The 4th CIRCUL-A-BILITY CONFERENCE

Re-thinking Packaging for Circular & Sustainable Food Supply Chains of the Future

Aarhus, Denmark 11-13 September 2024

BOOK OF ABSTRACTS

AARHUS UNIVERSITET

Funded by the European Union

cost EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

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Serena Pacchiani, Aarhus University, Denmark

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Alexander Bardenstein, DTI - Danish Technological Institute, Denmark
Begonya Marcos Muntal, IRTA - Institute of Agrifood Research and Technology, Spain
Elena Maria Arranz Gutierrez, Universidad Autonoma de Madrid, Spain
Emmanouil Tsochatzis, EFSA - European Food Safety Authority, Italy
Fátima Poças, Universidade Católica Portuguesa, Portugal
Frederic Debeaufort, Université de Bourgogne, France
Giancarlo Colelli, University of Foggia, Italy
Ilke Uysal Ünalan, Aarhus University, Denmark
Marit Pettersen, NOFIMA - Norwegian Institute of Food, Fisheries and Aquaculture Research, Norway
Matthijs Dekker, Wageningen University, Netherlands
Milena Corredig, Aarhus University, Denmark
Polymeros Chrysochou, Aarhus University, Denmark
Selçuk Yildirim, Zurich University of Applied Science, Switzerland
Victoria Krauter, FH Campus Wien, Austria

CONFERENCE VENUE

Aarhus University Conference Center - Stakladen

Frederik Nielsens Vej 2-4, 8000 Aarhus C

Building 1423

WIFI CONNECTIONS

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KEYNOTE SPEAKERS

Bahar Koyuncu, Ellen MacArthur Foundation

As a Senior Policy Officer at the Ellen MacArthur Foundation, I leverage my 17 years of experience across Research & Development, packaging innovation and sustainability policy to advance the circular economy with a focus on plastics and packaging. I hold a double major in Chemical Engineering and Chemistry and strongly believe in the role of science and multistakeholder collaboration to enable the transition to a circular economy.

Rafael Auras, Michigan State University, USA

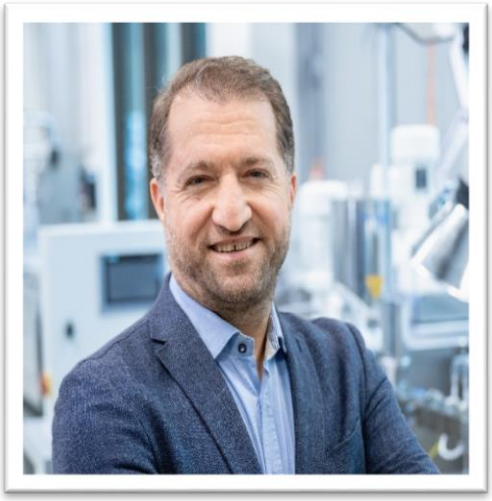
Dr. Rafael Auras is the Amcor Endowed Chair in Packaging Sustainability and a professor at the School of Packaging at Michigan State University (MSU). He heads a dynamic research group focused on mass transfer in polymers, biodegradable polymers, life cycle assessment, and designing packaging systems that promote sustainable development. With extensive experience collaborating on research projects for Fortune 500 companies and government agencies, Dr. Auras has co-authored over 200 publications and four books, cementing his reputation as a leading expert in his field.

INVITED SPEAKERS

Alexander Leo Bardenstein, Denmark Techological Institute, Denmark

Alexander Leo Bardenstein is a group and business manager for packaging materials and pilot production at Danish Technological Institute. He holds Master Degree in engineering physics and PhD in solid state physics. Alexander has broad expertise in ultrasonic and radiation technologies, plasma processing and coating of packaging materials, microwaveable food packaging and microwave decontamination of foods, equilibrium modified-atmosphere packaging (eMAP) for fresh produce, active food packaging, and cellulose-based barrier packaging.

Selcuk Yildirim, Zurich University of Applied Science, Switzerland



Selcuk Yildirim is a Professor and the Head of the Center for Food Processing and Packaging at the Institute of Food and Beverage Innovation, Zürich University of Applied Sciences (ZHAW), Switzerland. He holds a BSc in Food Engineering and an MSc in Process Engineering. Dr. Yildirim earned his PhD in Biotechnology from ETH Zurich, where he later served as a Post-Doctoral researcher and Group Leader in the Food Biotechnology Group. Before joining ZHAW in 2010, he worked as a researcher at the European Research and Development Center of Alcan Packaging. Currently, he also holds the position of Deputy Director at the Institute of Food and Beverage Innovation at ZHAW. Dr. Yildirim is a board member of Swiss Food Research and the International Association of Packaging Research Institutes (IAPRI). His research group collaborates closely with industry partners to develop innovative and sustainable packaging materials and processes. He has authored numerous book chapters, publications, and patents.

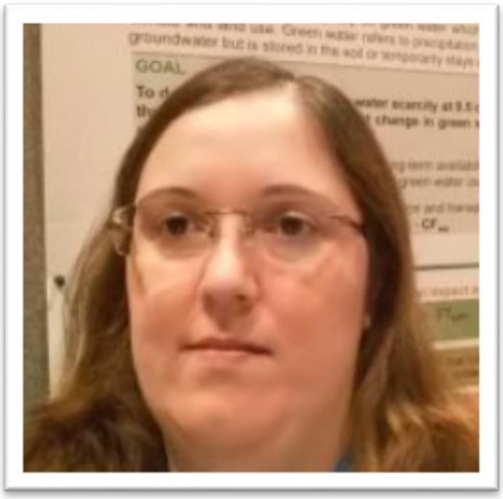
Ilke Uysal-Unalan, Aarhus University, Denmark

Ilke Uysal Unalan has been an Assistant Professor in the Department of Food Science at Aarhus University in Denmark since 2020. Her research focuses on a deeper understanding of the relationship between molecular structure (crystallinity, polarity, glass transition), end performance and end of life of polymers. She previously worked as a postdoctoral scientist at the School of Packaging, Michigan State University, and at the Laboratory of Food and Soft Materials of ETH Zurich where she intensively focused on bio-based sustainable packaging solutions for food. She researches and teaches how we can make our food system more sustainable with less food and food packaging waste. The main challenge for the transition to a zero-waste economy in food systems is no one can do it alone and we need a holistic approach by different disciplines related to food packaging along the supply chain involving all stakeholders in the value chain: producers, distributors, practitioners, and consumers. A systematic change is needed to make this green transition happen sooner rather than later.

Begonya Marcos Muntal, IRTA - Institute of Agrifood Research and Technology, Spain

Begonya Marcos Muntal, Agricultural Engineer and PhD in Science. Researcher in the Food Quality and Technology Program of IRTA (Institute of Agrifood Research and Technology), and Associate Professor in Food Packaging at Universitat de Girona. Her research career has developed around Food Processing and Packaging. Ongoing research activity is mainly focused on the development and implementation of novel packaging solutions for the food industry, packaging sustainability, interaction of food and packaging, valorization of by-products within the packaging sector, food safety and shelf-life extension. During the last years she has gained experience in the use of NIR and hyperspectral imaging to predict meat quality and for microplastic detection.

Paula Quinterio, University of Aveiro, Portugal

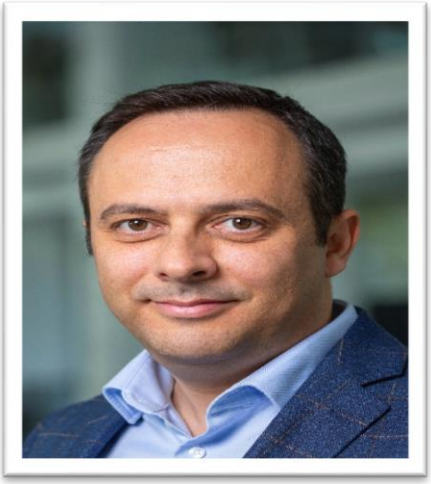


Paula Quinteiro currently works at the Centre for Environmental and Marine Studies (CESAM), University of Aveiro. Paula does research in Environmental Engineering.

Cristina Nerin, Zaragoza University, Spain

Cristina Nerín is Professor at the Department of Analytical Chemistry, University of Zaragoza. Cristina does research in Analytical Chemistry, Environmental Chemistry, Materials Chemistry and Food Packaging

Polymeros Chrysochou, Aarhus University, Denmark



Polymeros Chrysochou is a Professor of Marketing at the Department of Management, Aarhus University, Denmark. He is further an Adjunct Researcher at the American College of Greece, and member of the board of the Centre of Excellence in Food, Tourism, and Leisure. At Aarhus University, he is the coordinator of industry collaboration at the MAPP Centre, a research centre specializing in marketing and consumer behaviour research on food systems. His primary research focuses on areas of marketing communications and branding. He has published over 50 academic articles in academic journals in the area of marketing and consumer behaviour, such as *Marketing Letters*, *Psychology & Marketing*, and *Journal of Business Research*, as well as in areas of food science and sustainability research, such as *Food Quality and Preference*, *Trends in Food Science and Technology*, and *Climatic Change*. He has received funding and participated in several research projects funded by EU (e.g. R3PACK, FEASTS, Bi0SpaCE) or national funding bodies. He currently serves as associate editor at the *Journal of Product & Brand Management.*

Angelos Balatsas-Lekkas, University of Vaasa, Finland

Angelos Balatsas-Lekkas, Ph.D. (Eng.) is post-doctoral researcher at the University of Vaasa, School of Marketing and Communication. Angelos has over 7 years of experience in consumer research, studying the role of sustainable food and packaging innovations in consumers' transition toward more (or less) sustainable behaviors. His current focus is on consumers' attitudes and behavior related to reusable packaging for Fast-Moving Consumer Goods. He has been regularly producing new knowledge related to needs, expectations and behavior of European consumers for national and international projects attended by public and private organizations.

Fernando Rodriguez-Mata, New ERA - New European Reuse Alliance, Belgium

Fernando is the Director General of the New European Reuse Alliance (New ERA), the new EU trade association representing organisations that provide reusable packaging solutions across Europe. Before that, he worked for two public affairs firms in Brussels and Madrid, where he specialized in association management, circular economy and packaging matters. Fernando holds a Double Degree in Law and Business Administration from the Universidad Carlos III de Madrid. He also obtained a Master in European Law at the Université Libre de Bruxelles.

Diana Schiffer, LCA Center, Netherlands

With an education in environmental sciences & policy at Wageningen University & Research (NL), and food technology at the University of Technology in Munich (DE), Diana Schiffer has 2-year background working as packaging technologist and LCA practitioner at The LCA Centre (NL). The LCA Centre focuses on forensic LCA of packaging systems, reverse engineering, packaging innovation, and future packaging legislation. The regulatory landscape related to packaging is fast-changing and becomes increasingly complex. In her current role as Packaging Regulatory Advisor, it is her mission to bring together science, business realities and policy.

Emmanouil Tsochatzis, EFSA - European Food Safety Authority, Italy

I am a Food Technologist and Chemist with expertise on analytical chemistry and food safety, with a diverse career spanning academia and regulatory science with significant research and contributions to food and packaging safety, environmental sustainability and practical applications in food packaging and recycling. Currently I am a Scientific Officer at the European Food Safety Authority (EFSA), where he contributed to risk and safety assessment of food contact materials (FCM) and their recycling in the Food Ingredients and Packaging (FIP) Unit. toxicity studies, and evaluations of human exposure, particularly focusing on toxicokinetics. At the moment, I am an Adjunct Associate Professor at the Department of Food Science of Aarhus University with extensive knowledge and in targeted analysis, untargeted screening, and metabolomics to cutting-edge research in food science. My research also delves into the analysis of bioactive compounds, the use of insects as model organisms for biorecycling and biodegradation of plastics, microplastic and nanoplastics as well as the exploration of statistical and chemometric analysis methods, including univariate, multivariate, and complex modeling techniques. Prior to my role at EFSA, I was a researcher in Greece, Italy, Belgium and Denmark whilst I served as a scientific officer at the European Reference Laboratory of Food Contact Materials (EURL-FCM) at the Joint Research Centre of the European Commission.

Maria Dahl, Aage Vestergaard Larsen, Denmark

Maria Dahl is a product developer at Aage Vestergaard Larsen, specializing in mechanical recycling of plastics. She manages internal projects, and interdisciplinary with industry and academia. Her talk will focus on the industrial perspective of plastic packaging recycling, both the current status related to mechanical recycling and future perspectives.

Pieter Billen, University of Antwerp, Belgium

Pieter Billen is a chemical engineer and associate professor at the department of Biochemical and Chemical Technology of the University of Antwerp. He leads the research group iPRACS, aspiring to bridge organic synthesis and catalysis with chemical process and value chain design. Most of his recent work covers the circularity of organic materials by means of depolymerization, and the associated economic and environmental considerations.

Other Invited Speakers:

Davide Mazzanti, Einfach Mehrweg, Germany

Jeanette Morath, ReCIRCLE, Switzerland

Simon Rossau, City of Aarhus, Denmark

Peter Sommer Larsen, Danish Technological Institute, Denmark

PROGRAM

PROGRAM AT A GLANCE

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Sustainable food packaging definition, circularity, life cycle perspective</td><td>08:45 - 09:55
SESSION 4
STUDIES ON SUSTAINABLE FOOD PACKAGING</td><td>08:45 – 09:45
SESSION 8
NEW PACKAGING REGULATIONS
&
Q/A</td></tr>
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SESSION 5
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SESSION 6
MARKETING AND CONSUMER SCIENCE</td><td>13:30
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<tr><td colspan="2">COFFEE BREAK & POSTER SESSION & NETWORKING</td><td rowspan="2">OPTIONAL
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DAY 1 - 11 SEPTEMBER 2024		
8:30-9:00	REGISTRATION	
9:00-10:40	**OPENING SESSION**	**Chair: Giancarlo Colelli, Co-Chair of Circul-a-bility, Universita'di Foggia, Italy**
9:00-9:10	WELCOME	Giancarlo Colelli, Universita'di Foggia, Italy
9:10-9:20	What is sustainable food packaging? The Circul–a-bility definition	Milena Corredig, Chair of Circul-a-bility, Aarhus University, Denmark
9:20-10:00	Keynote: A circular economy for plastic packaging	Bahar Koyuncu, Ellen MacArthur Foundation
10:00-10:40	Keynote: Adapting to change: Achieving sustainability through life cycle perspectives in packaging systems.	Rafael Auras, School of Packaging, Michigan State University, USA.
COFFEE BREAK		
11:15-12:05	**SESSION 1 BIO-BASED PACKAGING (1)**	**Chair: Marit Pettersen, NOFIMA -Norwegian Institute of Food, Fisheries and Aquaculture Research, Norway**
11:15-11:45	Invited talk: Review and assessment of fully molded cellulose (paper) bottle production technologies.	Alexander Bardenstein, DTI - Danish Technological Institute, Denmark
11:45-12:05	Contributed talk: Biodegradable PVOH-based barrier coatings on kraft paper for sustainable food packaging applications	Paola Scarfato, University of Salerno, Italy
LUNCH BREAK, POSTER SESSION and NETWORKING		
13:10- 14:00	**SESSION 2 BIO-BASED PACKAGING (2)**	**Chair: Fatima Pocas, Universita Catolica Porto, Portugal**
13:10-13:40	Invited talk: Innovative approaches to valorizing food side streams: Transforming Swiss waste into sustainable packaging materials	Selcuk Yildirim, Zurich University of Applied Sciences, Switzerland
13:40-14:00	Contributed talk: Innovative	Esther Rincón,

	sustainable food active packaging films through bioactive pectic polysaccharides from agricultural waste valorization	Universidad de Córdoba, Spain
COFFEE BREAK, NETWORKING and POSTER SESSION		
14:30-16:50	**SESSION 3 CIRCULARITY, ECO-DESIGN AND END OF LIFE**	**Chair Milena Corredig, Aarhus University, Denmark**
14:30-15:00	Invited talk: Turning challenges into opportunities: Food-centric approach for compostable bioplastic packaging	Ilke Uysal-Unalan, Aarhus University, Denmark
15:00-15:30	Invited talk: Spectroscopic techniques enablers of sustainable food packaging	Begonya Marcos Muntal, IRTA - Institute of Agrifood Research and Technology, Spain
15:30-15:50	Contributed talk: Re3-Plast; Reduce, Reuse and Recycle - a new Green Platform project	Marit Kvalvag Pettersen, NOFIMA -Norwegian Institute of Food, Fisheries and Aquaculture Research, Norway
15:50-16:10	Contributed talk: A review of LCA tools used to optimize the food packaging supply chain	BrechtVan Der Hoeven, Pack4Food, Belgium
16:10-16:30	Contributed talk: Strategies for future decarbonized food cold supply chains	Igor Karlovits, Danfoss Power Solutions, Denmark
FREE EVENING		

DAY 2 - 12 SEPTEMBER 2024		
08:15-08:45	REGISTRATION	
08:45-09:55	**SESSION 4 STUDIES ON SUSTAINABLE FOOD PACKAGING**	**Chair: Begonya Marcos, IRTA, Spain**
08:45-9:15	Invited talk: Sustainable packaging for meat and fish products	Paula Quinterio, University of Aveiro, Portugal
09:15-09:35	Contributed talk: Vegan edible coatings based on fresh produce waste with active properties for preserving perishable fruits	Luana Carnaval, Technological University Dublin, Ireland
09:35-09:55	Contributed talk: Multi-dimensional sustainability assessment (MuDiSa); coffee packaging examples	Maxence Paillart, Wageningen Food & Biobased Research, Netherlands
COFFEE BREAK		
10:30-12:00	**SESSION 5 SAFETY OF FOOD PACKAGING**	**Chair: Matthijs Dekker, Wageningen University**
10:30-11:00	Invited talk: Sustainability and risk assessment	Cristina Nerin, Zaragoza University, Spain
11:00-11:20	Contributed talk: Migration of non-intentionally added substances in packaging of fresh cut vegetables	Sandra Pati, University of Foggia, Italy
11:20-11:40	Contributed talk: A study on migration from cork-polypropylene composites	Fatima Pocas, Universidade Católica Portuguesa, Portugal
11:40-12:00	Contributed talk: Chemical food safety and hazard assessment of a circular mono-plastic material film with improved barrier properties	Bina Bhattarai, Technical University of Denmark, Denmark
LUNCH BREAK, POSTER SESSION and NETWORKING		
13:00-14:40	**SESSION 6 MARKETING AND CONSUMER SCIENCE**	**Chair: Krisztina Dornyei, Hungary**
13:00-13:30	Invited talk: It is a matter of fairness: How partitioned pricing strategies can shift preferences for reusable food packaging	Polymeros Chrysochou, Aarhus University, Denmark

13:30-14:00	Invited talk: Consumer behavior results for a reuse packaging project in Finland	Angelos Balatsas Lekkas, University of Vaasa, Finland
14:00-14:20	Contributed talk: Research to reality: Survey and focus group analysis of starch-protein blend bioplastics—exploring applications and public perception	Jade Stanley, South East Technological University, Carlow, Ireland
14:20-14:40	Contributed talk: Insights into sustainability benchmarkings for food and non-food packaging in the DACH region	Michelle Klein, University of Applied Sciences Vienna, Austria
COFFEE BREAK, NETWORKING and POSTER SESSION		
15:30-18:00	**SESSION 7 REUSE**	**Chairs: Polymeros Chyrsochou, Aarhus University & Selcuk Yildirim, Zurich U Applied Science**
15:30-16:00	Invited talk: How to make reuse systems the new normal?	Fernando Rodriguez-Mata, New ERA - New European Reuse Alliance, Belgium
16:00-16:30	Invited talk: Transparency in Reuse: Environmental impact of our large-scale Reuse System with verified data	Davide Mazzanti, Einfach Mehrweg, Germany
16:30-17:30	Panel- Perspectives on reuse	Jeanette Morath ReCIRCLE, Switzerland Diana Schiffer LCA Center, Netherlands Simon Rossau City of Aarhus, Denmark Fernando Rodriguez-Mata New ERA - New European Reuse Alliance, Belgium Davide Mazzanti Einfach Mehrweg, Germany
17:30-18:00	Q&A and discussion	
CONFERENCE DINNER Place: Spise Lauget, Aarhus, 20:00 “Rotake Reusable” project in Aarhus - Simon Rossau, Aarhus Municipality		

DAY 3 - 13 SEPTEMBER 2024		
08:15-08:45	REGISTRATION	
08:45-09:45	**SESSION 8** **NEW PACKAGING REGULATIONS**	**Chair: Alexander Bardenstein, Danish Technological Institute (DTI), Denmark**
08:45-9:15	Invited talk: Packaging and Packaging waste directive	Diana Schiffer, LCA Center, Netherlands
9:15-09:45	Q&A and discussion	
COFFEE BREAK		
10:15-12:45	**SESSION 9** **RECYCLING TECHNOLOGIES & END OF LIFE DESIGN**	**Chair: Ilke Unalan, Aarhus University, Denmark**
10:15-10:45	Invited talk: EFSA's New Guidance on mechanical Recycling of PET	Emmanouil Tsochatzis EFSA - European Food Safety Authority, Italy
10:45-11:15	Invited talk: 50 years of experience in industrial re cycling of plastic: what has changed in a product developer portfolio?	Maria Dahl, Aage Vestergaard Larsen, Denmark
11:15-11:45	Invited talk: Chemical recycling -where are we	Pieter Billen, University of Antwerp, Belgium
	PANEL PRESENTATION	**Chairs: Ilke Unalan,** **Aarhus University, Denmark;** **Alexander Bardenstein,** **DTI - Danish Technological Institute, Denmark**
11:45-12:15	Panel presentations	Emmanouil Tsochatzis European Food Safety Authority, Italy Maria Dahl Aage Vestergaard Larsen, Denmark Pieter Billen University of Antwerp, Belgium Peter Sommer Larsen Danish Technological Institute, Denmark
12:15-12:45	Q&A and Discussion	
CLOSING		
LUNCH from 12:45 to 13:30		
14:00 OPTIONAL SITE VISITS TO Food Packaging Labs at AU FOOD SCIENCE & Consumer and Behaviour Lab (www.cobelab.au.dk) at AU MAPP center		

LIST OF POSTERS

1	**Francisco Silva**, Universidade Católica Portuguesa, Portugal *Development of multilayer coatings on kraft paper using bio-based materials*
2	**Gonçalo Oliveira**, University of Aveiro, Portugal *Water vapor resistant and antioxidant paper coating derived from coffee by-products*
3	**Vineta Srebrenkoska**, Goce Delcev University Stip, R. North Macedonia *Preparation of innovative polymer composite materials for food packaging*
4	**Mansurali Mithani**, Aarhus University, Denmark *Unlocking the role of plasma surface treated graphene in crystallization behavior of stereocomplex poly(lactide) systems*
5	**Nusrat Sharmin**, NOFIMA - Norwegian Institute of Food, Fisheries and Aquaculture Research, Norway *Preparation and characterization of alginate-carrageenan and alginate-mannitol films with better barrier and mechanical properties for food packaging applications*
6	**Ramune tkaite***,* Kaunas University of Technology, Kaunas, Lithuania *Immobilization of rosemary, clove, and thyme essential oils in electrospun cellulose acetate fibers for active food packaging applications*
7	**Meral Yildirim-Yalcin**, Istanbul Aydin University, Türkiye *Development and characterization of bioplastic films by starch obtained from avocado seeds*
8	**Vera Cebrián-Llore**, Instituto de Investigación en Ciencias de la Alimentación, Spain *Unlocking the full potential of seaweeds for sustainable bio-based packaging*
9	**Remziye Doğru**, Izmir Institute of Technology, Türkiye *Pectic compounds from grape wastes: characterization and utilization in novel bio-polymeric edible film formulations*
10	**Begonya Marcos**, IRTA – Institute of Agrifood Research and Technology, Spain *Foodwaste for foodpack: A model to convert residues from food industries into a packaging solution*
11	**Susana Guzman-Puyol**, Universidad de Málaga, Spain *Upcycling of potato peels for the fabrication of metal food packaging*
12	**Vanesa Benítez**, Universidad Autónoma de Madrid, Spain *Revealing the food packaging potential of coffee pulp extraction residues*
13	**Miray Buyuk**, Izmir Institute of Technology, Türkiye *Application of principal component and hierarchical clustering analyses for the evaluation of physical modifications on chickpea protein films*
14	**Eduardo Espinosa,** Universidad de Córdoba, Spain *Thermoformed fiber-polyethylene biocomposites: sustainable packaging solutions for cherry tomatoes*

15 **Sherry Stephanie Chan**, NOFIMA - Norwegian Institute of Food, Fisheries and Aquaculture Research, Norway
Combining soluble gas stabilization and high-pressure processing on rehydrated clip fish packaged in bio-based pouches

16 **Farzin Javanshou**, VTT - Technical Research Centre of Finland, Finland
Towards traceable and sustainable plastic packaging: A perspective on recyclability of reusable smart packaging

17 **Anna Mengozzi**, University of Parma, Italy
Life cycle assessment of cured meat product packaging: integrating the potential food waste related to the shelf life

18 **Inês Mota**, Universidade Católica Portuguesa, Portugal
LCA exercise on different packages for cherry tomatoes: Effect of considering packaging performance regarding air ventilation

19 **Chrysoula Kanakaki**, University of Athens / Tsakalidis Analysis & Testing Laboratories, Greece
FCMs: The dos and don’ts of chemical migration testing

20 **Luis Jiménez Munoz,** Aarhus University, Denmark
Evaluating the risk of oligomers and harmful compounds from food packaging materials

21 **Tiago Vieira**, Universidade Católica Portuguesa, Portugal
Biocides in food packaging: Safety concerns and migration insights

22 **Mevlüt Sedat Dönmez**, Süleyman Demirel University, Türkiye
Reflection of sustainable packaging as a brand communication tool on brand attitude

23 **Katerina Bojkovska***, University "St. Kliment Ohridski", R. North Macedonia*
Consumer behavior in the model of the circular economy in agrifood sector in the Republic of North Macedonia

ABSTRACTS

Biodegradable PVOH - based barrier coatings on kraft paper for sustainable food packaging applications

A. Barbato, M.C. Riccelli, A. Apicella, P. Scarfato, L. Incarnato
Department of Industrial Engineering, University of Salerno,Salerno, Italy
pscarfato@unisa.it

The packaging industry is moving to paper due to environmental worries about plastic pollution. Paper is biodegradable, recyclable, and compostable, but it faces challenges like hydrophilicity and high permeability, notably in food packaging. The use of biodegradable coatings can significantly improve paper properties, addressing its main limitations. In this regard, polyvinyl alcohol (PVOH), thanks to its film-forming ability, high barrier properties, and biodegradability, is an interesting candidate as coating material since it can provide protection against gas permeation, resistance to external agents, and adhesion ability.

In this study, we designed innovative packaging solutions based on a Kraft paper (grammage 100 g/m²) coated with a water-resistant, biodegradable and high-barrier ethylene-modified polyvinyl alcohol (m-PVOH, Exceval AQ-4104) at different concentrations (10, 15, and 20 wt%), and characterized the produced structures for their overall functional performance. Coated paper samples maintained a constant thickness despite increasing grammage, suggesting permeation of coating solutions into the paper's fibrous matrix. Cobb60 values demonstrated a maximum reduction of 57% in water absorption for Kraft paper/20% m-PVOH samples, while water vapor permeability (23°C, 50% RH) remained constant across all coated samples (~ 4.0 g/ (m2 day)), indicating enhanced resistance to both liquid and vapor water. As the m-PVOH concentration increase, air permeability resistance increased too, correlating with a rise in coat weight, whereas oxygen barrier properties remained approx. constant, ranging from 573.0 to 588.4 cm3/(m2 day) at 50% RH, and tensile strength was essentially unchanged, suggesting the potential of the developed structures as sustainable and improved-performance food packaging solutions.

Innovative sustainable food active packaging films through bioactive pectic polysaccharides from agricultural waste valorization

Esther Rincón[a], Eduardo Espinosa[a], Francisco Vilaplana[b], Luis Serrano[a], Amparo Jiménez-Quero[c]

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[b]Division of Glycoscience, Department of Chemistry, School of Engineering Sciences in Chemistry, Biotechnology and Health, KTH Royal Institute of Technology, Stockholm, Sweden
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Food loss and waste have significant environmental impacts, contributing to 16% of direct greenhouse gas emissions and 28% of material resource use. The food packaging industry plays a crucial role in reducing food waste through measures such as small format packaging. However, this solution often leads to increased plastic waste, which has substantial environmental repercussions. Consequently, research into new formulations for sustainable food packaging is continuously evolving. Lignocellulosic biomass, especially from agricultural and agri-food waste, has emerged as a valuable source of high-value compounds that can replace fossil-derived resources in the creation of new active packaging materials.

This work presents the isolation of bioactive polysaccharides from agricultural wastes using green extraction techniques and their application in developing food active packaging films, contributing advancements in the circular economy. The potential isolation of bioactive polysaccharides was explored by sequential extraction in subcritical water using different time-temperature combinations. The extracted polysaccharides, predominantly pectins, maintained their high molecular mass (10-100 kDa), presenting ideal properties for use as additives in food packaging. Pectin-enriched chitosan films were prepared, improving the optical properties (≥95% UV-light barrier), antioxidant capacity (≥95% radical scavenging activity) and water vapor permeability compared to pure chitosan films. Additionally, the antimicrobial activity of chitosan was preserved. The addition of 10% pectins improved the mechanical properties, increasing Young's modulus by 12%, and tensile strength by 51%. This study demonstrated the effective use of pectin-rich fractions from agricultural residues as an additive in active food packaging applications, with triple action as antioxidant, barrier and antimicrobial.

Re3-Plast; Reduce, Reuse and Recycle - A new green platform project

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Food packaging accounts for the largest share of plastic waste from households, with a great potential for resource utilization through recycling. Society and authorities have focused on the high consumption of plastic and the lack of circularity The EU has proposed a new regulation that set high demands that will require significant innovation and developments. There is a significant need for new technology, circular systems and a changed composition of food packaging that can either contribute to reducing, reusing and/or recycling into new food packaging. It is important with changes in the design, material, and composition of the packaging and new solutions without compromising the food quality and shelf life and does not increase food waste and increased climate and environmental impact.

The Green Platform is a national initiative in Norway. The project Re3-Plast: Reduce, Reuse, Recycle has been awarded 67 million NOK (6 mill. Euros); and a total budget of appr. 9 mill Euros and will develop and demonstrate circular solutions for plastic packaging for food, The Re3-Plast project's goal is to develop technologies and solutions that will reduce consumption, increase reuse, and increase the recycling of plastic packaging for use in new food packaging.

The project has a strong consortium representing the packaging value chain including the largest food and packaging producers in Norway and R&D partners. The initiative is funded by the Research Council of Norway, Innovation Norway, and SIVA.

A review of LCA tools used to optimize the food packaging supply chain

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All stakeholders in the food packaging value chain are increasingly pressured to assess and improve the sustainability of products and services to be compliant with future requirements of circular economy. To meet these challenges for (food) packaging, life cycle analysis (LCA) calculations and tools are often used nowadays. The results of LCA tools are used in an attempt to optimize packaging configurations and the value and supply chain, but also during discussions about policy such as the PPWR. To get a better understanding of the capabilities and scientific limitations of LCA tools for packaging systems, the TACTIC project was launched by Pack4Food and Flanders' FOOD. Within TACTIC, Pack4Food inventories, reviews and analyses LCA tools for (food) packaging systems. By bundling and reviewing knowledge on LCA tools, Pack4Food is answering relevant questions for stakeholders who are looking to integrate LCA tools in the sustainability decision making process for their products. For example, (i) which pitfalls to avoid when using LCA tools as an organization, (ii) what are capabilities and limitations of current tools, (iii) what about reuse systems, (iv) where do these new logistical models fit into the world of LCA tools and (v) which scientific basis (e.g. methodologies, system boundaries, etc.) is used in these systems? To maximize applicability of the research results, Pack4Food is also mapping the expectations of stakeholder in the value chain towards LCA tools leading to a best practice guide linking these expectations with capabilities of the tools and highlighting future improvements in LCA tools.

Strategies for future decarbonized food cold supply chains

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Cold chain distribution is a temperature controlled supply chain. For food supplies it is important that the series of storage and distribution activities maintain a given temperature range. Maintaining the cold chain is vital for preserving the safety and quality of refrigerated foods. The ranges used for constant temperature systems can vary from the chill range (2 to 40 °C) for fruits, vegetable and dairies, to frozen range /-10 to -200 °C) which is optimal for frozen meat, bakery products, and ice cream up to Deep Freeze Range (-25 to -30°C) mainly used for seafood and ice cream.

All of these system are using large quantity of energy. According to some researches the food cold chain contributes to approximately four percent of total global GHG emissions, considering both cold chain technologies and food loss due to lack of refrigeration. As food cold chains expand, energy demand will increase. Transitioning to renewable energy sources is crucial for sustainability. In this paper novel approaches in tackling decarbonization efforts with supply chain optimizations and packaging/distribution combinations are presented. Different technologies like variable speed compressors, thermal storage in form of different packaging solutions and smart controls building on artificial intelligence and machine learning systems can contribute to energy efficiency and decarbonization efforts. This paper will give an overview of possible combinations of smart energy solution and cold chain packaging to reduce the overall energy consumption and prevent food waste.

Vegan edible coatings based on fresh produce waste with active properties for preserving perishable fruits

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Active edible coatings have emerged as a novel technology to preserve/extend food shelf life. Materials based on renewable and low-impact resources, such as fresh produce waste, contribute to the development of sustainable and low-cost packaging solutions that secure extra protection/safety along the food supply chain. In addition to reduce food-borne illnesses and food waste/loss as their active properties can prevent microbial contamination, oxidation, and spoilage, maintain food quality/freshness, besides delay fruit ripening and extend shelf-life, leading to a potential increase of the food supply. This research work aims to develop vegan edible coatings for food preservation based on whole valorization of fresh produce waste, through minimum processing steps, whose various combinations have been applied along the formulation study to develop sustainable and active coating materials. Target coating characteristics cover mainly the reduction and/or prevention of water loss, respiration/transpiration rate, mechanical injuries, and microbial spoilage. Therefore, after optimization of the process, a base formulation has been established for experimental design studies. The selected formulation was submitted to a central composite design (CCD) approach based on response surface methodology (RSM) analysis, with 4 response parameters (water contact angle, tensile strength, elongation, and thickness) and further confirmation testing for the best combination of ingredients.

Final RSM results have shown hydrophobic and elastic characteristics of the new material, which are required for preservation purposes. Future work will cover a thorough investigation of the physical, thermal, chemical, barrier, antibacterial, antifungal, and antioxidant properties of the developed coating, as well as migration tests and shelf-life studies.

Multi-dimensional sustainability assessment (MuDiSa); coffee packaging examples

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To assist food industry in making well-founded choices for the most sustainable packaging solution, WFBR has developed a new tool that aims to include the most important aspects of packaging sustainability: food loss & waste, circularity, the (circular) recycling of the packaging, the use of renewable resources and the effects of (potential) leakage of materials into the natural environment. The calculation tool compiles case specific data of the packaging and food product, and background data including the emission factors of materials and processes and recycling efficiencies. Multiple sustainability indicators are calculated to describe the sustainability of the product-packaging combinations.

The tool has been used to compare different types of coffee bean packages and coffee capsules. In both case studies, packages are compared on two main dimensions of sustainability: carbon footprint and material circularity. In the first case study, reusable and single use coffee bean packages are compared. The tool allowed us to highlight the importance of attaining enough reuse loops when using a reusable packaging. In the second case study, bio-based compostable capsules, conventional plastic capsules and aluminum coffee capsules, with several end-of-life-scenarios, are compared. Clear differences in both dimensions of sustainability are observed for the various packaging options. The case study also included the assessment of the end-of-life treatment of the spent coffee grounds. Finally, the introduction of a third important dimension of sustainability into the assessment tool takes into account the accumulation of microplastics in the natural environment.

Migration of non-Intentionally added substances in packaging of fresh-cut vegetables

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The study of migration of non–intentionally added volatile substances from plastic packaging for fresh–cut vegetables, under storage real conditions, was the aim of this work. First, a screening of volatile compounds from several packaging materials, including polypropylene (PP), polyethylene terephthalate (PET), polypropylene/polyamide (PP/PA), polyethylene terephthalate/polyethylene (PET/PE), PP/PET, polypropylene/ethylene vinyl alcohol (PP/EVOH) and PET/PE/EVOH, was carried out by solid phase micro–extraction followed by gas–chromatography coupled to mass spectrometry analysis. The number and the structure of the emitted volatiles resulted different according to the material and to the producer. Most of the identified compounds belonged to the chemical class of branched aliphatic alkanes, such as 4-methyl-heptane, 2,4– dimethyl- heptane, 4-methyl-octane.

Afterwards, the release of some volatiles from the bilayer PET/PE, was studied, at several temperatures, finding that the behavior was not the same for all the investigated substances. The release of hexanal and dodecane, was constant over time indicating fast release kinetics; whereas, the release of some other compounds, such as the 2,2,4,6,6-pentamethyl heptane, increased with time until reaching steady state. Then, the possibility to find volatiles migrated from the packaging to the packaged fresh–cut vegetables was established storing some vegetables in the investigated packaging.

Finally, the presence of volatile compounds migrated from the packaging in the headspace of packaged fresh-cut vegetables bought in several supermarkets was ascertained. These results demonstrated that the study of volatile emission from food packaging is critical for fresh-cut packaging could have implications for encouraging the design of packaging solutions with low emission of volatile compounds

A study on migration from cork-polypropylene composites

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Cork is used for long as food contact material (FCMs) specifically for closures, either in its natural form or as granules agglomerated through a synthetic binder, usually based in polyurethane resin. The safety aspects of these FCM have been the target of food contact notification (FCN) to the FDA. However, cork is of great interest as an additive for polymeric matrixes, which are regulated under EU Reg 10/2011. The safety of migrants from plant-based materials must be evaluated on a case-by-case basis (EFSA, 2019). Furthermore, cork as an additive for plastics should be assessed using the established guidelines (EFSA, 2023). This work aimed at characterising migration of a cork-polypropylene (C_PP) composite. Cork granules were incorporated (15%) in PP and submitted to screening analysis by GC-MS (volatile and semi-volatile), and to migration tests (ethanol 10%, acetic acid and oil). Migration kinetics and repeated use tests were performed. Simulants were analysed by GC-MS and LC-MS. The samples after contact with simulants were evaluated by scanning electronic microscopy (SEM).

The impact of incorporating cork granules on migration (overall and migration of substances originating from the PP matrix), was not the same for all substances. Migration presents higher values for fat simulant, as expected. Screening showed potential cork migrants, in particular friedelan-3-one and 3,12-oleandione and high levels of furfural (~ 1 mg/kg), but this latter was not detected in the cork granules before incorporation. Therefore, is a NIAS from the process. Cork components were not detected in the migration simulants (LOD 30 µg/kg). EFSA CEP Panel, 2019. Scientific Opinion on the update of the risk assessment of ‘wood flour and fibres, untreated’ (FCM No 96) for use in food contact materials, and criteria for future applications of materials from plant origin as additives for plastic food contact materials.

Chemical food safety and hazard assessment of a circular mono-plastic material film with improved barrier properties

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Flexible plastic laminates are widely used for food packaging as multilayer-laminate films and heat-sealed products in the form of pouches and sealings. Multilayer-laminate film packaging has the desired functionalities for the food industries; however, they are difficult to recycle, and it is a challenge to maintain the quality of the recycled material.

Therefore, in a circular mono-plastic project the aim has been to develop food packaging using a mono-material with improved barrier properties that can be repeatedly recycled for food contact application. The developed packaging should not allow the migration of substances at exposure levels that could pose a risk for human health. We have screened the packaging material including the repeatedly recycled material for potential migrating substances using high-resolution mass spectrometry and performed the hazard assessment of substances using Quantitative Structure- Activity Relationship modeling (QSAR). Both total dissolution tests and migration testing were conducted. Untargeted screening analyses were performed using in-house developed MSMS databases and over 500 chemical features were detected of which 36 chemical features were annotated.

The chemical features were semi-quantified using relevant reference substances. We have classified the annotated chemical features based on the crammer classification of threshold of toxicological concern, where eight of the features were classified as class III. However, none of the chemical features exceeded the TTC of 90 ug/kg food. One of the chemical features was present on the positive list in Commission Regulation EU10/2011 but did not exceed the specific migration limit.

Research to reality: Survey and focus group analysis of starch-protein blend bioplastics- exploring applications and public perception

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The escalating severity of plastic pollution has spurred significant research into bioplastics. While certain bioplastics, such as those derived from protein and starch blends, exhibit biodegradable properties, many rely on unsustainable sources of starch. Even though bioplastics can decompose, sustainability and environmental friendliness are vital properties.

Since initial manufacturing of these bioplastics will be more expensive to produce, it is imperative that these new plastics appeal to the target user in terms of both practicality and novelty. The public perception of bioplastics and the potential uses of starch-protein blend biopolymers (SPBBs) derived from the starches of Potato, Tapioca, Sago, and Swamp Taro, are assessed in this study. The data was collected using a survey circulated via emailing systems, snowballing method and used to gather participants for a focus group. The results demonstrated that the public's comprehension of bioplastic terminology and acceptance of the use of biopolymers was influenced by age and level of education. The survey discovered that although most individuals understand biodegradability, they do not confidently understand what "biobased" means.

For bioplastics, they are willing to pay an extra 5 % maximum of the original item price. Approximately 80 % of participants identified packaging, mostly food packaging, as the leading cause of plastic pollution. Up to 74 % of people stated they actively used alternatives to plastics. The Focus Group discussed preferences for plastic, focusing on prospective applications, affordability, transparency, colour, and sustainability. Participants recommended using influencer endorsements and media campaigns to inform customers about eco-friendly options. The Focus Group also highlighted the importance of clear labelling, eco-friendly packaging, and recycling symbols in bioplastics. Future studies should explore public understanding of sustainability, bioplastic identification, and the cost-value of creating a greener future, where consumers can actively use and identify bioplastic products.

Insights into sustainability benchmarkings for food and non-food packaging in the DACH region

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The choice of packaging materials and design can have a significant impact on sustainability. In the context of comprehensive benchmarking studies in the DACH region more than 600 packaging samples for dairy products, beverages and cosmetics were analyzed.

The holistic sustainability assessment represents a powerful multi-criteria method for packaging which aims to consider various ecological aspects under inclusion of different criteria of sustainability. The relevant indices were selected from a comprehensive pool of sustainability assessment indicators, in accordance with the ECR guidelines. With regard to the aspect of circularity, the parameters consumer involvement, use of recyclate and of natural resources were assessed. Additionally, the recyclability of the packaging was calculated for the three respective countries. With respect to the environmental aspects, the use of certified materials and packaging efficiency and the direct and indirect environmental effects were considered. Additionally, a method to assess the littering potential was developed. The indirect effects were measured by a new standardized method to measure retained food residues.

The results demonstrate several weaknesses towards future regulations proposed in the PPWR. Most cosmetic packaging fails to meet targets for recyclability, in contrast to dairy and beverage packaging. Improvement is also needed in packaging efficiency and emptyability for high viscose products, as well as the use of recyclate and renewable resources. A limited number of FSC-certified materials were identified across all packaging categories, and recommendations include a shift towards the use of sustainable sourced materials.

Development of multilayer coatings on kraft paper using bio-based materials

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The food packaging industry has been exploring the application of cellulose-based materials (e.g., paper and board), known for their lower environmental impact when compared to synthetic materials [1]. These cellulosic materials lack the performance required for food packaging applications, due to their high hydrophilicity and porosity [2]. Coating technology has been widely used to address these deficiencies, to enhance moisture, grease, and air resistance. At industrial level, styrene acrylic emulsions/dispersions are typically used yet other bio-based alternatives may be used to functionalize the surface of cellulose substrates. In this work, a multilayer coating is adopted using cellulose nanofibrils (CNF) as inner layer and the blend of poly (butylene adipate-co-terephthalate)-esterified lignin (PBAT-E.lignin) as outer layer. Initially, the performance of CNF and PBAT-E.lignin was evaluated separately. CNF coatings were applied to paper with a maximum pick-up of 15 g/m2. Morphological analysis, air permeability, and oil absorption tests demonstrated the beneficial effect of CNF coating on the surface, improving air and grease resistance due to full paper pores coverage. To study the performance of the outer layer, the PBAT and E.lignin mixture was optimized by varying the E.lignin concentration from 1% to 20%. Lower concentrations of E.lignin (1%) offered better lignin distribution within PBAT matrix, enabling to achieve competitive values for oxygen and water vapor permeability, thus improving moisture resistance. A multilayer coating process using CNF and PBAT-esterified lignin is currently underway, with a total fixed pick-up of 15 g/m2. The pick-up of each layer is being optimized to achieve optimal overall barrier performance.

Water vapor resistant and antioxidant paper coating derived from coffee by-products

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Paper needs to be coated with non-biodegradable polymers before being used as food packaging, compromising its biodegradability and recyclability. Alternatively, biobased coatings for paper have been developed. In this work, the feasibility of using coffee fruit cascara (CFC), a byproduct obtained during the depulping of the coffee cherry, as a source of biomolecules suitable to develop biocoating formulations was evaluated. CFC was fractionated into water-soluble and water-insoluble fractions by microwave-assisted extraction. The first fraction was used to recover pectic polysaccharides through ultrafiltration. The second was used to obtain cellulose-rich nanostructures through an alkaline hydrogen peroxide oxidation followed by acid hydrolysis and ultrasonication. CFC pectic polysaccharides and nanostructures were combined in an aqueous formulation that was applied onto the paper's surface by bar coating. The coating of paper with 6 layers of the CFC-based formulation decreased ca. 4 times the water vapor transmission rate of a 200 g/m2 paper and conferred antioxidant activity (at least 50% ABTS●+ inhibition after 5 min). Therefore, following a holistic strategy that can contribute to a circular economy, CFC revealed to be a renewable source of biomolecules suitable to develop water vapor resistant and antioxidant paper coatings.

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Preparation of innovative polymer composte materials for food packaging

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In this study, the innovative polymer composite materials based on poly(lactic acid) (PLA) and rice hulls have been investigated for their application for food packaging. The compression and injection molding of PLA based composites reinforced with rice hulls have been carried out and their basic properties were examined. Rice hulls from rice processing plants represent renewable sources that could be utilized as a filler for polymer composites.

Maleic anhydride grafted PLA (MAPLA) was used as coupling agents (CA) to improve the compatibility and adhesion between filler and matrix. The composites containing 30 wt % reinforcement were manufactured by compression and injection molding and their mechanical and thermal properties were investigated. The flexural strength of the compressed composite sample is 51. 3 MPa in comparison with 46.7 MPa for the same composite produced by injection molding technique. The experimental results suggest that the compression and injection molding are promising techniques for processing of PLA- based composites. The polymer composites based on PLA and rice hulls are suitable for applications as innovative material for food packaging.

Unlocking the role of plasma surface treated graphene in crystallization behavior of stereocomplex poly(lactide) systems

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Designing high-performance bio-based and compostable poly(lactide) materials is gaining momentum as a sustainable alternative to fossil-based polymers. By mixing lactide enantiomers which form stereocomplex crystals, stereocomplex PLA (SCPLA) advances mass transport and thermomechanical properties, such as higher gas/vapor barrier and heat deflection temperature compared to conventional PLA. Polymer crystallinity and polymorphism have a significant impact on physical properties.

However, in-depth understanding the crystallization kinetics, and melting behavior of filler induced SCPLA systems is not fully covered that affects the structure-property relationship. This understanding is critical to tailor material properties for high-performance SCPLA. For this purpose, a very low amount of plasma treated graphene nanoplatelets (GNP) (0.1 wt%) was incorporated into SCPLA by melt-extrusion approach and thermo-physical properties of SCPLA/GNP systems were fully investigated by Dynamic Scanning Calorimetry (DSC). The results demonstrated that the crystallization half-time (t1/2) was reduced by 5-fold compared to control SCPLA, lowered the kinetic parameter (Kg) at 140 °C which indicates the rapid polymer chains folding and the good nucleating capability. Also, in-situ Fourier Transform Infrared Spectroscopy (FTIR) analysis further supported these findings by showing notable changes in the molecular structure during isothermal processing and subsequent melting. These results can support the design of bio-based materials with an improved crystalline structure and technological performance in food packaging applications.

Preparation and characterization of alginate-carrageenan and alginate-mannitol films with better barrier and mechanical properties for food packaging applications

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In recent years, research on renewable and biodegradable materials has been widely carried out to substitute fossil-derived polymers with biopolymers. Among biopolymers, alginate has attracted commercial attention due to its low cost, biodegradability, biocompatibility, non-toxicity, renewability, and abundance. However, alginate films possess poor mechanical and barrier properties.

The aim of this work was to improve the mechanical and barrier (water vapor; WVTR and oxygen transmission rate; OTR) of alginate films via blending with carrageenan and chitosan. Three different concentrations of carrageenan (10, 30 and 50% w/v) were added to 1% w/v alginate solution, while 1% chitosan solution was added to alginate solution in different combinations (5:95, 10:90 and 15:85). It was possible to get films from all alginate-carrageenan combinations. However, it was only possible to obtain films from 95:5, alginate:chitosan combination. The WVTR and OTR of the alginate films decreased with increasing carrageenan content up to 30%, however no additional increase were observed with further increase in the carrageenan content up to 50%. The tensile strength and tensile strain of the alginate films increased with increasing carrageenan content. A significant improvement in the barrier and mechanical properties was observed for alginate:chitosan films as compared to the pure alginate films. However, the alginate-chitosan films were milky white while the alginate-carrageenan films were transparent. Considering the time required to make the film forming solution and also the appearance of the films, the alginate-carrageenan films have higher potential to be used as bio-based food packaging material as compared to the alginate-chitosan films.

Immobilization of rosemary, clove and thyme essential oils in electrospun cellulose acetate fibers for active food packaging applications

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Among various approaches for preparation of functional materials, electrospinning can be used to quickly fabricate nanofibrous mats with high surface area to volume ratio, high porosity and uniform morphology. To explore the use of essential oils as bioactive materials in food packaging, in this work, rosemary (RO), clove (CL) and thyme (TH) essential oils were chosen as target antioxidant and antimicrobial agents, and antioxidant and antimicrobial cellulose acetate based nanofibrous films were fabricated by two different electrospinning techniques.

Electrospun cellulose acetate/rosemary essential oil (CA/RO) fiber films were successfully fabricated under the optimal conditions by using single-needle electrospinning equipment. The cylindrical nanofibers with average diameter ranging from 255 to 617 nm were obtained by using acetone, dichloromethane and dimethylformamide as solvents in initial composition, meanwhile, the elimination of dimethylformamide from electrospinning solution yielded flat microfibers with average diameter varying from 1242 to 2939 nm. Alternatively, the electrospun nanofibers of CA and RO, CL or TH essential oils were produced by using needle-free NanospiderTM electrospinning equipment. The data of FTIR spectroscopy and thermogravimetric analysis indicated the immobilization of essential oils into CA fibers, which enhanced thermal stability of the oils. Moreover, the gas chromatography experiments confirmed the continuous release of bioactive components from CA/RO nanofibrous film. Water contact angle analysis showed that electrospun fiber films obtained by NanospiderTM technology were much more hydrophilic. The electrospun nanofibers of CA/RO, CA/CL and CA/TH secured excellent antioxidant activity as demonstrated by 2-2-diphenyl-1-picrylhydrazyl (DPPH) free radical inhibition during the period of 14 days. Furthermore, the CA/RO, CA/CL and CA/TH nanofibrous films exhibited antimicrobial activity, and its minimum inhibitory concentration against Escherichia coli, Pseudomonas aeruginosa and Listeria monocytogenes was approximate 5-10 mg/mL and minimum bactericidal concentration was approximate 10-15 mg/mL. In addition, the CA/CL nanofibrous film can effectively preserve the quality of fresh beef, indicating its potential for the application in active food packaging.

Development and characterization of bioplastic films by starch obtained from avocado seeds

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In recent years, interest in bio-based alternatives to synthetic polymers has been increasing. The shelf life of foods coated or wrapped with biodegradable materials increases and they do not lose their quality during storage. As biodegradable polymers, polysaccharides, proteins and lipids are frequently used as packaging materials. As resources have become increasingly scarce in recent days, it can also use a variety of substances, including protein, cellulose, starch and lipid, obtained from various food industry wastes and by-products. Because of their high carbohydrate content, avocado seeds are a significant source of food waste. Reducing environmental issues and acquiring new functioning components can be largely achieved through recycling and reusing these wastes.

The study aimed to produce and characterize films containing avocado seed starch and glycerol as plasticizers. It was also aimed to optimize the effects of avocado seed starch and glycerol concentration on some physical, mechanical, and barrier properties of the films by using full factorial design. To obtain the film solution different amounts of avocado seed starch were gelatinized in 100 mL of distilled water at 90 °C and added glycerol. Various physical, optical, barrier and mechanical properties of the produced films were analyzed and compared with the other films. The optimum conditions of the film formulations were selected to obtain maximum mechanical strength and barrier properties and minimum opacity and water solubility.

The experiments showed that ingredients affected the properties of films. Increased glycerol concentration increased the elongation and sensitivity against water.

Unlocking the full potential of seaweeds for sustainable bio-based packaging

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In the quest for sustainable alternatives to conventional plastics, seaweeds have emerged as a promising source to produce biodegradable packaging materials. Seaweeds are rich in polysaccharides such as cellulose and phycocolloids (e.g. agar, carrageenan, alginate) which are suitable for producing packaging materials through industrial processing methods. However, the composition and microstructure of seaweeds depends on the species, affecting their processability and the properties of the produced materials.

This work presents several strategies to valorize seaweed biomass for producing bio-based packaging for food applications: (i) processing whole seaweed biomass to generate packaging structures through minimal processing strategies, (ii) extracting less refined polysaccharides and subsequently processing them to produce packaging materials blended with other biopolymers, and (iii) valorizing industrial seaweed residues (biomass remaining after extracting phycocolloids or proteins) to generate cellulose-rich fractions as reinforcing agents in packaging materials. The composition and microstructure of the starting biomass were characterized, and the techno-functional properties of the obtained packaging structures were investigated to identify materials with the greatest potential for food applications.

Our results showed that the composition and structure of seaweed cell walls are crucial for understanding how each species behaves during processing and the properties of the resulting materials. The valorization of solid residues generated after protein extraction, enriched in cellulose, is a promising strategy for developing sustainable and biodegradable packaging, reducing plastic use, and promoting a circular economy.

Pectic compounds from grape wastes: characterization and utilization in novel bio-polymeric edible film formulations

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The overgrowing world population leads to massive production of waste. The waste produced by grape processing composes of stalks, stems, seed, leaves, pomace that are rich in valuable compounds such as proteins, dietary fiber, phenolic compounds, oil etc. Industrial pectin obtained mainly from citrus and apple peels are used in food, medical, cosmetics and nutraceutical industries for their vast techno-functional properties. Due to increasing demand for pectin, alternative sustainable sources are being evaluated. In this study, the grape stalk and stem waste was used to extract pectic compounds to be utilized in edible films to prolong shelf life of foods.

Pectic compounds were extracted (SP) with hot acidic extraction using citric acid. The extract was characterized in case of its galacturonic acid content, esterification degree, total protein content, total phenolic content and sugar composition. The extraction yield was high as 13% with a galacturonic acid content of around 24 mg GA/g. Also, further purified pectic substances were extracted (SSP) with 8.5% yield and 37 mg GA/g galacturonic acid content.

Edible films of SP and SSP were formed and characterized for their transparency, colour, microstructure (SEM images) and mechanical and water barrier properties. The high water vapor permeability (WVP) of SP was decreased 28% with ultrasonication (US) to a similar value with SSP film’s barrier property that is only 9.4 g.mm.m-2.day-1.kPa-1.

This study lays the groundwork of utilization of grape stems and stalks in edible film formulations while showcasing the effect of ultrasonication and purification on the film structure.

Foodwaste for foodpack: a model to convert residues from food industries into a packaging solution

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"Foodwaste for foodpack" is a project led by food industries concerned with the amounts of food residues derived from processing vegetables and fruits into soups and juices. Hence, the final aim of the project is to convert vegetable and fruit residues into fibre resources suitable for food packaging applications. In brief, residues from vegetables, fruits or roots (carrots, cauliflower, broccoli, pineapple, citrus, ginger, turmeric) were treated and conditioned to be introduced in a disintegrator equipment. The resulting fibrous materials were combined with other secondary fibres and blended with biodegradable adhesives to guarantee the internal cohesion. Samples of about 300 g/m^2 were produced and characterized in terms of mechanical behaviour, internal bonding, and porosity. Additionally, a coating layer was applied to ensure a proper hydrophobicity of the final product. The viability of the formulations was tested in a prototype currently used as primary food packaging. The results were compared to already commercial products for the same application. The beneficiary companies of the project are Ametller Origen Obradors SL and Delafruit SLU, which worked in collaboration with other companies, such as Co Beverage Lab SL, Samtack SL, Gráficas Salaet SA, Mercados de Abastecimientos de Barcelona SA, Consorcio de la Zona Franca de Barcelona, Packaging cluster, and two research centres, which are IRTA – Institute of Agrifood Research and Technology and the University of Girona.

This project represents an implementation of innovative pilot projects by the Operational Groups of the European Innovation Partnership (AEI) in the field of agricultural productivity and sustainability (operation 16.01.01 of the Rural Development Programme of Catalonia (PDR) 2014-2020).

Upcycling of potato peels for the fabrication of metal food packaging

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Bisphenol A (BPA) has been widely used for decades for the fabrication of lacquers for metal food packaging. However, its use has recently been banned in Europe, making it necessary to find new safe and sustainable alternatives. In a circular bioeconomy context, food and crop by-products appear as interesting raw materials due to their high content of high-value substances. Potato is one of the most abundant and widespread crops in the world. Thus, about 55 million tons of potato are processed annually in the European Union, resulting in 5.5 million tons of peel wastes, of which about 25 wt.% is suberin, a polyester composed primarily of long-chain polyhydroxylated acids, aromatics, and glycerol. The typical methodology for obtaining suberin monomers is time-consuming and involves the use of organic solvents to remove the so-called “extractives”.

Here, we report a simpler, cheaper, and greener process to obtain the “hydrolyzed extract” of potato peels and a comparison of its chemical composition with those suberin monomers from the classic method. Then, the fabrication of suberin-based lacquers for metal food packaging by using scalable technologies such as spray and melt-polycondensation is presented. Finally, the main properties of the lacquers in terms of morphology, corrosion, sterilization, wettability, and mechanical resistance are shown and discussed.

Revealing the food packaging potential of coffee pulp extraction residues

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In the production of extracts rich in bioactive compounds for the development of functional ingredients, it is common to produce leftover residues during the extraction process. These residues could hold the potential to be repurposed for other applications, hence strengthening the ethical and sustainable concept of zero-waste. In this regard, after the infusion and a supercritical carbon dioxide extraction of coffee pulp to obtain functional food-like ingredients, the obtained residues (IR and SFR, respectively) could be used for food packaging. Thus, adhering to the circular bioeconomy principles, this work aims to elucidate the potential of these residues as film-forming materials by analyzing their chemical composition and antioxidant capacity.

The IR exhibited greater lipid content (2.8-fold) and a higher total fiber content (14%) than SFR, with a higher proportion of insoluble fiber (76% vs. 68%). However, the insoluble fiber composition of both residues was similar, with glucose being the major sugar (25%), followed by uronic acids (12%) and arabinose (9%). Likewise, soluble fiber showed a similar sugar profile except for uronic acids, more present in the IR (28%) vs. SFR (20%). However, the total phenolic compounds stood out in SFR (24 mg GAE/g material), being mainly free phenolic compounds, while the observed slight content of bound phenolics was similar for both residues (1 mg GAE/g material). Accordingly, the ABTS antioxidant capacity was superior in SFR. These findings exhibited the IR and SFR potential for active food packaging and wide the possibilities for coffee pulp valorization enhancing the food systems' sustainability.

Application of principal component and hierarchical clustering analyses for the evaluation of physical modifications on chickpea protein films

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Nowadays the demand for vegan and sustainable options have increased especially for food packaging. Most commonly carbohydrates or proteins are utilized. However, their films have high water vapor permeability (WVP) mostly due to low polarity. These films can be modified enzymatically, chemically or physically to increase their barrier properties. The physical modification methods are inexpensive and safer choices. In this study, the physical modification of chickpea protein (CP) films was done with the combination of thermal (TH) and ultrasonic (US) modification to enhance film forming properties and the results were visualized with the principal component analysis (PCA) and hierarchical clustering.

A Pluckett-Burman design with 4 factors (TH time, TH temperature, US amplitude, US time) was applied to evaluate the effect of modification on the film mechanical properties (MP), WVP and colour. The milder TH conditions resulted in visually appealing film colours. The MP and WVP of films changed with the combination of different factors resulting in difficulty of discussion while the use of multivariate analysis techniques allows the interpretation of these data.

The PC1 vs PC2 graph and the hierarchical clustering shows similar grouping where PC1 and PC2 explained 52% and 24% of the data. Both methods formed three main clusters of same samples. The hierarchical clustering graph that is relatively easier to interpret by most people was a useful alternative to PCA analysis for the grouping of data. However, PCA was able to show the relation of film properties which allowed the interpretation of correlations among parameters.

Thermoformed fiber- polyethylene biocomposites : Sustainable packaging solutions for cherry tomatos

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The current European food packaging legislation necessitates the exploration of new alternatives to address upcoming challenges. One promising approach involves using sustainably sourced biomass, such as pruning residues, for sustainable packaging solutions. In this study, biocomposites were produced by thermoforming technology using avocado pruning fiber (10-40%) combined with bio-polyethylene. These materials were assessed for their suitability for food contact. Incorporating avocado pruning fiber into bio-polyethylene enhanced processability, resulting in functional trays containing up to 30% fiber. The biocomposites demonstrated reduced bacterial adhesion, particularly with 20 % fiber, and increased antioxidant activity, achieving 17.82% SA/cm^2 with 40% fiber. Soil degradation tests revealed a 23% reduction for samples with 40% fiber after 91 days.

Migration tests for hydrophilic, acidic, and fatty foods showed compliance within limits for samples containing up to 20% fiber. Cherry tomatoes stored in these biobased trays exhibited preservation qualities comparable or superior to those in commercial high-density polyethylene trays, with reduced fungal growth, lower weight loss, and better color retention.

Combining soluble gas stabilization and high pressure processing on rehydrated clip fish packaged in bio-based pouches

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Food industries are shifting towards the use of sustainable food packaging materials. In addition, mild non-thermal processing technologies are increasingly preferred to inactivate microorganisms and prolong shelf life without significantly compromising the sensory and nutritional quality of food products. This published study investigated the effect of combining two mild processing technologies (soluble gas stabilization, SGS and high-pressure processing, HPP) with vacuum packaging on bio-based pouches. This study focused on the quality of rehydrated clip fish (dried salt-cured cod), a popular export product from Norway. The variables examined include SGS (with SGS/ without SGS), HPP at 400MPa/600MPa (5min, 8-9 °C), and packaging material (conventional laminate/bio-based). The bio-based packaging was made from cellulose film laminated to bio-polybutylene succinate. Quality parameters analyzed include drip loss, water content, protein and free amino acid content, colour, texture, and microbiological shelf life.

Our results showed that bio-based packaging can be used for SGS and HPP, presenting an environmentally friendlier alternative to traditional laminates. In addition, treating the samples with SGS and/or HPP significantly improved the shelf life than non-treated samples. Samples treated with SGS had a higher drip loss, softer texture, lower water content, and higher protein and free amino acid content. Otherwise, no differences were seen in colour. Including SGS as a pre-treatment before HPP allows a lower treatment pressure at 400MPa with an extended shelf life than using HPP at 600MPa alone, contributing to energy and cost savings.

Towards traceable and sustainable plastic packaging: A perspective on recyclability of reusable smart packaging

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Modern consumer driven society is heavily reliant on different types of packaging solutions, which enable consumer goods to be purchased, transported and stored safely across the world. Increased consumption has also led to increased amounts of waste. Increasing reuse and applying sensors for monitoring purposes have been identified as a method to curb the problem of increasing packaging waste, ie European Green Deal, Ecodesing Product Regulation proposal and PPWR. The revised PPWR also requires all packaging to be reusable or recyclable by 2030.

However, there is the question if novel traceable smart packaging are in fact recyclable. To shed light on the matter, mechanical recycling of plastic packaging equipped with NFC tags was simulated by combining the NFC tags and polypropylene (recycled PP and virgin PP) granulates with a twin-screw minicompounder. The effect of the NFC tags compounded in the polymer matrix was investigated using tensile and impact tests, visual outlook and bulk material composition analysis. The results show that the presence of NFC tag particles in PP does impact the polymer's mechanical properties. The impact strength of both the virgin and recycled PP decreased ~10% whereas the tensile behaviour did not show a significant common trend. The visual outlook of the material was also affected by the NFC tag addition but could be mitigated with appropriate coloring choices or melt filtration. This shows that small amounts of NFC tag residue could be tolerated in recyclates coming from smart packages, however, without additional purification they are not suitable for structural or aesthetic applications. This research is currently being continued in EU-project STOPP and VTT internal project FuseREuse.

Life cycle assessment of cured meat product packaging: integrating the potential food waste related to the shelf life

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Conventional packaging for cured meat products relies on plastic, which has been perceived as an environmental problem because it depends on non-renewable materials. Therefore, an urgent demand is to identify alternative materials that ensure the same food quality as conventional packaging, with a sustainability degree, preventing food waste generation throughout the supply chain.

This study aims to compare the environmental impact of two food packaging systems, based on a life cycle assessment following a cradle-to-grave approach: a conventional solution composed of a multilayer, multi-material tray (APET/PE-EVOH-PE) and lid (PET/EVOH–PE), and an alternative solution consisting of a tray (PET-EVOH-PET) and lid (APET-AlOx-APET) combined with a modified atmosphere designed for cured meat products, considering the food waste (FW) in relation to the different shelf life. The functional unit is one unit of packaging containing 100 g of sliced cooked ham. Environmental impacts were calculated for seven impact categories from the ReCiPe 2016 midpoint method.

The results revealed that the mono-material-packaging system presented the worst environmental performance for all the impact categories, due to crude oil extraction required to produce polyethylene terephthalate, the main polymer. Regarding the generation of FW, the shorter shelf life of the mono-material-packaging system (21 days) compared to the one of the multilayer, multi-material-packaging system (35 days) led to a higher amount of potential FW with a higher environmental impact for all the impact categories. Eco-design approaches for cured meat packaging should provide a longer shelf-life to generate less FW and consequently a lower environmental impact.

LCA exercise on different packages for cherry tomatoes. Effect of considering packaging performance regarding air ventilation

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Packaging plays a crucial role in sustainability optimizing resources, reducing waste, protecting food, preventing losses, promoting efficient business practices, and offering consumers the benefits of the products it contains. Selecting the optimal packaging solution is a complex task, as it involves considering the entire value chain of food products. Different packaging systems influence shelf-life and impact the potential for losses and waste. A comparative Life Cycle Assessment (LCA) study was conducted on five packaging systems for cherry tomatoes in current market. The packaging options included a PET clamshell, one PET and two paperboard trays with OPP pouch and a PE-coated cup. Factors such as the material recycled content, the perforation areas allowing the tomatoes ventilation, and the end-of-life scenarios were considered.

The effect of different packages on tomato moisture loss was experimentally determined and included in the analyses. The PE-coated cup had the lowest weight loss and the lowest impact in the global warming category. Packaging made from a tray in corrugated board was the next most favorable, followed by packaging made from a paperboard tray. PET clamshell and tray packaging were the least favorable due to the environmental impact associated with PET extrusion. Data on the mass loss percentage associated to the perforations of each package was used to apply a scenario analysis in the LCA study in order to integrate in the analysis, the different packages performance. The PET tray exhibited the greatest increase in global warming, impact, approximately 7%, compared to the current market packaging system.

FCMs: The dos and don’ts of chemical migration testing

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The safety assessment of Food Contact Materials is of paramount importance, since chemical migration is directly connected to consumer safety. With a wide spectrum of analytical techniques being applied for the characterization of migrating substances, comprehensive identification of the compounds transferred from the packaging to the food should be an easy task. But this is not the case for migration testing, and the lack of standardized procedures proves that there are a lot of difficulties associated with this analytical problem. In practice, there are only a few laboratories that have both the resources and the required expertise to potentially tackle the problem of complete IAS & NIAS determination. And there are available analytical protocols that can be followed and facilitate the identification and quantification of migrating substances. However, every suggested method has besides its benefits some substantial limitations, which should be clarified whenever such an application takes place.

In the frame of this presentation, we will go through all the proposed complementary methodologies employed in migration testing and discuss which are the key parameters to be considered for the determination of particular groups of substances. Only after obtaining an in depth understanding of what results can be provided by which technique under the given conditions, we can evaluate the provided data and conclude on the inertness and subsequent safety of conventional and next-generation food contact materials.

Evaluating the risk of oligomers and harmful compounds from food packaging materials

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Information on microplastics and nanoplastics (mps) as food contaminants is limited, and legislation addressing this issue is sparse. There is a significant gap in scientific data regarding the exposure levels and toxicity of plastic oligomers, complicating accurate risk assessments. This project aims to qualitatively identify PET and PBT oligomers in samples after in vitro digestion and cell absorption and to develop a comprehensive framework on this topic.

This study introduces a novel research approach to evaluate the risk associated with oligomers and other potentially harmful chemical compounds consumed through food. Using polyethylene terephthalate (PET) and polybutylene terephthalate (PBT) oligomers, we simulate real food conditions to evaluate digestion using the INFOGEST method. This method employs enzymes and digestive juices to simulate human digestion and measure the bioccessible and bioavailable levels of these substances. The analytical work, including sample preparation, was performed at Aarhus University, while extraction and untargeted analysis using UHPLC-TIMS/TOF-MS were conducted at Aristotle University of Thessaloniki. By integrating in vitro digestion models, migration experiments, and advanced analytical techniques, the research aims to identify and quantify oligomers and harmful substances migrating from food contact materials (FCMs). It also assesses the bioavailability and potential toxicity of these substances following human digestion using epithelial cells isolated from colon tissue (Caco-2 cell line).

This novel research approach enhances our understanding of the risks associated with PET and PBT oligomers in food packaging materials. By providing a robust risk assessment framework, the study contributes to improved consumer safety and informs regulatory bodies on the potential health impacts of these widely used plastics.

Biocides in Food Packaging: Safety Concerns and Migration Insights

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This work aimed at characterizing the migration behavior of three biocides—BIT, CMIT, and MIT—from Kraft paper intended for food applications (dry and fat-containing foods). While biocides play a crucial role in ensuring food packaging preservation and food safety through their antimicrobial properties, concerns regarding their migration into food contact materials (FCMs) remain largely underexplored. Kraft paper samples were immersed in cold water for 24 hours (EN 645), hot water for 2 hours (EN 647), and 95% ethanol for 2 hours (EN 15519), followed by quantification using HPLC-MS/MS with LOD for BIT, CMIT and MIT of 0.02, 0.20 and 0.15 ppb in cold/hot water, and 0.01, 0.34, and 0.28 ppb in 95% ethanol, respectively.

The results indicated that MIT was the most prevalent biocide in cold and hot water extractions. However, in the 95% ethanol extraction, BIT and CMIT showed significantly higher content, suggesting their larger solubility in ethanol. MIT displayed reduced migration in ethanol, likely due to its hydrophilic properties and higher affinity for water. This behavior aligns with the log Kow values: BIT (1.45 - 2.20) and CMIT (0.75 - 0.95) favored migration in ethanol, whereas MIT (0.29 - 0.40) exhibited limited migration. Additionally, higher temperatures during extraction (e.g. EN 647) may enhance degradation or adsorption to the paper matrix, influencing biocide availability for BIT and CMIT.

In conclusion, this study highlights the complex interplay between temperature, log Kow values, and the effects of the paper matrix on biocide migration. These findings underscore the need for stringent food safety and packaging standards, with ongoing research evaluating biocide presence in different matrices, food simulants and in food products.

Reflection of sustainable packaging as a brand communication tool on brand attitude

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The theme of sustainability, originally emerging from environmental concerns, has become a focal point in the communication strategies of socially responsible brands. Packaging, a crucial component of brand identity, serves as a medium for conveying intended messages to consumers. In this context, brands utilize sustainable packaging designs to communicate with consumers and convey their contributions to environmental preservation to their target audience.

This study aims to investigate the attitudes of consumers in Turkey towards brands that employ sustainable packaging. A focus group study was conducted with 7 male and 7 female participants, randomly selected from the Faculty of Communication at Süleyman Demirel University. The findings indicate that both male and female participants perceived brands that use sustainable packaging as being of higher quality, high-performing, reputable, responsible, and expensive. They also expressed feelings of trust, sympathy, and admiration towards these brands. While packaging design significantly influenced women's purchasing decisions, it was not deemed as important in influencing men's preferences. Female participants were willing to pay a premium for brands with sustainable packaging in the personal care category; however, they were reluctant to change their habits and unwilling to pay more for sustainable packaging in the fast-moving consumer goods and other product categories. Male participants expressed a general unwillingness to pay more for sustainable packaging. It was observed that female participants held a more positive attitude towards brands utilizing sustainable packaging compared to male participants, who exhibited a neutral attitude towards these brands.

Consumer behavior in the model of the circular economy in agrifood sector in the Republic of North Macedonia

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This paper examines consumer behavior within the circular economy framework in the agrifood sector of the Republic of North Macedonia. As sustainability becomes increasingly critical, circular economy models provide a viable alternative to traditional linear consumption, particularly in agriculture and food industries.

The main goal of the paper is to analyze and understand consumer behavior within the context of the circular economy in the agrifood sector of the Republic of North Macedonia, identifying key factors influencing consumer attitudes and practices. The study aims to provide actionable insights and recommendations for policymakers, businesses, and stakeholders to foster the adoption of sustainable consumption practices and effectively implement circular economy principles in the region's agrifood industry. Utilizing a mixed-methods approach, this study combines quantitative surveys and qualitative interviews to analyze consumer attitudes, awareness, and practices regarding circular consumption. Results indicate a growing awareness and readiness among consumers to adopt sustainable practices, although significant barriers such as insufficient information, economic limitations, and inadequate infrastructure remain. The findings highlight the necessity for targeted policies, enhanced public awareness campaigns, and investments in circular economy infrastructure to overcome these challenges. By addressing these factors, this research offers actionable insights for policymakers, businesses, and stakeholders aiming to promote a sustainable agrifood sector in North Macedonia. Ultimately, the study contributes to the broader understanding of how consumer behavior can drive the successful implementation of circular economy principles, fostering a more resilient and sustainable agrifood system in the region.

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