranged from 252.3 to 286.0 nm, and zeta potentials ranged from -51.7 to -52.7 mV for all samples except frozen-thawed SLNs. The solid fat content was 6.5±0.1% for refrigerated SLNs and 7.1±0.2% for supercooled SLNs, while room temperature-treated samples contained solid fats of 0.2±0.1%, indicating the status of nanoemulsion. Thermal analysis revealed an α-form crystal structure for both supercooled and refrigerated SLNs. However, the crystallized lipid core of supercooled SLNs melted faster than refrigerated ones. In addition, the supercooled SLNs exhibited higher storage stability than the refrigerated SLNs over 14 days, with the latter displaying particle size growth. This study demonstrates the ability of OMF treatment to inhibit nucleation, thus preserving the supercooled state of SLNs at -9°C, and highlights the potential for the physicochemical properties of supercooled SLNs to surpass those of the control groups.

Exploring the effect of cold atmospheric plasma on proteins and allergenicity: A scoping review

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ABSTRACT

Food allergies pose a significant health concern, affecting millions annually in the United States alone. Accurate labeling and allergen control are vital for managing allergies effectively. While existing allergen control measures focus on prevention, there is a growing need to investigate post-cleaning treatments. Cold Atmospheric Plasma (CAP) technology offers promise in enhancing food safety and extending shelf life by modifying food biomolecules. However, its impact on food allergens remains largely unexplored.

This scoping review, conducted following the PRISMA method, aimed to assess the scale and scope of scientific literature on the effect of CAP on allergens. Utilizing multiple databases, articles in English were screened by two independent reviewers. The review revealed that CAP treatment not only alters the structure of proteins but also influences their allergenicity. However, a notable gap in research exists concerning CAP's influence on the primary structure of proteins.

Furthermore, the review highlighted a scarcity of studies addressing the inactivation of traces of allergens on food contact surfaces. Collaborative efforts and further exploration are needed to bridge these gaps and advance understanding of the complex relationships between CAP, protein structures, and allergenic properties. Ultimately, this research may lead to innovations in food safety and technology, paving the way for the development of safer food products for individuals with food allergies.

Reducing Salmonella contamination in pizza dough through cold plasma-based hurdle interventions

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ABSTRACT

Wheat, a crucial part of human diets, faces a significant food safety threat due to potential microbial contamination throughout its production and processing. This vulnerability exposes wheat to various sources of intrusion, including harmful pathogens like Salmonella, posing risks to wheat-based foods. Recent incidents, like the 2022 French outbreak and the 2023 pizza recall, highlight these dangers, with investigations tracing the pathogens back to wheat flour. This underscores the ongoing threat of these harmful microorganisms in wheat products. This study aims to utilize a cold plasma-based hurdle approach for Salmonella control in the pizza dough.

Organic wheat flour was inoculated with Salmonella (cocktail) and dried for ~6 h at 37^{o}C until it reached its pre-inoculated weight. Subsequently, the wheat flour was exposed to plasma generated in the air for 15 min. The pizza dough prepared using plasma-activated water (PAW) was further subjected to in-package cold plasma treatment (generated in atmospheric pressure air at 30 kV) to extend its shelf life. The reduction of the pathogenic load was evaluated by plating them on xylose lysine deoxycholate agar (XLD) after serial dilution. The study's findings revealed that wheat flour treated with atmospheric cold plasma at 21 kV/6 min showed a notable reduction of 2.08 log CFU/g in Salmonella load. Additionally, incorporating plasma-activated water in pizza dough formulation led to a reduction of at least 0.87 log CFU/g. Furthermore, in-package cold plasma exposure of packaged pizza dough further contributed to a reduction of 0.94 log CFU/g in Salmonella load. The collective implementation of these hurdle interventions resulted in a combined reduction of 3.91 log CFU/g in Salmonella contamination. The results from this study have the potential to be utilized for developing more effective methods for improving the food safety of pizza dough against Salmonella contamination.

Inactivation of *Escherichia coli* AW 1.7 in water by light activated graphene oxide nanoparticles and nanochitosan

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ABSTRACT

Water quality is important in maintaining public health, yet microbial contamination remains a persistent challenge, necessitating the need for innovative water treatment approaches. This study investigated the inactivation of Escherichia coli AW 1.7 in water by the application of light pulses of varying wavelengths including, ultraviolet-A (UV-A, 365 nm), near UV-Visible (NUV-Vis, 395 nm), and blue (455 nm) light, generated from light-emitting diodes (LED) coupled with graphene oxide (GO) nanoparticles and nanochitosan (NC). The nanoparticle (NP) solutions were prepared by mixing 0.2 and 0.3 % GO and NC in 10 mL of distilled water with continuous stirring for 24 h. Subsequently, E. coli inoculum was added and vortexed before LED exposure. Results demonstrated that all LED treatments (UV-A, NUV-Vis, Blue light) in combination with GO nanoparticles for the durations of 10 and 20 minutes, resulted in the inactivation of E. coli, below the limit of detection (LOD) (>5 log CFU/mL reduction). For NC (0.2% and 0.3%), UV-A LED treatment exhibited superior photocatalytic inactivation, achieving >5 log CFU/mL reduction in E. coli populations compared to NUV-Vis and Blue LED treatments. The effect of LED treatment duration on the photocatalytic inactivation of E. coli was more pronounced with NC at both concentrations used. Among individual LED treatments, UV-A was more effective than NUV-Vis and blue light pulses for E. coli inactivation. The higher oxidation-reduction potential, conductivity, and lower pH of water contributed to the greater E. coli inactivation, when GO was used in combination with LED treatments. The study underscores the photocatalytic antibacterial activity of GO and NC, highlighting their potential for application in water treatment.

Biomimetic hybrid porous microspheres with plant membrane-wall structure for evaluating multiscale mechanisms of ultrasound-assisted mass transfer

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ABSTRACT

Determination of mass transfer during ultrasound-assisted extraction (UAE) has always been a challenge, not to mention the novel breakthrough of mechanisms for its positive effects. Herein, versatile porous microspheres (PM) with membrane-wall structure like plant tissues, which were made from sodium alginate/polyacrylamide dual crosslinking gels loaded with liposomes, were prepared to reveal the micro mass transfer effects during UAE. Results showed that prepared PM kept stable microstructure during extraction and ultrasound significantly accelerated the pore diffusion rather than surface diffusion. This effect resulted in higher UAE efficiency of PM with 60% porosity than solid microspheres (143.72 to 155.47 mg/L), and the finding can be further explained as the accelerated internal diffusion (14.25%) under ultrasound treatment. Moreover, multi-physics coupling simulations were performed to elucidate the enhanced pore flow and UAE efficiency. Acoustic streaming induced by cavitation effect increased the seepage velocity within the PM, and the pore structure would undergo compression and expansion deformation with alternated acoustic pressure due to its elastic characteristic. Both microscale effects improved the mass transfer and increase the UAE efficiency without structural damage from cavitation. This study fills the UAE mechanisms from micro view and provides a novel method for the study of vital micro processes.

Microbiological safety of frozen beef burgers through synergistic effect exploration of gamma irradiation and allicin

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ABSTRACT

Meat and its derived products are susceptible to degradation in quality due to their complex nutritional profile, often resulting from biochemical alterations and microbial contamination. To combat these challenges, various technological interventions are employed, with irradiation emerging as a recognized method for enhancing the microbiological safety of food products. The main objective of this study was to develop frozen beef burgers supplemented with allicin extract and subjected to different doses of gamma irradiation, aiming to evaluate the effect of these treatments on product quality and shelf life extension. Burgers were formulated using a commercial formulation comprising 70% ground meat and divided into control groups with and without allicin extract (at a concentration of 0.1%). Following preparation, the burgers underwent irradiation with gamma radiation doses of 3, 5, and 7 kGy. Microbiological analyses were conducted to quantify Staphylococcus aureus, Salmonella enteritidis, and Escherichia coli, previously inoculated on the products at approximately 7 log (UFC/g). Significant reductions in microbial load were observed across all doses, with reductions reaching 6.1 log (UFC/g) for Staphylococcus aureus, 5.2 log (UFC/g) for Salmonella enteritidis, and 5.9 log (UFC/g) for Escherichia coli. The optimal dose of gamma radiation was identified as 5 kGy in conjunction with allicin extract supplementation. Furthermore, the inclusion of allicin extract enhanced microbial inactivation against all examined microorganisms across all doses, with Salmonella demonstrating the highest resistance. Samples treated with the optimal combination were monitored over a 120-day period and exhibited stability throughout the entire period of the freeze (-10°C) storage period.

Modeling the inactivation kinetics of *Escherichia coli* on pecan halves treated by intense pulsed light

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ABSTRACT

Log-linear, shoulder + log-linear, and non-linear Weibull models were evaluated for predicting the inactivation kinetics of Escherichia coli (E. coli) on pecan halves treated by intense pulsed light (IPL). Pecan halves were spot inoculated with ~ 6 log CFU/pecan E. coli (ATCC 8739) and then treated with IPL using a Z-1000 modular sterilization system (1.27J/cm2 pulse of energy) for 1, 3, 5, 9, 12 or 15 s, and at distances of 4.5, 7, or 9.5 cm. Results showed that IPL was effective for inactivating E. coli with reductions of 2.06 log CFU/pecan at 7 cm distance and 12 s treatment. The treatment times and distances had significant effect on the log reduction ($P \leq 0.05$). Regression analysis was performed using the GInaFiT tool (Geeraerd and Van Impe Inactivation Model Fitting Tool) for Microsoft Excel. Three (Log-linear, shoulder + log-linear, and Weibull) of the ten models describing microbial survival in the GInaFiT tool were used in the analysis of data. The log-linear, shoulder + log linear, and Weibull models presented comparable performances and were suitable for describing the inactivation kinetics. The shape parameter value ($\beta > 1$) of Weibull model indicated that the remaining E. coli cells became increasingly damaged, showing decreasing resistance over time. The time for the first log reduction was 7 s. With respect to adjusted-R2, Pearson coefficient-R, and root mean square errors (RMSE), the models were ranked in the following order: Shoulder + log-linear > Weibull > log-linear. With superior adjusted-R2(0.96), Pearson coefficient-R (0.98), and RMSE (0.22) values, the shoulder + log linear model was identified as the best fit model. This study provided new insights into the effective evaluation of IPL microbial inactivation method and can be a valuable tool in improving pecan safety.

Combined effect of mechanical shear and moderate electric field on the inactivation of pathogenic microorganisms in fresh orange juice

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ABSTRACT

With heightened consumer demand for fresh-like products, the food and beverage industries are seeking effective nonthermal methods to inactivate pathogenic bacteria in their products.

Our recent studies have shown that rotational shear stress and moderate electric field (SS+MEF) in combination inactivates microorganisms such as Escherichia coli K12 and Listeria innocua at ambient temperatures. However, the efficacy of SS+MEF treatments on the inactivation of pathogenic microorganisms in real food matrices is quite unknown. Therefore, our objective of this study was to examine the inactivation of the pathogenic microorganisms Escherichia coli O157:H7, Salmonella Typhimurium and Listeria monocytogenes, in fresh orange juice by subjecting them to SS+MEF treatments at various temperature conditions. Freshly squeezed orange juice samples were inoculated with the pathogenic bacteria and treated with a combination of 1600 s-1 shear rate and 105 V/cm field strength at the temperature ranges between 27-55 °C, using a laboratory scale batch shear-MEF device. Kinetics of inactivation was studied by sampling at different time points up to 30 minutes. It was possible to achieve the 5-log cycle reduction at 10 minutes of treatment time at 45 °C for the pathogenic microorganisms E. coli O157:H7 and 55 °C for both S. Typhimurium and L. monocytogenes. The (SS+MEF) approach demonstrated a clear advantage over traditional thermal pasteurization (≥ 90 °C) of fruit and vegetable juices. Furthermore, the results of this study are useful for the food industry which strives to find nonthermal alternatives for the inactivation of pathogenic microorganisms.

Effect of electrode shapes on spore inactivation and quality properties during atmospheric cold plasma

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ABSTRACT

Storing fresh fruits and vegetables under inappropriate conditions results in food waste because of quality losses and microbiological spoilage. It is possible to improve the shelf life of foods with alternative food processing methods. Atmospheric cold plasma (ACP) is one of the current nonthermal food processing technologies that may reduce quality losses and provide microbial inactivation. In this study, the effects of ACP treatment (35 kV and 20 min) performed using different electrode shapes (E1: rectangular, E2: conic) on the reduction of Alternaria alternata spores, one of the main microorganisms that cause spoilage in tomatoes, total phenolic content and lycopene content of tomatoes were evaluated. The change in the electrode shape affected the inactivation of Alternaria alternata spores ($p<0.05$); a greater log reduction value was obtained with the E1 electrode (0.46±0.02) compared to the E2 electrode (0.37±0.02) ($p<0.05$).

ACP treatment using the E1 electrode led to a 31.0±1.0% decrease in the total phenolic contente of tomatoes while the using the E2 electrode resulted in a 20.9±3.7% decrease ($p<0.05$). In addition, the reduction in the lycopene content of tomatoes compared to that of untreated tomatoes were higher in case of using the E2 electrode ($p<0.05$). This study highlights the potential of ACP treatment as a promising technique to increase the shelf life of fresh produce and reduce food waste. In the following studies, the effect of shape and size of the ACP electrodes should be evaluated comprehensively not only on microbiological safety but also on the quality perspective and the energy requirement. This study is financially supported by Ege University Scientific Research Projects Coordination (Project No. FBG-2021-23013).

Keywords: Atmospheric cold plasma, Alternaria alternata, total phenolic content, lycopene

Evaluation of novel cold plasma treatment to reduce rotten tissue in sugar beets for improving postharvest storage

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ABSTRACT

Introduction: Sugar beets are commonly grown in Minnesota. During storage, beets respire to recover from mechanical injuries sustained during harvesting which causes sucrose losses. They are prone to attack by post-harvest fungi, e.g., Botrytis cinerea. An increase in the respiration rate, presence of storage rot disease, an accumulation of undesirable invert sugars deteriorates sugar quality, causes problems in sucrose extraction, ultimately leading to losses. Cold plasma is a novel technology that can inactivate bacteria and fungi. Plasma-activated water (PAW) has shown potential as a sanitizing liquid in the decontamination of fresh produce, helping in delaying senescence and reducing spoilage.

Objective: This research aims to evaluate the potential of plasma-activated water in reducing the rotten tissue caused by Botrytis cinerea in sugar beets.

Methods: Beets were mechanically harvested and were washed with water to remove soil. They were surface sterilized with bleach and wounded with a sterile cork borer. A suspension of Botrytis cinerea of 2*10^6 conidia/ml was used as inoculum. PAW was prepared by exposing distilled water to an atmospheric plasma jet for 15 (PAW-15) and 30 minutes (PAW-30). Beets were dipped into PAW-15 and PAW-30 for 5, 10, 20 minutes and stored at 4°C and high relative humidity. Rotten tissue was excised and weighed at 30, 45, and 60 days.

Results: No significant differences were found between PAW-15 and PAW-30 for 5, 10 minutes of treatment at 30, 45, and 60 days of storage. However, PAW-30 indicated a significant reduction in the rotten tissue at 60 days of storage for a treatment of 20 minutes against PAW-15 (47%) and control (60%).

Relevance: When properly upscaled, this treatment can be employed to long-term storage piles. It offers the potential to reduce the economic losses caused by storage rot which can improve post-harvest storage.

Intense pulsed light treatment for microbial safety of fresh lettuce

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ABSTRACT

Several outbreaks of foodborne pathogens infections have been linked to minimally processed leafy greens in the United States. Traditional washing and sanitizing techniques offer only limited effectiveness in eliminating pathogens from produce. Intense pulsed light (IPL) treatment presents a novel and efficient approach for pathogen inactivation. In this study, we investigated the efficacy of IPL on the inactivation of E. coli O157:H7 from fresh romaine lettuce. A pulsed light system (model X-1100, LH-910) was used with one pulse lasting 540 µs at intensity of 1006 J. The pulses (0 to 14) were delivered at a frequency of 0.7 Hz in burst mode at 2.7 kV. Romaine lettuce samples (3 x 3 cm) inoculated with E. coli O157:H7 (≈ 6. 5 log CFU/cm2) were treated at a constant distance of 10.6 cm from the lamp source. A maximum log reduction of ≈ 3.0 log CFU/cm2 was obtained with 14 pulses without any visual damage to the lettuce. These results suggest that IPL represents a promising strategy for microbial inactivation for fresh lettuce and may also be applicable for other types of leafy greens. The effectiveness of IPL on different foodborne pathogens and the quality of treated lettuce samples under different IPL parameters are currently underway.

Effect of cold plasma on corn grains (*Zea mays* L.): Fungal inactivation, microstructure stability, and germination capacity

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ABSTRACT

Fungal contamination, particularly in the case of corn (Zea mays L.), poses significant challenges for the food and agriculture sectors. Due to environmental and health considerations, conventional fungal control measures, such as pesticides (fungicides and/or insecticides), have declined in popularity. Consequently, there is increasing interest in developing ecologically friendly, safe, and sustainable methods for fungal decontamination of corn. In this study, naturally contaminated corn grains, with moisture levels of 11.42%, 12.72%, and 17.96%, were exposed to Cold Plasma (CP) in a dielectric discharge barrier reactor. The CP parameters used were: frequency 130 Hz, voltage 30 kV, energy 100 ± 5 mJ, distance between electrodes of 0.8 cm, atmospheric pressure, and air as ionizing gas. Exposure times tested were: 0, 2, 5, 7, 10, 15, and 20 minutes. The effect of CP treatment and exposure time was assessed on fungal inactivation, microstructure, and grain germination capacity. A significant reduction in fungal contamination was observed in treatments longer than 5 minutes. The highest fungal contamination logarithmic reduction, ranging from 0.75 to 1.4 log, occurred in treatments of 10, 15, and 20 minutes. The different moisture content of the corn did not significantly influence the effectiveness of the CP treatment. Compared to the control samples, the surface of the corn husk developed a wrinkled texture, with the roughness increasing with longer exposure times. The CP treatments of 15 and 20 minutes caused a more pronounced delay (greater than 2.5-fold) in germination capacity. However, treatments shorter than 10 minutes did not show a statistical difference in this parameter compared to the untreated sample. These results suggest that, with an exposure time of about 10 minutes, CP treatment has the potential to reduce fungal contamination in corn grains without compromising germination capacity.

Inactivation of *Clostridium sporogenes* PA 3679 spores by combined pressure, thermal, and antimicrobial compounds

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ABSTRACT

Conventional thermal processing methods for food preservation employ prolonged and elevated thermal treatment to guarantee the microbiological safety of food. Although safety is ensured, thermal exposure severely deteriorates the heat-sensitive nutrients and quality of food. A potential approach to address this problem is by using pressure-assisted thermal processing (PATP) in combination with natural antimicrobial compounds. PATP is an emerging sterilization method for food processing with reduced heat damage while ensuring microbiological safety. PATP employs simultaneous temperature (90-120 °C) and pressure (400-600 MPa). For commercial sterilization, microbial safety is the most crucial prerequisite, where C. botulinum spores are the critical targets for elimination. Clostridium sporogenes, is a surrogate for C. botulinum that is commonly employed for process validation.

This study aimed to investigate the sporicidal efficacy of 25 antimicrobials from a group of enzymes, polysaccharides, cyclodextrins, surfactant, polymers, and plant & fruit extracts to enhance the inactivation of C. sporogenes PA 3679 spores during PATP.

Experiments were conducted using a bench-scale high-pressure processor. Spores suspended in pressure-stable buffer with the antimicrobial compounds individually (0.2% w/v)) were pressurized at 600 MPa, 90ºC and 105ºC for 3- and 6-min holding time, analyzed by spread-plating on TPGY (Trypticase-Peptone-Glucose-Yeast Extract) agar, and incubated at 32°C for 5 days in anaerobic conditions to determine the survivors. The results showed that among all the treatments tested, PATP (600 MPa, 105ºC, 6-min holding time) with the addition of low- and high-molecular-weight chitosan from the group of polysaccharides reduced significantly ($P<0.05$) the spore survivors of C. sporogenes PA 3679 by 7.9- and 6.9-logs, respectively. Additionally, PATP reduced the particle size and increased the zeta potential of chitosan particles, which possibly enhanced their sporicidal activity. These results can help food processors develop methods to process foods using less severe thermal conditions than those currently used.

The synergistic effect of mechanical shear and moderate electric field on the inactivation of *Listeria monocytogenes* in peach puree

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ABSTRACT

The food industry has been seeking nonthermal treatment alternatives to replace conventional thermal processing. The goal is to meet the microbiological safety requirements while preserving the freshness, shelf-stability, and nutritional quality of products.

We have recently demonstrated the efficacy of rotational shear stress and moderate electric field (SS+MEF) synergistically to inactivate microorganisms in buffer solutions at ambient temperatures. Nevertheless, the efficacy of this technology to inactivate pathogenic bacteria in real food matrices is still an active area of study.

Our objective for this study was to examine the inactivation of the pathogenic bacteria Listeria monocytogenes in consumer grade peach puree by subjecting it to SS+MEF treatments at various temperatures.

Diluted 10% peach puree samples were inoculated with the pathogenic bacteria and treated with a combination of 1600 s-1 shear rate and 105 V/cm field strength at the temperature ranges between 45-50 °C, using a laboratory scale batch shear-MEF device. Kinetics of inactivation were studied by sampling at different time points up to 30 minutes.

Treatment at 45 °C resulted in log10 reduction of only 2.88 at 30 min. Treatment for the same length of time without the electric field applied yielded a log10 reduction of 2.16. On the other hand, treatment at 50 °C resulted in a log10 drop of 2.71 at 10 min and 6.12 at 20 minutes with the electric field applied and 1.87 and 3.6 respectively without it.

In conclusion, the industry standard 5-log cycle reduction was achieved at 20 minutes of treatment time at 50 °C. The (SS+MEF) approach was significantly more efficient than the conventional thermal-only treatment.

This is a step forward for the food industry in the quest to advance the SS+MEF as an effective nonthermal technology.

Effects of cold plasma fumigation treatments on the inactivation of *Escherichia coli* on food contact surfaces

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ABSTRACT

The application of cold plasma fumigation (CPF) generated by two plasma reactors, rod-to-mesh dielectric barrier discharge (DBD) plasma reactor and rod-to-cramp plasma jet reactor, using compressed air as the carrier gas, was evaluated for the inactivation of E. coli TVS355 on multiple food contact surfaces.

The stainless-steel and glass coupons (2.5 x 7.5 x 0.1 cm) were spot inoculated with E. coli TVS355 and placed inside an enclosure (24 x 37 x 14 cm) for plasma treatment at different combinations of voltages (80 V, 150 V, and 200 V) and discharge frequencies (500 Hz and 1000 Hz) for 10, 15, and 20 mins. E. coli TVS355 recovered from inoculated control and plasma-treated coupons were enumerated on MacConkey agar with 80 mg/L rifampicin. All the samples were analyzed in triplicate, and statistical analysis was conducted with One-way ANOVA ($p = 0.05$).

CPF treatments by both DBD and jet reactors demonstrated significant reductions ($p < 0.01$) of E. coli TVS355 on the contact surfaces. With the DBD reactor, CPF treatment at 200 V and 1000 Hz achieved the most significant log reduction of 4.43 CFU/mL on stainless-steel coupons in 10 mins and 4.26 CFU/mL on glass coupons in 20 mins. At a higher bacterial concentration (7.38 ± 0.06 CFU/mL), CPF treatment reduced 1.06 log CFU/mL on stainless-steel (200 V, 1000 Hz, and 20 mins) and 1.19 log CFU/mL on glass coupons (200 V, 500 Hz, and 20 mins). With the jet reactor, CPF treatment at 80 V and 1000 Hz for 15 mins reduced 4.28 log CFU/mL on stainless-steel coupons, and CPF treatment at 80 V and 500 Hz for 15 mins reduced 2.59 log CFU/mL on glass coupons.

The results demonstrate that CPF is a promising food contact surface treatment with scaling up potential to mitigate food pathogens.

Efficacy of plasma-activated mist technology against Escherichia coli biofilms on stainless steel surface

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ABSTRACT

Microbial pathogens such as Escherichia coli can exist as biofilms on equipment or contact surfaces used in food processing facilities. Conventional chemical disinfectants are not always effective in removing biofilms. Hence, there is a need to explore the efficacy of new surface sanitation technologies such as plasma-activated mist (PAM) to reduce biofilms in processing facilities.

In this study, plasma-activated solutions (PAS) were generated with water and chemical additives including hydrogen peroxide (3.4% H_2O_2), sodium hydroxide (0.01% NaOH), and also, a combination of peracetic acid (0.01% PAA) and 3.4% H_2O_2 by a bubble spark discharge reactor. The PAS were converted to PAM using the micronice nebulization technology to achieve an average mist particle size ranging from 10-12 mm, determined by dynamic light scattering method.

Stainless-steel coupons with biofilms of E. coli 877 and E. coli AW 1.7 were prepared after 6 days of incubation. The PAM was generated for 10 and 20 min, and the coupons were treated with PAM for 10 min. The PAM treatment was effective in inactivating E. coli biofilms, attributed to the high concentrations of reactive oxygen and nitrogen species (RONS), ORP and low pH. The addition of H_2O_2, NaOH, and PAA increased the biofilm inactivation efficacy of PAM. For instance, the treatment of PAM generated using the 3.4% H_2O_2 alone and the combination of 3.4% H_2O_2 and 0.01% PAA resulted in >1.5 and >4 log CFU/cm^2 reductions in E. coli biofilm population on coupons, respectively. The confocal laser scanning microscopy and crystal violet staining data supported this observation. However, more research is needed to understand the scientific reasons behind the changes in RONS and the characteristics of PAM with enhanced antibiofilm properties, when these additives are used.

Cold atmospheric plasma for controlling pathogenic bacteria in cooked ham

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ABSTRACT

Ham and other ready-to-eat meat products pose challenges regarding microbiological safety since contamination after the thermal treatment is often observed. Cold atmospheric plasma (CAP) emerges as a promising non-thermal technology for microbial inactivation on food surfaces, acting as a second kill-step. This study developed a multipin-to-plane CAP system and investigated its efficacy for inactivating Listeria monocytogenes and Salmonella Typhimurium on culture media and sliced ham. Additionally, how each treatment impacted the ham quality was assessed. The CAP systems parameters evaluated were electrode distances (20 and 30 mm) and discharge frequencies (2, 11, and 20 kHz). The developed system exhibited non-thermal characteristics and stability over the entire treatment. Both bacteria were sensitive to CAP treatment, with an initial decay (up to 5 logs) followed by tail behavior when present in culture media. In ham, injured L. monocytogenes cells almost fully recovered during cold storage (4, 7, and 10°C), while S. Typhimurium cells were highly impacted by combining CAP and refrigeration. CAP treatment did not significantly affect ham quality parameters, including pH, water activity, color, and lipid oxidation observed throughout storage. The multipin-to-plane CAP system effectively injured the pathogenic bacteria, causing cellular damage without compromising product quality. This study highlights the potential of CAP technology in enhancing microbiological safety and potentially extending the shelf life of ready-to-eat meat products, offering insights into the dynamics of bacterial response to this treatment combined with refrigerated storage.

Cold plasma-assisted extraction of phenolics and polysaccharides

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ABSTRACT

Agriculture produces the vast majority of the world's food supply; however, many agricultural materials are still largely underutilized. Since these agricultural materials contain a large quantity of nutrients, nutrient extraction is a critical process to convert them into high-quality functional foods and nutraceuticals. Cold plasma is a partially ionized gas that contains energetic and reactive species, and cold plasma treatment has recently been used as a novel approach to assisting in solvent extraction (cold plasma-assisted extraction) of various nutrients from plant materials. Cold plasma can modify material surfaces by creating surface rupture, increasing surface roughness and wettability, and further causing intracellular structure breakdown, thereby facilitating nutrient diffusion during extraction. Tomato and grape pomace treated with helium plasma generated by dielectric barrier discharge (DBD) showed 10–23% higher extraction yields of phenolic compounds, and the extracts had increased antioxidant capacity by up to 35% due to their different phenolic profiles. While applying air DBD plasma as extraction pretreatment on dry fenugreek seeds improved the extraction yield of galactomannan by 67%, direct plasma treatment on seeds soaked in extracting solvent nearly doubled the improvement. Plasma-treated galactomannan showed higher water-binding capacity, swelling index and viscosity, as well as lower melting enthalpy. Bubbling the extracting solvent with air DBD plasma during pectin extraction from apple pomace increased the extraction yield by 30%. Plasma-assisted extraction showed higher extractability of rhamnogalacturonan I (RG-I) pectin and the pectin extracted had lower molecular weight and degree of esterification. The diverse applications proved the great potential of the novel cold plasma-assisted extraction technology for broadening the functional food and nutraceutical sectors, ultimately promoting human health and bioeconomy.

Measurement of Far-UVC (222 nm) intensity using chemical actinometry and quantification fluence required for microbial inactivation

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ABSTRACT

Justification: The direct application of UVC light (254 nm) has limitations as its exposure to humans poses health hazards to the skin and eyes. By contrast, far-UVC light (222 nm) can efficiently kill pathogens while being safe for humans. The radiometers available for the quantification of far-UVC light are costlier, and limited research has been conducted on the measurement of far-UVC fluence required for inactivation of a gram-positive and gram-negative microorganism.

Objectives: The objectives of this study were to 1) measure the far-UVC intensity at different distances from a light source, 2) evaluate the efficacy of far-UVC for microbial inactivation, and 3) quantify the fluence required for microbial inactivation.

Methods: The intensity of far-UVC was measured using the potassium iodide/iodate chemical actinometer method for 30 sec at distances 2, 3, 5, 7, 9, and 11 cm from the light source. The triiodides formed in the reaction were quantified at 352 nm to determine the far-UVC intensity. The antimicrobial efficacy of far-UVC light was assessed in planktonic for Enterococcus faecium and E. coli at fluence 78.42, 156.84, 313.68, and 627.36 mJ/cm2. The far-UVC fluence absorbed by the microorganism was quantified by radiochromatic film dosimetry.

Results: The plot of the intensity of far-UVC light at various distances from the light source followed the power function (R2 = 0.959). The far-UVC treatment at fluence 78.42, 156.84, 313.68, and 627.36 mJ/cm2 resulted in 0.6, 0.9, 1.6, and 1.9 log CFU/ml reduction of E. faecium, and 1.5, 2.1, 2.5, and 3.2 log CFU/ml reduction of E. Coli respectively. The fluence absorbed for microbial reduction ranges from 22.520 to 256.064 mJ/cm2 for E. faecium, and from 29.307 to 285.591 mJ/cm2 for E. Coli. respectively.

Significance: The information on fluence required for microbial inactivation will be helpful in further studies on the application of far-UVC technology for food safety.

Bacterial spore proteins and their role in influencing spore inactivation during ohmic heating

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ABSTRACT

Ohmic heating (i.e. heating by electric field) has previously been found to accelerate inactivation of bacterial spores compared to conventional heat, raising the question as to the reason for the efficacy of the field. Our hypothesis has been that electrical fields present during ohmic heating interact with some key component(s) of the spores. Towards this end, we investigated the effects of ohmic (OH) and conventional heating (CH) on various genetically modified strains of Bacillus subtilis: isogenic PS533 (wild type_1), PS578 (lacking spores' α/β-type small acid-soluble proteins (SASP)), PS2318 (lacking recA, encoding a DNA repair protein), and isogenic PS4461 (wild type_2), and PS4462 (having the 2Duf protein in spores, which increases spore wet heat resistance and decreases spore inner membrane fluidity). Removal of SASP brought the inactivation profile of OH and CH closer suggesting the interaction of these proteins with the field. However, the reemergence of difference between CH and OH killing for SASP-deficient spores at the highest tested field strength suggested interaction of the field with another component. Furthermore, recA deficient spores yielded results similar to that with the wild type spores for CH, while the OH resistance of this mutant increased at the lower tested temperatures implying that recA is a possible additional target for the electric field. Addition of the 2Duf protein markedly increased spore resistance both to CH and OH, although some acceleration of killing was observed at OH at 50 V/cm. In summary, both membrane fluidity and spore core proteins are key factors in spore killing with electric field-heat combinations.

Computational design of a continuous flow microwave system for thermal processing of ice-cream mixtures

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ABSTRACT

Ice cream has a high economic and nutrition value and widely consumed. Thermal processing of ice-cream mixtures is carried out in conventional heat exchanger systems to assure safety before the final production. For the United Nations 2030 Sustainable Development Goals (SDGs), use of clean energy and reduction of carbon footprint of the processes have become a strategic goal. Due to these recent concerns with increased quality and safety of the process, it is important to develop a novel innovative approach. Therefore, the objective of this study was to develop a continuous flow microwave system for thermal processing of ice-cream mixtures.

For this purpose, the ice-cream mixtures were obtained from a local producer, and dielectric properties and rheological were measured experimentally while the thermophysical properties were determined with respect to the composition. Then, a computational model was developed to determine the temperature evolution of ice-cream mixture in a batch 2450 MHz custom-designed (manufactured) microwave system. Model validation studies were completed with the experimentally measured temperature data.

The developed model results compared well with the experimentally obtained time-temperature data. Then, the validated model was extended for designing a novel continuous flow microwave system for processing, and the required design parameters were presented. The microbial inactivation calculations were also carried out using the literature data for Listeria spp. in terms of food safety concerns.

With respect to these results, microwave processing was demonstrated to be a sustainable novel process approach for using in industrial ice-cream thermal processing. Considering the recent food safety reports related with ice-cream consumption, presentation of the design parameters of an efficient process is an important aspect in the view of the industrial manufacturing.

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Production of carotenoids from sotol bagasse (*Dasylirion sp.)* pre-treated by non-thermal plasma

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ABSTRACT

Lignocellulosic biomass represents an attractive feedstock since it can be used as a carbon source in bio-based product synthesis. However, pretreatments must be carried out in order to deconstruct the lignocellulosic structure to release fermentable sugars. During the manufacturing of sotol (distilled beverage), a considerable amount of bagasse is generated, which becomes an environmental problem for producers. Sotol bagasse (SB) contains high amounts of lignin, so a pre-treatment is needed before enzymatic hydrolysis of cellulose. Thus, this work aimed to develop a strategy for SB pre-treatment with cold plasma (CP) and its further hydrolysis for the bio-production of carotenoids by yeast. SB underwent CP treatment, and a Full factorial experimental design was employed with frequency (Hz: 500, 750, and 1000) and power (W: 60, 80, and 100) as independent variables. Lignin removal was evaluated as the response. After CP treatment, SB was further treated via enzymatic hydrolysis (24 h, 50 ºC, Cellic® CTtec3 HS) and the hydrolysate was used for carotenoids production by *Rhodotorula glutinis*. Fermentations were carried out at 30 ºC, 180 rpm for 96 h with an initial sugar concentration of 18 g/L. Results revealed that the highest lignin removal level was 28.73±.06 % at 750 Hz and 60 W treatment conditions, where no significant difference was observed with other combinations. Total sugars released during enzymatic hydrolysis reached 26.24±7.24 g/L, demonstrating the potential for carotenoid production. Regarding carotenoids production, it was possible to obtain carotenoids (845.24±61.6 mg/L) after 96 h of fermentation using hydrolysate SB. Finally, plasma treatment proved to be rapid and efficient for removing lignin from sotol bagasse. Additionally, SB hydrolysate exhibited potential as a renewable feedstock for the bio-production of carotenoids.

Poster Session 6: Sustainability & Waste Utilization

Exploring the utilization of upcycled almond protein in extrusion processing to create nutritious direct expanded snacks

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ABSTRACT

This study aimed to understand the viability of upcycled ingredients from almond press-cake in direct expanded products using extrusion processing. The specific objectives included, to evaluate the impact of the inclusion of almond protein into rice flour for the development of extruded direct expanded snacks. To develop a profile of the proximate analysis of almond protein flour and observing its functional properties to better understand its viability as an ingredient. Understanding the interactions between the almond protein within rice flour through extrusion processing. The methods used in observing potential interactions in this study include proximate analysis (starch, ash, protein, fiber, fat), thermal properties (DSC), functional properties (WAI/WSI and Pasting Properties) and extrudate characteristics (Expansion ratio, WAI/WSI, Texture profile). We used a BRABENDER co-rotating twin-screw extruder with a die size of around 3.15 mm varying the treatment levels to three screw speeds (300, 400, 500rpm) , three moisture contents (18%, 20%, 22%), and three inclusion levels (5%, 15%, 25%). Looking at some preliminary data, visual changes to the surface structure and appearance were apparent for increasing inclusion of almond protein within the expanded products. Changes were seen in the air bubble structure, product color, and expansion ratio. Expansion ratio also coincided with the screw speed of the extruder, with increasing speeds leading to smaller average expansions. Some correlations may be drawn from screw speed and air bubble structure, as within inclusion levels, smaller air bubble formations were seen at higher screw speeds. Highest expansion readings occurred at 15% inclusion of protein, though with the variation of the other treatment parameters also showed the smallest expansion readings at the same inclusion level. Full study will include a Box-Behnken design to model the response to the process parameters to show what parameters will improve overall characteristics of almond direct expanded snacks.

The effect of liquid properties on microbubble size distribution and concentration in decompression type generation

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ABSTRACT

Microbubbles have recently been used in diverse industries due to their unique properties that can enhance process performance. The efficiency of such processes is closely related to the bubble size distribution and concentration. While bubble size is known to depend on various liquid properties, the combined effects of these parameters have not been thoroughly investigated. The purpose of this study is to evaluate the effect of different liquid properties on the size distribution and concentration of bubbles generated using a decompression type bubble generator.

Microbubbles were generated using a decompression type bubble generator. We used the phase Doppler anemometry (PDA) system to assess the impact of various process parameters, including saturation pressure, pH, and temperature, on bubble size, size distribution, and concentration. To validate the PDA system, the results were compared with those obtained using shadow image analysis, a widely used direct measurement technique.

We found that the size distributions derived from PDA system closely aligned with those obtained by shadow image analysis. We also found that increased pressure led to a decrease in the mean bubble diameter. Additionally, the solution properties, particularly pH and temperature, had a significant impact on bubble characteristics. Lower pH resulted in larger bubble diameters, while higher temperatures contributed to the generation of smaller bubbles. Notably, a combined effect of pH and temperature was observed, suggesting a complex interplay between these factors.

This research provides valuable insights into the microbubble generation process and highlights the importance of considering the combined effect of pH and temperature as critical parameters for optimizing the performance of industrial applications using microbubbles.

Influence of microbubbles on impinging jet cleaning efficiency

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ABSTRACT

Recent studies indicate that incorporating low-viscosity gas-filled microbubbles into cleaning fluids holds significant promise for enhancing CIP (cleaning-in-place) processes within pipe systems. However, in large tank environments, jet impingement remains a common method for CIP operations, particularly in the food and bioprocessing industry. Yet, the efficacy of microbubble-laden fluid jet impingement for cleaning efficiency is not thoroughly understood.

This study aims to assess the cleaning performance of microbubble-laden fluids, specifically focusing on the impact of microbubble concentration during free surface jet impingement. Two types of soil layers, categorized by their removal mechanisms (dissolution and erosion), were applied to stainless steel surfaces with varying thicknesses. Cleaning progress over time was meticulously tracked using high-speed imaging techniques.

Results indicate a critical microbubble concentration threshold beyond which the cleaning efficacy plateaus for soil layers are removed through erosion. Conversely, for dissolution-based soil layers, higher microbubble concentrations corresponded to enhanced cleaning efficiency. These findings offer valuable insights for optimizing CIP operations in the food and bioprocessing industry, where precise and effective cleaning is essential for maintaining product quality and safety.

Engineering packaging for a sustainable food chain

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ABSTRACT

There is high level of inadequate methods at all level of food supply in the global food industry. The inadequacies have led to vast wastages of food, hence there is need to curb the wastages that canlater have effect on natural resources, water resources and energy to avoid negative impact on the climate and the environment. There is need to engage multifaceted engineering packaging approaches for a sustainable food chain that will ensure active packaging, intelligent packaging, new packaging materials and sustainable packaging system.

Packaging can be regarded as indispensable components approach that can be applied to solve majorproblems of sustainable food consumption globally; this is about controlling the environmental impact of packed food. As earlier stated, scientific innovation will definitely solve the problem of food wastagesand eliminate diseases associated with ineffective food packaging.

The creative innovation will ensure packaged foods are free from food borne diseases and food chemicalpollution. This paper evaluates the key shortcomings that must be addressed by innovative food packaging so as to ensure safe natural environment that will preserve energy and sustain water resources. Certain solutions which include fabrication of microbial biodegradable chemical compounds/polymers from Agro food waste remnant appears a bright path to ensure a strong and innovative wastebased food packaging system.

Over the years, depletion in the petroleum reserves has brought about the emergence of biodegradable polymers as a proper replacement for traditional plastics; moreover, increase in the production of the traditional plastics has raised serious concern of environmental threat.

As a matter of fact, biodegradable polymers have proven to be biocompatible in nature which can as well be processed for other useful applications.

Therefore, this study will show case workable guiding framework for designing sustainable food packaging system that will not constitute danger to our present society and that will surely preserve natural water resources, because it will take the entire life cycle of food package into considerations with strong emphasis on complete prevention of food losses in the process of packaging design.

Various assessments methods will be deployed at different stages of the packaging design, in order to enhance the sustainability of the package. Every decision that will be made must be facilitated with methods that will be engaged per stage so as to allow for corrective measures through the cycle in the design process.

Basic performance appraisal of packaging innovations Food wastages can result to inimical environmental impacts, and ethical practice must be carried out majorly for food loss at homes. An examination conducted in West Africa quantified preventable food wastages over the entire food value chain at almost 180kg per person in a year. That is preventable food wastages, 35% of which originated at household level.

Many food losses reported, happened at the harvesting, storage, transportation, and processing stages are not preventable, which are without much environmental impact because such wastages can be used for feeding. Food wastages happening at homes and in many eateries are mostly preventable; furthermore, lost food materials do no find alternative use and are always completely lost. Other surveys have shown that 15%-20% household food losses can be traced to food packaging.

Therefore, new innovative packaging systems can lessen the environmental effect of food wastages so as to extend shelf-life in order to lower food loss in the process of distribution chain and at the household level.

Moreover, there is need for extension of secondary shelf life after package opening process, it should receive future research attention so as to further reduce food wastages at homes.

Nevertheless, to appraise the balance between technological innovation and environmental safety, the environmental effect of packaging innovations and food wastages must be scrutinized through the life-cycle assessment (LCA) methodology (including raw material extraction and processing, packaging manufacture, transport, and retail, and disposal of food and packaging, even at the household level) in addition to assessing the effect on food shelf -life or packaging features such as optical, physical, thermal, and mechanical properties.

Water demand in food manufacturing – usage and trends

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ABSTRACT

The food industry, a major water consumer, is facing significant environmental challenges (i.e., depletion of freshwater resources due to climate change) that are building up pressure on food security – as the global population is growing, both food and water demand for food production are expected to increase too. In this context, this work identifies water consumption hot spots in food manufacture processes, which will help to allocate resources more effectively and create a more sustainable food chain.

Water usage data was collected from literature and clustered by product and processing technique. Before analysis, data was transformed into standard units when needed/possible.

Findings show that the meat and dairy sectors are the most water intensive ones – water is systematically used to rinse/clean surfaces, pipework and vessels and thus guarantee hygienic standards; however, most cleaning-in-place (CIP) protocols are based on very conservative and outdated protocols, which could be significantly optimised. Similarly, literature reveals scope for further improvement of sterilisation and pasteurisation operations used in packed foods (e.g., pouches, cans, jars) - alternative preservation techniques, like microwaves or pulsed-electric-field (PEF) are being slowly introduced in the sector, so heat could be generated without using water/steam. Water is also a main component in the formulation of a number of food products, although in most cases is removed either by evaporation or sublimation, through drying or freeze-drying processes. Therefore, processing of dough-based products, as well as processing of powder foods and ingredients, constitute a major source of water consumption, too. Finally, this study has analysed water usage per location too, revealing those areas/countries more compromised by climate changes and draught.

The outcomes of this work constitute valuable information for the sector and policy makers that can help to re-evaluate current environmental and manufacturing strategies, increasing sustainability and security of food chains.

Fermentation of fish by-products and acid whey: microbial dynamics and protein hydrolysis for sustainable waste management

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ABSTRACT

The fishing industry provides vital high-quality proteins but faces challenges with fish by-products and waste. Acid whey, a byproduct from fermented dairy foods, also poses disposal problems with serious environmental impacts. An economically and environmentally sustainable approach involves extracting value from the remaining nutrients in these by-products. This research delves into the fermentations of two distinct waste streams - fish byproducts and acid whey. The objective in the first phase is to monitor the fermentation process using microbial population analysis, protein hydrolysis and product physical changes during fermentation. Fish byproducts and acid whey were mixed in a ratio of 1:1 (w/w) with the addition of molasses and subjected to fermentation at 37℃ for 10 days. Lactobacillus rhamnosus having a demonstrated enhanced proteolytic activity was used as the starter culture. Throughout the fermentation period, viable cell counts for lactic acid bacteria (LAB) remained high, ranging from 7 to 8 log CFU/g. The acid production by LAB led to a significant decrease in pH levels, effectively inhibiting the growth of E. coli and coliforms, which fell below the detection limit after three days of fermentation. Analysis of the molecular weight distribution of proteins revealed the degradation of large protein bands as early as the first day, with a subsequent accumulation of bands with lower molecular weights over the fermentation period, indicating efficient protein hydrolysis. Furthermore, a high degree of hydrolysis was confirmed. Interestingly, the viscosity of the fermented mixture was observed to be highest before the start of the fermentation, suggesting dynamic changes in the physical properties of the mixture throughout the fermentation process. This study demonstrates the potential of valorizing nutrient-rich by-products, by a marked increase in small peptides and amino acids without putrefaction, offering an alternative to their current disposal methods.

A Community to Sustain Digital Food Engineering

Ashim Datta and Debmalya Ghosh

ABSTRACT

"Alone, we can do so little; together, we can do so much." A community is essential to sustain long-term growth and success of an idea, even more so for a budding one. Digital food engineering is finally flourishing, but it doesn't (and likely will not) have a home of its own. What can we do to build a community, nevertheless?

Three complementary collaborative digital tools/platforms developed in multi-year, multi-project ongoing effort will be shared. They cover a properties knowledge base, a repository of numerical models, and a web-based educational tool matching the digital skill needs. Their eventual goal is to speed up product and process design. They are freely available, with crowdsourcing capabilities that allow growth with community contributions without the need of significant additional investment.

The first of these tools is a food properties knowledge base where the user can easily and quickly estimate ~100 properties of ~10,000 food materials. In addition to obtaining quick data, such effortless visualization allows comparison of multiple materials for a property, multiple properties of the same material, and composition and temperature effects, leading to a materials science understanding in a discovery mode. The second resource is a repository of accurate and robust numerical models of important food processing operations, to be shared among the design, research, and education communities. Easy availability of these models through the repository, with their advantages of quick "what if" scenarios and a vastly improved mechanistic understanding, will propel the community faster toward simulation-based design of food products and processes. The third resource is a pedagogically rich, modularized, active learning-enabled, multistage educational material that is synthesized from recent research, available freely on a learning management platform.

The three tools address a vast swath of food applications in industrial design, academic and industry research, and education. Their built-in crowdsourcing ability, allowing growth with community contributions, should be a game changer that will go beyond sustaining, making the digital food engineering community grow.

Sotol bagasse (*Dasylirion* spp.) a renewable biomass for biofuels production: ABE fermentation by cellulolytic microbial consortium

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ABSTRACT

Sotol production is an agro-industry in Mexico that generates sotol bagasse (SB) as a solid waste. This has the potential as a renewable lignocellulosic biomass for biofuels production such as biobutanol through acetone-butanol-ethanol (ABE) fermentation. This work studied the competency of four microbial consortia (IC, EC, GA, EST) to hydrolysate the cellulose of SB then ABE biofuels production was performed. The consortia were conditioned to accomplish cellulose hydrolysis employing different carbon sources. Subsequently, the consortia were inoculated in a SB medium to evaluate its ability to use it as substrate. From this the consortia EC and EST were selected to perform microbial growth kinetics and quantify ABE compounds production, individually and in co-culture with C. beijerinckii. The co-culture strategy proved to produce higher values of ABE compounds for both consortia. LASSO regression was implemented to select the supplementation ingredients that improved the production of ABE solvents. By adding CaCO3 to sotol bagasse medium it was possible to raise the concentration from 3.71 ± 0.12 g ABE/L to 6.02 ± 0.09 g ABE/L for the co-culture EC+C. beijerinckii. These results demonstrate that the isolated consortia in this study offer an alternative for biobutanol production via ABE fermentation.

Poster Session 7: Encapsulation Systems

Biomimetic hybrid porous microspheres with plant membrane-wall structure for evaluating multiscale mechanisms of ultrasound-assisted mass transfer

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ABSTRACT

Determination of mass transfer during ultrasound-assisted extraction (UAE) has always been a challenge, not to mention the novel breakthrough of mechanisms for its positive effects. Herein, versatile porous microspheres (PM) with membrane-wall structure like plant tissues, which were made from sodium alginate/polyacrylamide dual crosslinking gels loaded with liposomes, were prepared to reveal the micro mass transfer effects during UAE. Results showed that prepared PM kept stable microstructure during extraction and ultrasound significantly accelerated the pore diffusion rather than surface diffusion. This effect resulted in higher UAE efficiency of PM with 60 % porosity than solid microspheres (143.72 to 155.47 mg/L), and the finding can be further explained as the accelerated internal diffusion (14.25 %) under ultrasound treatment. Moreover, multi-physics coupling simulations were performed to elucidate the enhanced pore flow and UAE efficiency. Acoustic streaming induced by cavitation effect increased the seepage velocity within the PM, and the pore structure would undergo compression and expansion deformation with alternated acoustic pressure due to its elastic characteristic. Both microscale effects improved the mass transfer and increase the UAE efficiency without structural damage from cavitation. This study fills the UAE mechanisms from micro view and provides a novel method for the study of vital micro processes.

Formation of microcapsules of pullulan by emulsion template mechanism: Evaluation as vitamin C delivery systems

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ABSTRACT

Pullulan is a polysaccharide that has attracted the attention of scientists in recent times as a former of edible films. On the other hand, its use for the preparation of hydrogels needs more study, as well as the formation of pullulan microcapsules as active ingredient release systems for the food industry. Due to the slow gelation kinetics of pullulan with sodium trimetaphosphate (STMP), capsules cannot be formed through the conventional method of dropping into a solution of the gelling agent, as with other polysaccharides, since the pullulan chains migrate to the medium before the capsules can form by gelation. Pullulan microcapsules have been obtained by using inverse water-in-oil emulsions as templates. The emulsion that acts as a template has been characterized by monitoring its stability and by optical microscopy, and the size of the emulsion droplets has been correlated with the size of the microcapsules obtained, demonstrating that it is a good technique for their production. Although some flocs of droplets form, these remain dispersed during the gelation process and two capsule size distributions are obtained: those of the non-flocculated droplets and the flocculated droplets. The microcapsules have been evaluated as vitamin C release systems, showing zero-order release kinetics for acidic pH and Fickian mechanism for neutral pH. On the other hand, the microcapsules offer good protection of vitamin C against oxidation during an evaluation period of 14 days.

Development and characterization of pullulan biofilms using the response surface method for protection of blueberry and its phenolic compounds

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ABSTRACT

Currently, the use of plastics in food protection represents a serious contamination problem. Given the need to reduce the use of plastics in the food industry, the focus of researchers and industries is on possible substitutes for conventional materials of petrochemical origin. Pullulan is a polymer widely studied today, individually or in combination with other components, due to its potential in the production of biodegradable and edible films for food protection. The present work exposes the possibility of obtaining plastic-like materials from pullulan. A study is carried out based on an experimental design to evaluate the characteristics of the films obtained according to the concentration of pullulan used and the pullulan/sorbitol ratio, with sorbitol being the plasticizing agent used. From the experimental design, the significant variables are determined and one of the films is optimized so that it has the same characteristics as a commercial polyethylene plastic. Finally, it was decided to test the effectiveness of the film by using it as a container for blueberries. Due to the ability to add active ingredients to the films, vitamin C is introduced as an oxidizing agent to evaluate its effectiveness. The optimization of the mechanical properties of the films resulted in values considerably higher than those reported in the literature. The application of pullulan films, alone and in combination with ascorbic acid, showed a significant reduction in fruit weight after 5 days of evaluation. The application of pullulan films, alone and in combination with ascorbic acid, showed a significant reduction in fruit weight after 5 days of evaluation.

Biocompatible hydrophobic cross-linked cyclodextrin-based metal-organic framework as quercetin nanocarrier for enhancing stability and controlled release

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ABSTRACT

Cyclodextrin-based metal-organic frameworks (CD-MOFs) have gained prominence as versatile carriers in various drug delivery systems due to their commendable attributes, including edibility, degradability, and high drug loading capacity. However, challenges persist in their widespread application, stemming from their inherent bulky size and vulnerability to brittleness in aqueous environments. In response to these challenges, we introduce an innovative approach involving ultrasonic-assisted synthesis, aimed at achieving uniform nanoscale CD-MOFs. Furthermore, to enhance their water stability, we implement a hydrophobic modification through ester bond cross-linking, leading to the creation of Nano-COFs. To assess the effectiveness of this modification, we employed quercetin (Qu) as a model compound, investigating its encapsulation stability and controlled release properties. The ultrasonic treatment successfully reduced the particle size of CD-MOFs to a nanoscale dimension. Notably, the carbonate ester cross-linking method significantly enhanced the water stability of CD-MOFs, preserving their cubic structure and high specific surface area. This engineering achieved a remarkable retention rate exceeding 90% across various media. The loading of Qu within the Nano-COFs exhibited outstanding storage stability, with particle sizes remaining at approximately 400 nm over a 14-day period. Crucially, Nano-COFs, owing to their superior water stability, enabled the controlled release of Qu both in aqueous environments and during simulated digestion. Nano-COFs protected Qu and amplified its antioxidant capacity. Additionally, Nano-COFs demonstrated remarkable biocompatibility, underscoring their substantial potential as a novel platform for nutritional delivery systems, with applications spanning the food and biomedical domains.

Chitosan-oligosaccharide based nanoemulsion for thymol encapsulation: long-term stability, enhanced antimicrobial properties for food preservation

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ABSTRACT

Thymol, an aromatic compound derived from plants, exhibits potent antioxidant and antibacterial properties. Addressing thymol's volatility and susceptibility to oxidation, we developed a nanoemulsion containing pure thymol. This emulsion was prepared through an ultrasonic-assisted method, leveraging the interaction between cinnamaldehyde, a food flavor small molecule, and natural polysaccharide chitosan oligosaccharide. The ultrasonic treatment yielded a nanoscale emulsion with a uniform droplet size distribution, approximately 225 nm in diameter. This emulsion demonstrated exceptional long-term stability, with no substantial changes in particle size or zeta-potential (30 mV) over a 21-day storage period. During the long-term storage, the emulsion was always brown without obvious stratification, and microscopic observation illustrated that the emulsion had no demulsification phenomenon. Encapsulation efficiency exceeded 95%, significantly enhancing thymol's antioxidant and antimicrobial efficacy. The emulsion displayed notable inhibitory effects on the growth of Escherichia coli, Staphylococcus aureus, and Penicillium, with a minimum inhibitory concentration of 312.5 μg/mL. Inhibition zone experiments also confirmed its effectiveness inhibitory effect on the growth of both bacteria and fungi. In general, this natural emulsion has an effective protective effect on thymol, which showcases remarkable long-term stability and outstanding antioxidant and antimicrobial activities, holding promise for various fresh food preservation applications.

Cell surface display of *Geobacillus* sp. laccase in pichia pastoris

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ABSTRACT

Laccase, a multi-copper oxidase first discovered in 1883 in the sap of the Japanese lacquer tree by Yoshida, is widely found in plants, fungi, bacteria, and insects. It oxidizes phenolic and non-phenolic compounds using oxygen as an electron acceptor, reducing oxygen to water. Laccase has broad applications in bioremediation, enhancing the stability of color and flavor in juice filtration, removing phenolic compounds in wine production, and as a biosensor. Recent findings highlight the unique properties of bacterial laccase, including lower redox potential, wider pH range, higher thermal stability, and stability in alkaline environments and high salt concentrations, offering advantages in industrial applications. This study constructs a pPIC9K-laccase plasmid in Pichia pastoris X-33 to express a heat-tolerant laccase gene from Geobacillus sp., analyzing enzyme characteristics like optimal pH, temperature, reusability, and dye decolorization. The results show successful plasmid construction and transformation into Pichia pastoris X-33, with optimal induction at 37 °C for 96 hours. The enzyme exhibits high relative activity with 2,6-DMP and significantly lower activity with catechol and no oxidation with ABTS and guaiacol. Optimal activity is at pH 6-7.5 and temperatures 70-90 °C, retaining 40% activity after 10 consecutive cycles. Fourier-transform infrared spectroscopy (FTIR) spectra of Congo red decolorization with acetophenone and vanillin as mediators show functional group changes, especially in amino and hydroxyl structures, indicating dye decolorization by laccase.

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Impact of dynamic gastrointestinal conditions and food matrices on survival and release of encapsulated *Lactobacillus rhamnosus* GG

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ABSTRACT

Microencapsulation is a promising strategy to enhance the stability of probiotics in the human GI tracts. The most convenient method to investigate the functions of microencapsulated probiotics is to use in vitro digestion models. However, most in vitro digestion models are based on static conditions, where they do not consider important physiological activities observed in the GI tracts, such as pH changes, continuous digestive juice secretions, and shear forces caused by physical contractions. In addition, the effects of co-existing food matrices on the functions of probiotic microcapsules in the human GI tracts were rarely investigated. This research aims to study the survivability and release properties of microencapsulated probiotics using dynamic in vitro digestion models, along with the complex digestions with food matrices. Lactobacillus rhamnosus GG (LGG) was entrapped in chitosan-coated alginate beads at 9 Log CFU/g by extrusion. The survival and release of encapsulated LGG were investigated using a dynamic GI model, with a static model used as comparison. The microcapsules were mixed with simulated gastric or intestinal fluid in an Erlenmeyer flask. Static digestion tests were performed by incubating at 37 °C with a shaking bath, while dynamic digestion tests were demonstrated by incorporating continuous juice secretion and emptying at 2 ml/min with peristaltic pumps. Multiple model food matrices including casein, starch, and soybean oil, were incorporated with the microcapsules for digestion studies. The survival and released cells in the digesta were enumerated after each digestion test. The findings showed that dynamic gastric juice secretion notably decreased the survivability of LGG within alginate- and chitosan-based capsules. Moreover, dynamic intestinal conditions affected the release kinetics of encapsulated LGG. However, these effects were not observed in static models. The findings provide valuable insights for the performance of microencapsulated probiotics, and are useful to develop practical evaluation protocols for viability of probiotics.

Enhancing the physical stability of O/W emulsions through the interaction of mung bean protein aggregates and soy lecithin

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ABSTRACT

This research aimed to formulate oil-in-water (O/W) emulsions stabilized with thermally-induced mung bean protein aggregates (MBA) and soy lecithin (LEC) to improve the emulsion stability during storage. Mung bean isolate (5%) was subjected to pH 2 with heating (0, 1, 2, and 4 h) at 90°C to produce MBA, and added LEC (1%) into the MBA dispersion to prepare the complex (MBA/LEC). The results show that MBA/LEC is more aggregated and linked to very thin and short fibers than MBA. The heating time significantly impacts the MBA and MBA/LEC size and surface hydrophobicity. For the emulsion system, protein molecules (non-heated, pH 2 and 7) were not nearly absorbed around the oil droplets and dispersed in the aqueous phase themselves, leading to the instability of emulsions. In addition, protein molecules did not stabilize emulsions over time, although LEC was added. Meanwhile, MBA (heated, pH 2) was better covered on the oil droplet surface and homogeneously distributed within the aqueous phase. LEC reduced oil droplet size during homogenization and stabilized the emulsion with improved interaction ability with MBA. This demonstrated the interfacial properties of MBA/LEC, which built mixed interfacial layers prone to changes over time. Afterward, the dispersed MBA in the bulk phase could develop interactions among each other, leading to improved emulsion stability. The MBA/LEC more effectively suppressed droplet flocculation during storage. Such structural properties suggested that MBA was formed through hydrogen bond restructuring, which was shown to stabilize the emulsion by binding to LEC and increasing its hydrophobic function. Therefore, these findings will contribute to forming and stabilizing O/W emulsions with plant-based proteins by providing the potential of MBA or MBA/LEC as natural emulsifiers/stabilizers in food development.

Development of cellulosic particles converted from spent coffee grounds (SCG) for fabricating stable Pickering emulsions (PE) to enhance antimicrobial activity of essential oils (EOs)

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ABSTRACT

Justification: Pickering emulsions (PE) utilize solid micro/nanoparticles to adsorb onto the interface between the aqueous and oil phases of an emulsion. Advantages include biocompatibility and greater resistance to the coalescence of droplets, thus enhancing emulsion stability. Oregano essential oil (OEO) has antimicrobial effects but low oil-in-water emulsion stability with conventional emulsifiers. Cellulosic particles (including nanocellulose) have the potential to act as PE agents due to their easy surface modification and amphiphilicity. Spent coffee grounds (SCG) are rich in lignocellulose, ideal for producing cellulosic PE agents.

Objective: This study aimed to investigate the effects of converted SCG cellulosic particles as a PE agent and to develop oregano essential oil-Pickering emulsions (OEO-PE) for antimicrobial food packaging applications.

Methods and Experimental Design: A 10:1 10 mm steel ball to dried converted SCG cellulosic material ratio was used to reduce particle size with a Retsch PM 100 planetary ball mill. The OEO-PE was made using deionized (DI) water, OEO, and cellulosic particles and homogenized at 22,000 rpm for 2 min. Tween 80 and cellulose nanocrystals (CNC) were used for control emulsions. Emulsification ratio was determined by measuring emulsion volume to system volume. Emulsion morphology was determined using a light microscope to measure oil droplets. A two-way factorial design was applied with factors and levels: cellulosic material types (untreated and bleached/pulped materials: (a) bleached pulping with formic acid/acetic acid/DI water solvent and peracetic acid (PAA) and (b) 60% (v/v) ethanol and PAA) and dry milling (0 min and 60 min).

Results: It was observed that SCG cellulosic particles can adsorb onto the OEO-PE interface based on the formation of an emulsion cream layer. The CNC formed an immiscible O/W layer. Dry milling enhanced Pickering functionalities of cellulosic particles with reduced particle sizes, its adsorption ability, and stability based on the droplet morphologies after 7 days.

Poster Session 8: Food & Health

Dietary exposure assessment of oxidized sterols in ready-to-eat foods commercially available in the USA

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ABSTRACT

Increased consumption of ready-to-eat (RTE) foodstuff has been questioned in terms of safety and nutritional value. Dietary intake is now a new basis for epidemiological research. RTE are characterized by attractive packages and mixtures store-prepared, containing high amounts of total and added sugars and low amounts of dietary fiber, which have been linked to adverse effects on human health. Lipid oxidized molecules, such as dietary oxysterols (DOxS), are formed because of food's over-processing during their confection, storage, and transportation processes. DOxS are associated with several chronic diseases, such as cardiometabolic diseases (CMD), cancer, diabetes, and other neurological diseases. Recently, our group reported the presence of different DOxS in RTE foodstuff. However, no estimation of the consumption of DOxS from RTE has been reported. In this study, a dietary exposure assessment of 20 RTE foods consumed in the US is reported. EPA's integrated probabilistic model called "Stochastic Human Exposure and Dose Simulation Model High-Throughput" (SHEDS-HT) determined the dietary exposure to these compounds. Even though β-Sitosterol was the most exposed bioactive lipid with 75.4 mg/day, cholesterol was the most absorbed compound among the USA population (19.3 mg/day). Additionally, 7α-hydroxycholesterol (7α-OH) was suggested as a potential DOxS biomarker of the RTE manufacturing process. This is the first time an exposure assessment (including DOxS) after RTE consumption is performed, enabling much-needed information regarding these hazardous compounds and their potential effects on human health.

Fabrication of casein-inulin conjugates for improved physicochemical properties and investigation of delayed digestion thereof

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ABSTRACT

While fortifying foods with fiber seems like a straightforward method to boost fiber intake, it faces significant engineering hurdles like low solubility and adverse effects on physicochemical, textural, and sensorial properties. This project aims to develop a protein-dietary fiber complex suitable for incorporation into various food matrices, enhancing nutrition and satiety without compromising sensory or functional attributes. Casein micelle structure (CAS) was distended using metal chelation and physically conjugated with dietary fiber – inulin (IN) using cold homogenization under high pressure (~4500 psi). Milk protein isolate (MPI) or micellar casein concentrate (MCC) along with two different IN varieties: low (GR; DP>10) and high (HP; DP>23) degree of polymerization were used to prepare dispersions ranging from 1.5 to 3% of CAS or IN. CAS-IN mixtures were prepared in 3 different ratios: 1:1, 1:2 and 2:1. These mixtures were analyzed for particle size, zeta potential and viscosity and compared with unhomogenized mixtures and individual 3% protein or fiber dispersion. Preliminary results suggest that CAS-IN conjugates prepared using IN-GR formed the most stable dispersion, resisting separation at refrigerated conditions (~4 °C) for at least 14 days. Particle size analysis revealed bimodal distribution indicating presence of both caseins and inulin. CAS-IN conjugates prepared with IN-GR had the highest zeta potential (21.2±1.2 mV) regardless of protein used while IN-HP samples were least stable with a zeta potential ~0.5±1.6 mV suggesting poor dispersion stability. There were no significant changes in viscosity of the conjugates (~1.88±0.13 mPa.s) as compared to controls indicating desirable physical properties. The conjugates will be studied microscopically to understand structure, SDS-PAGE and Raman spectroscopy to explore conjugation and to investigate digestion-delaying effects on protein, in-vitro digestion assays will be performed. The stable conjugates would lead to fabrication of a novel food ingredient that would improve techno-functional properties, enhance nutritive value while controlling satiety.0.13 mPa.s) as compared to controls indicating desirable physical properties. The conjugates will be studied microscopically to understand structure, SDS-PAGE and Raman spectroscopy to explore conjugation and to investigate digestion-delaying effects on protein, in-vitro digestion assays will be performed. The stable conjugates would lead to fabrication of a novel food ingredient that would improve techno-functional properties, enhance nutritive value while controlling satiety.

In vitro digestion of starch and protein based nanoporous aerogels generated from defatted rice bran via supercritical carbon dioxide technology

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ABSTRACT

Rice bran (~8-10% of total grain weight), a rice processing byproduct, is a rich source of macro-and micro-nutrients. Despite its high nutritive value, defatted rice bran (DRB) is being discarded as waste or used as animal feed, creating a serious concern for the rice industry. Therefore, this study aimed to generate starch, crude starch, and protein-based aerogels from DRB using supercritical carbon dioxide (SC-CO_2) drying (10 MPa, 40°C, and 1L/min CO_2 flowrate) and investigate the in vitro digestibility of produced aerogels. DRB containing ~14 % protein and~33% starch content was used at different concentrations (10, 15, and 20%) to form aerogels. They were characterized for their morphology, crystallinity, chemical structure, textural properties, and solubility. Next, aerogels were subjected to in vitro digestion (oral, gastric, intestinal, and sequential). All concentrations revealed a three-dimensional open porous structure. However, the concentration was optimized to 15%, showing a better ability to form a strong gel, and the concentration >15% led to a denser structure with higher viscosity. Among aerogels, crude starch exhibited the highest surface area (47 m^2/g), and protein showed higher porosity (87%) and ultra-low density (0.19 g/cm^3). The impact of gelatinization/gelation revealed a noticeable reduction in crystalline peaks and an increase in hydrogen bonding in aerogels, resulting in higher solubility as compared to extracts. Additionally, the starch (i.e., 86 and 72% in starch and crude starch aerogels, respectively) and protein (i.e., 83% in protein aerogels) hydrolysis in the aerogels were higher after sequential digestion as compared to separate oral, gastric, and intestinal phase digestions. Overall, this study highlights the potential of DRB as a promising source for functional food formulations while increasing the sustainability of rice production.

Understanding microplastics interactions with various nutrients in food during digestion: An in vitro investigation

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ABSTRACT

Microplastic pollution has become a global concern, with ubiquitous presence in the environment, including the food chain. The impact of microplastics on human health is unknown and has attracted the interest of researchers in recent years. Micro and nano plastics commonly enter the body through ingestion, primarily via seafood, salt, water, and beverages. This study aims to explore the intricate relationship between microplastics and different nutrients in foods, using food materials rich in diverse nutrients as substrates. The current study was conducted to study the behaviour of micro plastics during in vitro digestion process using protein, carbohydrate, and lipid rich food medium to assess the interaction of different nutrients with microplastics. The analytical techniques including Electron microscopy, Fourier transform infrared spectroscopy, and gas chromatography techniques were employed to characterize the microplastics and digesta. Scanning electron microscopy results revealed the rough and fragmented surface structure of plastics after digestion process. FTIR analysis revealed the new peaks around 1500 – 1600 cm^{-1} indicating the amide regions that might be due to the interaction with protein molecules. The study revealed that when food with a higher lipid concentration was used, there was a noticeable increase in the release of additives. These interactions can potentially impact the digestibility of foods and nutrient absorption, and cause safety concerns.

An ionic gelation method to produce chitosan and polyethylene glycol containing resveratrol nanoparticles from blueberries: enhancing resveratrol bioavailability and intestinal uptake

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ABSTRACT

Resveratrol is a widely studied phytochemical renowned for its bioactive properties, including antioxidant and anti-inflammatory effects, as well as its ability to efficiently reduce intraocular pressure. This research presents a novel approach utilizing ionic gelation with chitosan and polyethylene glycol (PEG) to develop nano-encapsulation of an oil-based blueberry extract, aimed at enhancing the bioavailability of resveratrol. The constructed blueberry extract nanoparticles (NPs) were optimized to possess a particle size of 343.9 nm, an entrapment efficiency of 98.2%, a polydispersity index (PDI) of 0.231, and a zeta potential of 8.6 mV. Results showed that the ratio between PEG and blueberry extract and preparing pH were significantly related to particle size, while the ratio between PEG and blueberry and the ratio between chitosan and blueberry extract impacted entrapment efficiency. The release behaviour of resveratrol from blue berry extracts constructed with the optimized NPs showed a faster release in solutions with pH = 7.1 and good stability at pH values of 2.5 and 6.6, respectively.

Assessment of bioavailability through in vitro digestion revealed a significant increase of up to 78.6% for resveratrol NP in the blueberry extract compared to other formulations. Moreover, utilizing differentiated Caco-2 cells, the study demonstrated superior cellular uptake and penetration of NPs compared to free blueberry extract and blueberry extract in polyethylene glycol (PEG) ($P<0.05$). We conclude that the optimized NPs described here in can enhance cellular uptake and penetration of reseveratrol while having no in-vitro cytotoxicity side affects on Caco-2 cells.

These findings underscore the potential of employing chitosan/PEG for optimizing NP assembly to enhance resveratrol bioavailability when incorporated into an oil-based blueberry extract. This innovative methodology holds promise for improving the therapeutic efficacy of resveratrol and advancing the utilization of blueberry extract as a delivery system for bioactive compounds.

