# The Future of Packaging is Circular

32ND iapri Member's Conference | 2025

ORGANIZED BY VIRGINIA TECH™

June 9 - 13, 2025
Hotel Roanoke · Roanoke, Virginia

# Contents:



32ND iapri Member's Conference | 2025

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COLLEGE OF NATURAL RESOURCES AND ENVIRONMENT
VIRGINIA TECH

# WELCOME!

On behalf of IAPRI and the Virginia Tech planning committee, it is our great pleasure to welcome you to the 32nd IAPRI Members Conference in beautiful Roanoke, Virginia!

We are truly honored that you have traveled from around the world to join us. Your presence reflects our shared commitment to advancing packaging science, and we are grateful for the opportunity to gather in person to exchange ideas, present research, and strengthen our global community.

Thank you for bringing your knowledge, innovations, and the latest discoveries in packaging research to this event. Your contributions are what make this conference such a valuable forum for learning and collaboration.

We extend our sincere thanks to the local organizing committee, whose dedication and hard work have made this conference possible. We are also deeply grateful to the scientific committee for their careful review and proofreading of all the research papers being presented—your attention to detail and commitment to academic excellence are vital to the success of this program.

We also wish to express our heartfelt appreciation to all of our sponsors. Your generous support—at the Gold, Silver, and Bronze levels—has made this event possible and reflects your strong commitment to the advancement of packaging science and education.

We look forward to an exciting and enriching week filled with engaging presentations, thoughtful discussions, and meaningful networking opportunities—both at the historic Hotel Roanoke and throughout the area's vibrant local dining and social venues.

We're delighted to host you and can't wait to see the impact that this week will have on our field and our connections with one another.

Sincerely,

Dr. Laszlo Horvath

Associate Professor, Director of CPULD
Chair, IAPRI Conference Planning Committee

# IAPRI Scientific Committee

Rafael Auras – Michigan State University, USA
Matthew Baker – Virginia Tech, USA
Alexander Bardenshtein – Danish Technological Institute, Denmark
Gregory Batt – Clemson University, USA
Peter Borocz – Szechenyi Istvan University, Hungary
Yifan Cheng – Virginia Tech, USA
Vanee Chonhenchob – Kasetsart University, Thailand
Maria Jose Galotto – University of Santiago, Chile
**Changfeng Ge** – Rochester Institute of Technology, USA
**Cristina Guzman** – Universidad de Monterrey, Mexico
**Daniel Hellstrom** – Lund University, Sweden
**Chang-Ying Hu** – Jinan University, China
**Haibo Huang** – Virginia Tech, USA
**Amin Joodaky** – Michigan State University, USA
**Young Kim** – Virginia Tech, USA
**Roland ten Klooster** – University of Twente, Netherlands
Marit Kvalvag – Nofima, Norway
Eric Martine – University HEIG-VD, Switzerland
Henrik Palsson – Lund University, Sweden
Jay Park – Toronto Metropolitan University, Canada
Mary Paz Alvarez – University of Winsconsin Stout, USA
Vincent Rouillard – Victoria University, Australia
Jay Singh – California Polytechnic University, USA
Paul Singh – Packaging Forensic Associates, USA
Kevin Smith – Packaging Forensic Associates, USA
Zhi-Wei Wang – Jinan University, China
Renee Wever – Linköping University, Sweden
Yves Wyser – Nestle R&D, USA
Selcuk Yildirim – ZHAW University, Switzerland

# IAPRI Conference Organizing Committee

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## About Virginia Tech

Adopted in 1896, the university motto, Ut Prosim (That I May Serve), has long pointed to true north for Hokies. Hokies leave Virginia Tech with far more than an academic degree. Students and alumni engage with others in the community, knowing that global leaders and valuable citizens must serve others in their daily lives.

- Main campus is located in Blacksburg, Virginia
- Nine colleges and graduate schools
- 110+ undergraduate majors
- 120+ master's and doctoral degree programs
- 38,000 students on and off the main campus
- 13:1 student-faculty ratio
- Main campus includes 221 buildings, 2,600 acres, and an airport
- Facilities across VA & around the globe, including a strong presence in Washington, D.C.
- Ranked 54th in university research in the United States


## About Virginia Tech's Packaging Program:

Virginia Tech's Packaging Program pushes the boundaries of knowledge by taking a hands-on, transdisciplinary approach to preparing scholars to be leaders and problem-solvers through education at the commonwealth's most comprehensive university and leading research institution

The Packaging Program, within the Department of Sustainable Biomaterials at Virginia Tech, is a recognized leader in the packaging industry, driving innovation and sustainability in this critical field. Our program has established itself at the forefront of the industry through cutting-edge research, pioneering sustainable packaging solutions that meet the demands of a rapidly evolving market.

With a faculty composed of experts who are influential in both academic and industry circles, VT's Packaging Program consistently pushes the boundaries of what is possible in packaging technology. Our strong ties with industry partners and involvement in organizations like IAPRI further solidify our reputation as a key player in shaping the future of packaging. Through experiential learning, future-focused research, and an inclusive, spirited culture, the VT Packaging Program strives to accomplish the charge of VT's motto 'That I May Serve.'

The Packaging Program at VT is an inclusive community of knowledge, discovery, and creativity dedicated to improving the quality of life and the human condition within Virginia and throughout the world.

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# 32nd IAPRI Member's Conference Keynote Speakers

**Mr. Omar Asali, Chairman & CEO, Ranpak**
Keynote Address: "AI Meets Packaging"
Tuesday, June 10th, 8:30am-9:15am

Omar Marwan Asali is Chairman and CEO of Ranpak Holdings and Co-Founder of One Madison Group. Ranpak is a leader in environmentally sustainable packaging and end-of-line logistics innovation. One Madison is a multi-strategy family office with a focus on long-term oriented, fundamental investing.

Over the course of his career, Asali held numerous leadership positions such as CEO of HRG Group Inc., Vice Chairman of Spectrum Brands, Director of Fidelity & Guaranty Life, and various roles at Goldman Sachs. In addition to his professional experience, Asali has deep ties and ongoing involvement to the Virginia Tech community.

Asali is emerging as an influencer within the CEO community, advocating about working conditions of the manufacturing assembly line, promoting safe working conditions under COVID and ongoing, and is seeking other CEOs to adopt such universal principles.

Asali began his career working for a public accounting firm. He graduated with a B.S. in Accounting in 1992 from the Pamplin College of Business, Virginia Tech, and an MBA from Columbia Business School.

**Dr. Yunil Hwang, CEO, CJ America**
Keynote Address: "Long Live Plastic!"
Tuesday, June 10th, 9:15am-10:00am

Dr. Yunil Hwang is currently the CEO of CJ America, the CJ Group's Americas headquarters, USA. He used to lead CJ CheilJedang's Bio Business Division as CEO. He worked as the director of the Energy Lab. at Samsung Electronics for advanced batteries.

He also spent years in LG, developing strategies and roadmaps for technology and future new businesses in the fields of functional materials.

Dr. Hwang holds a BS from Seoul National University in Korea and a Ph.D. from Carnegie Mellon University in the States. In addition, He earned a certificate in technology management from the Caltech, making him an expert in tech management and innovation.

Currently he serves as a member of "Global R&D Special Committee" under the President's direct control in Korea.

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# Conference Social Events



## Welcome Reception: Monday, June 9th, 2025

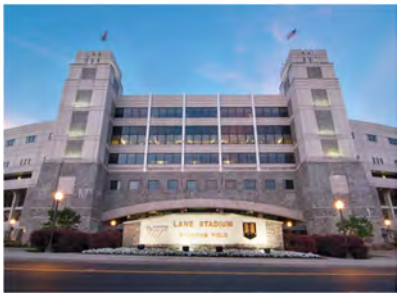
6:00pm-8:00pm, Garden Courtyard, Hotel Roanoke

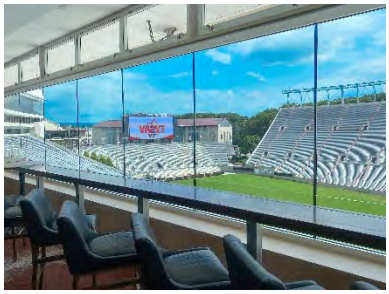
- Hotel Roanoke map included (following pages)


## VA Museum of Transportation Reception: Tuesday, June 10th, 2025

6:00pm-9:00pm, Main Museum Lobby, 303 Norfolk Ave. SW, Roanoke VA 24016

- Walking map included (following pages)

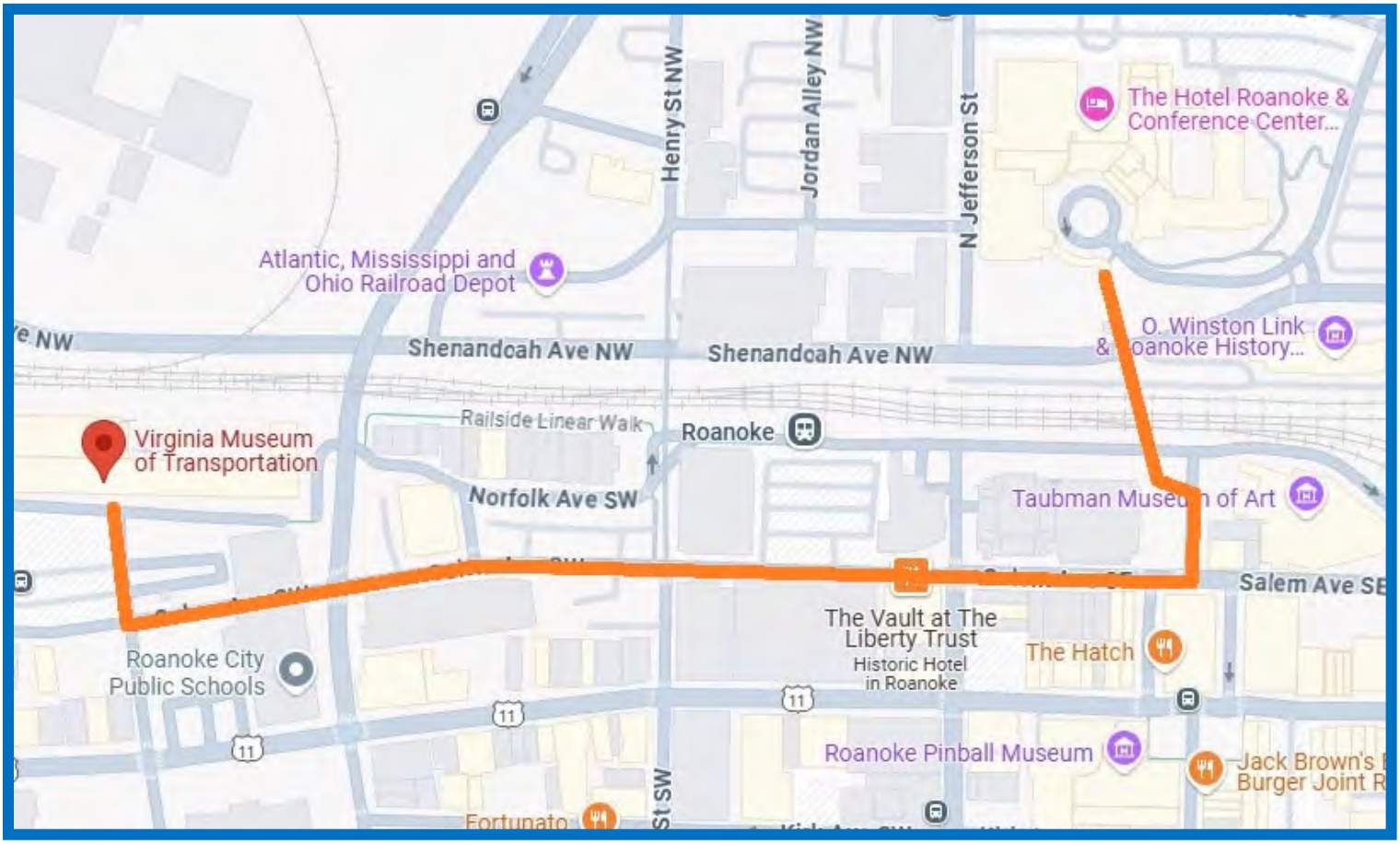




## University Club Dinner: Wednesday, June 11th, 2025

6:00pm-11:00pm, Lane Stadium, 185 Beamers Way, Blacksburg VA 24061

**The tour bus will leave the BACK of Hotel Roanoke at 5pm – the Wells Ave. entrance**. Map included on following pages. If you choose to drive yourself, a parking pass can be provided; you're responsible for finding the stadium and parking lot on VT's campus.




# Virginia Museum of Transportation

## 303 Norfolk Ave SW, Roanoke VA 24016

## Tuesday, June 10th - 6:00pm to 9:00pm

- Leave Hotel Roanoke thru the main doors, go past the traffic circle and walk thru the Market Street Walkway.
- Go down the stairs and turn right out of the walkway stairs onto Market Street →
- Go ½ block and turn right onto Salem Avenue.
- Walk 4 blocks on Salem Ave & turn right onto 3rd Street SW.
- Walk 2 blocks on 3rd Street, cross Norfolk Ave and the Virginia Museum of Transportation will be straight ahead →

THE HOTEL ROANOKE & CONFERENCE CENTER

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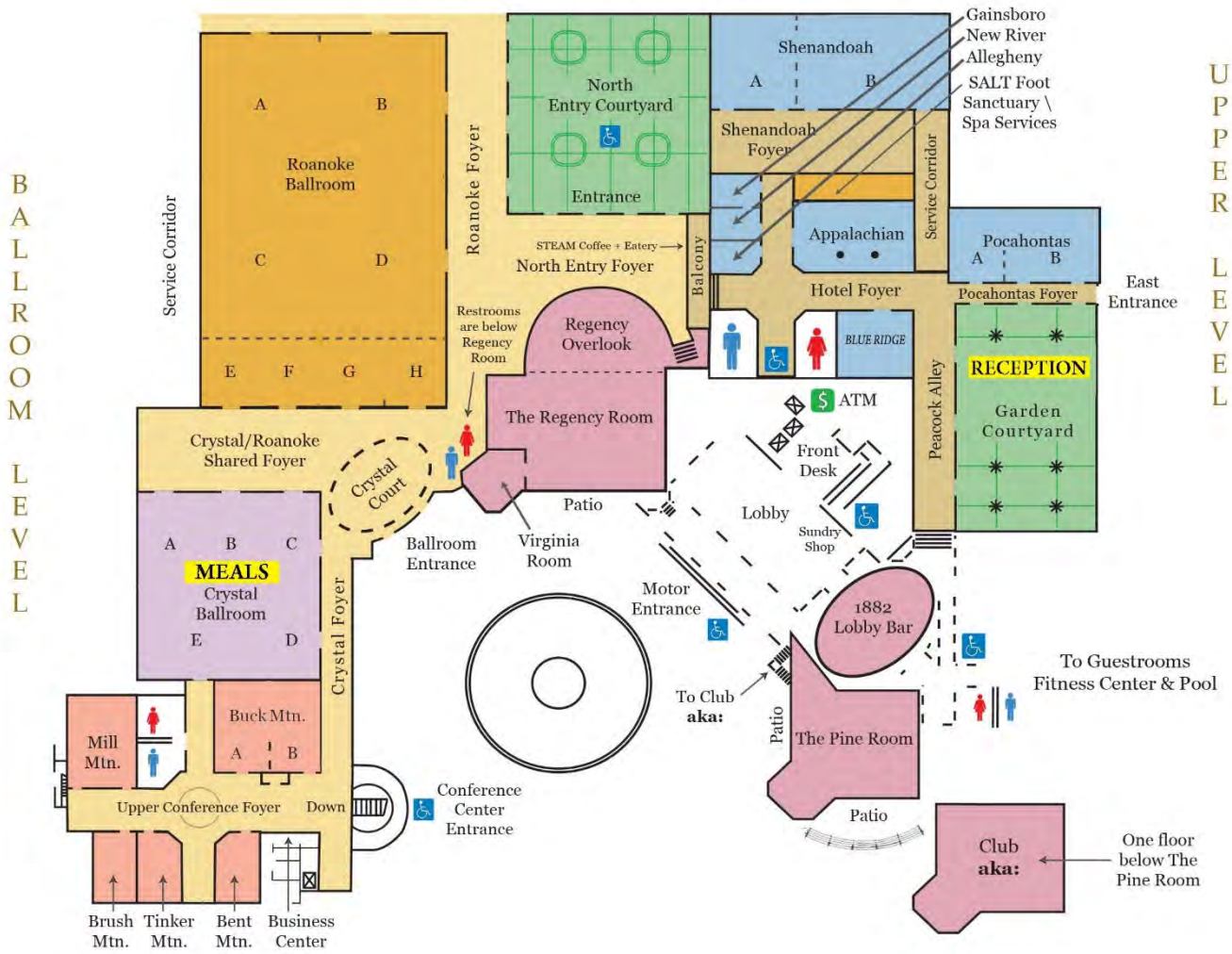
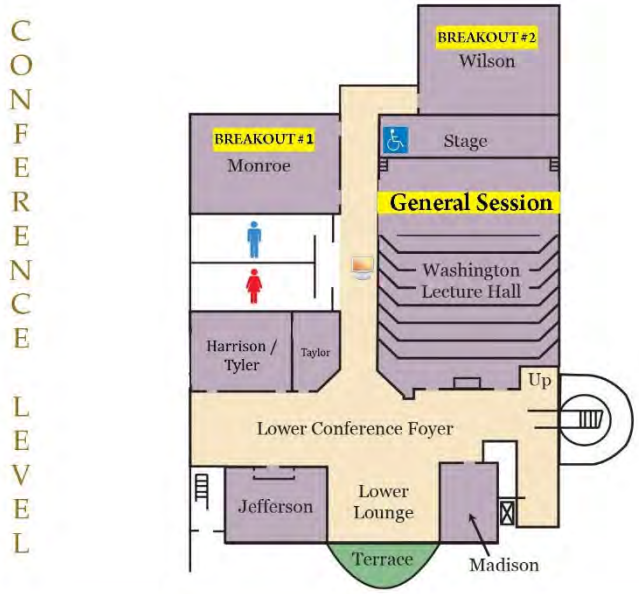



## *Accommodations & Services*

- *63,000 square-foot state-of-the-art conference center*
- *329 elegant guest rooms, including 19 suites*
- *High-speed internet, wired and wireless availability*
- *The historic Regency Room*
- *The Pine Room & 1882 Lobby Bar*
- *Club aka:*
- *Complete fitness center & outdoor pool*
- *Complimentary shuttle with Roanoke-Blacksburg Reg. Airport*

= Wheelchair accessible ramp or lift

# Moderator Schedule

32nd IAPRI Member's Conference, Roanoke VA – June 9th-12th, 2025

## Tuesday, June 10th, 2025:

### Room 1 Sessions (Wilson):

1. Distribution packaging - Tuesday 10:30am-12:00pm = Amin Joodaky
2. Distribution packaging - Tuesday 1:30pm-3:00pm = Vincent Rouillard
3. Distribution packaging - Tuesday 3:30pm-5:00pm = Eduardo Molina

### Room 2 Sessions (Monroe):

4. Active and Intelligent Packaging - Tuesday 10:30am-12:00pm = Paul Singh
5. Food and Agriculture - Tuesday 1:30pm-3:00pm = Cristina Fernanda Guzman Siller
6. Medical / Sustainability Packaging- Tuesday 3:30pm-5:00pm = Yves Wyser

## Wednesday, June 11th, 2025:

### Room 1 Sessions (Wilson):

1. Distribution packaging - Wednesday 8:00am-10:00am = Mary Paz Alvarez
2. Distribution packaging - Wednesday 10:30am-12:00pm = Changfeng Ge
3. Packaging materials - Wednesday 1:30pm-3:00pm = Alexander Leo Bardenstein
4. Packaging Materials and Distribution - Wednesday 3:30pm-4:30pm = Young Kim

### Room 2 Sessions (Monroe):

5. Sustainable packaging - Wednesday 8:00am-10:00am = Mieke Buntinx
6. Sustainable Packaging - Wednesday 10:30am-12:00pm = Eric Martine
7. Sustainable Packaging - Wednesday 1:30pm-3:00pm = Carmen Sanchez
8. Sustainable Packaging - Wednesday 3:30pm-4:30pm = Roland ten Klooster

## Thursday, June 12th, 2025:

### Room 1 Sessions (Wilson):

1. Packaging materials - Thursday 8:00am-10:00am = Marit Kvalvag Petterson
2. Packaging Ergonomics - Thursday 10:30am-11:00am = Kevin Smith

### Room 2 Sessions (Monroe):

3. Logistics and Supply Chain - Thursday 8:00am-10:00am = Roland ten Klooster

# IAPRI 2025 Member's Conference Schedule

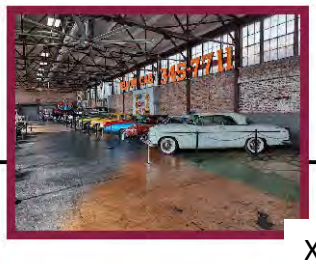
**Tours of Virginia Tech Laboratories**
VT Campus, Blacksburg, VA
8:00am-12:00pm, Mon. June 9th, 2025

## Monday, June 9th, 2025

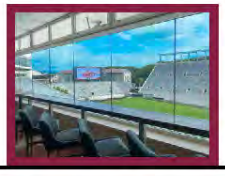
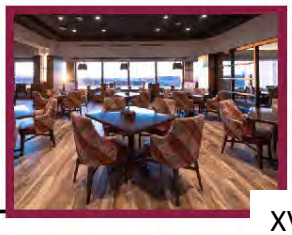
| | | |
|---|---|---|
| 8:30am-12:00pm | IAPRI - Board of Directors Meeting, Closed to Public | **Tours of VT laboratories** |
| 12:00pm-1:00pm | Lunch – Board of Directors Only, Crystal Ballroom<br>**Registration – General Public, Lower Conference Foyer** | |
| | **Wilson** | **Monroe** |
| 1:00pm-2:00pm | "Sustainable Packaging" Communities of Practice | |
| 2:00pm-3:00pm | | "Food Packaging" Communities of Practice |
| 3:00pm-4:00pm | "Distribution Packaging" Communities of Practice | |
| 4:00pm-5:00pm | | "University Education" Communities of Practice |
| 5:00pm-7:00pm | **Registration – General Public, Lower Conference Foyer** | |
| 6:00pm-8:00pm | **Welcome Reception Garden Courtyard (rain = Crystal Ballroom)** | |

# Tuesday, June 10th, 2025

| | | |
|---|---|---|
| 8:00am-8:30am | **Conference Kick-Off and Welcome from Dean Paul Winistorfer, Washington Lecture Hall** | |
| 8:30am-10:00am | **Keynote:** "AI Meets Packaging" Omar Asali, CEO Ranpak<br>**Keynote:** "Long Live Plastic!" Yunil Hwang, CEO CJ America<br><br>Topics in all following sessions are color-coded. The list of topics by color is included on page 5. | |
| 10am-10:30am | **Coffee Break** | |
| | **Wilson** | **Monroe** |
| 10:30am-11am | "An Elastic Model for Predicting the Stretch Film Forces on Unit Loads" **Mark White 101** | "Circularity in Active and Intelligent Packaging" **Kiara Winans 201** |
| 11am-11:30am | "Prediction modelling of pallet overhang on box compression strength" **Hiral Makwana 119** | "Study on the Properties of PLA/PP-based Films for Food Applications Incorporating Orange Peel from Agricultural Products" **Ana Tone 202** |
| 11:30am-12pm | **Poster Presentations Introduction (see page 5 for details) – Washington Lecture Hall** | |
| 12:00pm-1:30pm | **Lunch, Crystal Ballroom** | |
| | **Wilson** | **Monroe** |
| 1:30pm-2:00pm | "Comparing Multiaxial Vibration and Shock in Truck Using Smartphone and Data Logger" **Changfeng Ge 103** | "Best Methods for Incorporating Nano ZnO into Polyhydroxy-alkanoates to Obtain Antimicrobial Packaging Films" **Mieke Buntinx 203** |
| 2:00pm-2:30pm | "Development of New Sustainable Packaging for Fresh Products Using Temperature Control Procedures" **Marta Garrido 104** | "Cellulose-based trays with plastics for food packaging: A case study on modified atmosphere packaging of chicken fillets" **Marit Kvalvag 204** |
| 2:30pm-3:00pm | "Analysis of Long-Duration, Low-Acceleration Events in Truck Transport" **Changfeng Ge 102** | "Optimizing Oblong Cutout Shapes in Ventilated Food Packaging Designs" **Mojtaba Safari 226** |
| 3:00pm-3:30pm | **Break** | |
| 3:30pm-4:00pm | "Effect of Moisture Absorption and Drying on the Compression Strength of Corrugated Fiberboard Boxes" **Peter Csavajda 106** | "Using real-world data to predict failure modes for repackaging sensitive molecules: a risk-based approach" **Mercy Okezue 305** |
| 4:00pm-4:30pm | "Measurement and Analysis of Trailer Location Effects on Vibration in Canadian Cold Chain Long-Haul Trucking" **William Snyder 107** | "Visible light responsive packaging material for broad-spectrum antibacterial control on food and contact surfaces" **Haibo Huang 227** |
| 4:30pm-5:00pm | "Experimental Evaluation of the Hilbert Envelope Shock Detection Algorithm" **Vincent Rouillard 108** | "PackMit: Empowering the Transition to Sustainable and Circular Packaging in the Food Industry" **Markus Schmid 208** |
| 5:00pm-6:00pm | **Break** | |
| 6:00pm-9:00pm | **Social Dinner, Transportation Museum** | |



# Wednesday, June 11th, 2025

| | Wilson | Monroe |
|---|---|---|
| 8:00am-8:30am | "Empirical Validation of the Horizontal Transient Response Study on Braking and Stability Testing for Palletized Loads" **Manuel Garcia Romeu Matinez 109** | "New requirements and methodologies for the evaluation of packaging recyclability" **Cesar Aliaga 219** |
| 8:30am-9:00am | "Cargo-vehicle coupling jumping generated by road hump and hole" **Zhi-Wei Wang 110** | "Review of passive packaging solutions for transport and their thermal characterization" **Sibylle Blaise 210** |
| 9:00am-9:30am | "Investigating the Impact of Multi-Axis Vibration on Strain Levels in an Aluminum Rod Structure During Road Transportation" **Saeid Ansari Sadrabadi 111** | "Steps towards a template for fair comparisons between single use and reusable items" **Roland ten Klooster 211** |
| 9:30am-10:00am | "Measurement and analysis of shock events generating by various vertical speed calming elements" **Bence Molnar 112** | "Understanding the Nexus of Plastic Packaging and Atmospheric Pollution for Greener Tomorrow" **Yoorae Noh 212** |
| 10:00am-10:30am | **Coffee Break** | |
| | **Wilson** | **Monroe** |
| 10:30am-11:00am | "Method for Measuring Friction Performance under Dynamic Loading Representative of Transport Conditions" **Antonin Gehin 113** | "Circular and Sustainable Packaging Challenges for US Military versus Consumer Packaging" **Kevin Smith 213** |
| 11:00am-11:30am | "Predicting the thermal performance of bio-based cold chain packaging systems through finite element modeling." **Abid Hassan 114** | "Enhanced one-pot glycolysis of printed electronics to recycle PET-based supports and metal-based inks" **Sergio Clemente 214** |
| 11:30am-12:00pm | **Poster Presentations Introduction (see page 5 for details) – Washington Lecture Hall** | |
| 12:00pm-1:30pm | **Lunch, Crystal Ballroom** | |
| | **Wilson** | **Monroe** |
| 1:30pm-2:00pm | "Innovation in cellulosic materials to be used in high performance packaging applications." **Saul Calabuig Cobo 115** | "Plastic packaging and freshwater a commodity that is fast decreasing and its impact on natural disasters and wars" **Paul Singh 301** |
| 2:00pm-2:30pm | "Development of Low-Cost Bio-Binder for Biochar Based Sustainable Thermal Insulating Packaging" **Carlos Diaz & Elena Merle 116** | "The Role of Packaging Engineers in Informing Evidence-Based Policy Making to Minimize Export Market Disruptions…" **James Sternberg 216** |
| 2:30pm-3:00pm | "Effect of converting steps on dissolved cellulose coated carton board barrier properties" **Ville Leminen 117** | "Thinking models for recycling information in packaging design" **Roland Ten Klooster 217** |
| 3:00pm-3:30pm | **Break** | |
| 3:30pm-4:00pm | "Experimental and Numerical Investigation of OTR in Metallized Monomaterial Films" **Yves Wyser 118** | "Leveraging LCA for Informing Packaging Eco-design and Eco-Modulation to Promote Sustainable Production" **Dwi Yudison 218** |
| 4:00pm-4:30pm | "Descriptive study and evaluation of shrink hoods with recycled content for regulatory compliance" **Bram Bamps 129** | Novel Spray Coating Process to Develop Bioplastics onto Paper-Packaging material **Chenxi Cao 128** |
| 4:30pm-6:00pm | **Break** | |
| 6:00pm-11:00pm | **Social Dinner, University Club, Blacksburg VA**    | |

# Thursday, June 12th, 2025

| | Wilson | Monroe |
|---|---|---|
| 8:00am-8:30am | "Optimization of properties of industrial compostable materials for flexible and rigid food packaging" **Maria Jose Jimenez Pardo 121** | "Enhancing freshness and sustainability through a monitoring and traceability system" **Pablo Garcia Corcoles 220** |
| 8:30am-9:00am | "Polyethylene terephthalate-based heat sealable packaging film without heat sealing layer" **Alexander Leo Bardenstein 122** | "Packaging Impact on Consumer Experience: Voice of the E-Customer" **Daniel Hellstrom 221** |
| 9:00am-9:30am | "Industrial-Scale Processing of PHA/HPMC Multilayers Using Aqueous Spray-Coating Technology." **Kihyeon Ahn 127** | "Real-time optimization of reusable package transportation" **Monireh Mahmoudi 222** |
| 9:30am-10:00am | "Artificial Intelligence as a Catalyst for Advancing Circular Bioeconomy in Packaging" **Alina Kleiner 206** | "How Patents Providing a Functional Invention Prevent Competition from Stealing Market Share" **Kevin Smith 126** |
| 10:00am-10:30am | **Coffee Break** | |
| | **Wilson** | |
| 10:30am-11:00am | "Can Packaging Prevent Food Waste in Homes?" **Monireh Mahmoudi 207** | |
| 11:00am-12:00pm | **Break** | |
| 12:00pm-1:30pm | **Lunch, Crystal Ballroom** | |
| 1:30pm-2:30pm | **General Meeting, Awards, Conference Closing, Washington Lecture Hall** | |

## Tours of Virginia Tech Laboratories

VT Campus, Blacksburg, VA

8:00am-12:00pm, Friday, June 13th, 2025

Friday, June 13th, 2025

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# Poster Presentations (5-Minute Presentation/Introduction for each Poster)

| | Washington Lecture Hall | |
|---|---|---|
| Tuesday, June 10th 11:30am-12:00pm | "Uncovering UTSA-280 A Metal Organic Frameworks as A Safe Bioactive Food Packaging Material" **Ajay Kathuria 402** | "Corrugated Packaging Manufacturing Evaluation: Laser Cutting vs. Traditional Methods" **Jean-Baptiste Nolot 404** |
| | "Analysis of pallet stability and mechanical properties under horizontal constraints" **Jean-Baptiste Nolot 403** | "Impact of cellulose dimensions on the crystalline structure and properties of thermoplastic starch composites" **Dongho Kang 405** |
| | "Exploring Packaging Solutions for Vegan Meat Alternatives: Towards More Circular and Sustainable Designs" **Alina Kleiner 406** | |
| | **Washington Lecture Hall** | |
| Wednesday, June 11th 11:30am-12:00pm | "Lignin as a Compatibilizer for Biodegradable Polymer Blends: Enhancing Compatibility and Barrier Properties for Sustainable Packaging Applications" **Dongho Kang 407** | "Improving the recyclability of flexible packaging for meat: a comparison of conventional and new designs" **Fiorella B.H. Dantas 411** |
| | "Eco-Design Based on Distribution Risks as a Key Tool to Develop a Sustainable Packaging System for the Bathroom Sector" **Marta Garrido 105** | |
| | "Enhancing Moisture Barrier Properties of Poly(lactic) Acid Films with Beeswax for Sustainable Packaging Applications" **Dionne Mitchell 409** | |

| |
|---|
| Distribution and Transport Packaging |
| Packaging Materials |
| Active and Intelligent Packaging |
| Packaging Sustainability |
| Logistics and Supply Chain |
| Packaging Ergonomics |
| Medical Packaging |
| Packaging for Food and Agriculture |

# Conference Abstracts and Notes

# 101 A Simplified Elastic Model for Predicting the Stretch Film Forces on Unit Loads

**Marshall S White[1]* and Mark Scott[2]**

*1. Professor Emeritus, Department of Sustainable Biomaterials, VT, Blacksburg VA, USA*
*2. Senior Product Development Manager, White and Company, Blacksburg VA, USA*
**Corresponding author: mswhite@vt.edu*

**Abstract:** The most common method of stabilizing unit loads of products moving through supply chains is the application of stretch film. The metric most common for characterizing the level of stabilization is the "Containment Force" as described in ASTM D8314. Vector analysis and the elastic properties of the film were used to predict the horizontal forces being applied to the vertical edges of a test unit load. The model was sensitive to both film properties and wrapping patterns. An instrument was designed and built to measure these forces on the edge of the unit load.

Three levels of layering, film overlap, and three levels of film pre-stretch were tested. The difference between predicted and measured edge forces varied from 0.7 to 2.3 %. The same instrument was used to compare the force on the edge of the to the containment force using the "pull plate" method in ASTM D8314. The correlation between the edge forces and the film force on the side was an $R^2$ of 0.6712. The average ratio of film force/edge force was 0.094 with a standard deviation of 0.0069. Using this factor to adjust the edge force resulted in the model over predicting containment force by 2 to 13%. An adjustment of .090 would result in better predictions.

These results indicate the potential for a commercial tool that can help packaging and logistic professionals select the most efficient and safe film applications for stabilizing unit loads, moving consumer and industrial products through unitized supply chains.

**Key Words**: Unit Loads, stability, supply chains, film force, stretch film

**Notes:**

# 102 Analysis of Long-Duration, Low-Acceleration Events in Truck Transport: Improved Packaging Safety and Unit Load Stability

**Kyle Dunno[1], PhD, Associate Professor, Packaging and Graphic Media Science**

*[1] Rochester Institute of Technology, 78 Lomb Memorial Dr. Rochester, NY 14623*

**Abstract:** This study investigates the characteristics and effects of long-duration, low-acceleration events in truck transportation, focusing on the stability of unit load systems in the supply chain. Using a SAVER 3D15 sensor, data were collected from a 53-foot dry trailer over 2700 hours during a two-year observation period across the northeastern United States. The data were categorized into braking and lateral turning events. Analysis revealed a right-skewed distribution with a mean peak acceleration of 0.31 g and a maximum of 0.9 g for events classified as braking (decelerating). Meanwhile, the lateral turning data showed a mean acceleration of 0.27 g, with peaks reaching 0.6 g. These findings underscore the significance of accounting for low-acceleration dynamics, as cumulative low-force impacts can lead to substantial wear on packaging and unit load systems. This research addresses a critical knowledge gap, offering actionable data for improving packaging design and load restraint standards to enhance product integrity and transit safety. This abstract is for submission into the PTS Journal

**Keywords:**

**Notes:**

# 103 Comparing Multiaxial Vibration and Shock in Truck Cabin vs. Trailer Container Using smartphone and Data Logger

**Changfeng Ge[1], Naoya Akita[2], Katsuhiko Saito[2], Kazuaki Kawaguchi[3]**

*1. Rochester Institute of Technology, Rochester, NY 14623, United States*
*2. Kobe University, Kobe 658-0022, Japan*
*3. Shinyei Technology, Kobe 650-0047, Japan*

**Abstract:** The study of multiaxial vibrations in trucks, induced by road profiles and long-duration motions from turning and braking, has gained increasing attention. MEMS-based DC response accelerometers paired with gyroscope sensors are widely used to measure six degrees of freedom (6 DOF) motions in applications such as drones, automobiles, and smartphones. This research compares multiaxial vibration and shock data collected in a truck cabin and trailer container using a smartphone and a professional data logger. The study aims to: 1. Assess whether DC response accelerometers can serve as alternatives to conventional AC response accelerometers for vibration analysis. 2. Analyze correlations between rotational and translational motions to identify key metrics for lab simulations. 3. Evaluate the feasibility of smartphones, paired with GPS, for capturing multiaxial vibrations and shocks in truck cabins and compare them with trailer container data. This study found that DC and AC response accelerometers exhibit similar power spectral density (PSD) profiles. DC response data provided greater detail in the 0-50 Hz frequency range, while AC response data was more sensitive to frequencies above 50 Hz. The smartphone effectively measured multiaxial long-duration impacts in the field, identified locations using GPS, and quantified horizontal impacts, roll, and pitch angles. However, smartphones are unsuitable for vibration analysis above 50 Hz and cannot reliably predict trailer container vibrations based on cabin data. Finally, Finally, this study pinpoint that the multiaxial vibrations in the lab should be based on the combination of vertical, pitch and roll acceleration.

**Keywords:**

**Notes:**

# 104 Development of new sustainable packaging for fresh products using temperature control procedure

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**Abstract:** Because of the requirements derived from environmental legislation, manufacturers of packaging for refrigerated and frozen products have developed sustainable solutions, through design improvements and recyclable materials. However, to ensure the efficiency of some of these new packaging solutions, vs the current packaging solutions, a case study has been carried out for fish products, comparing different packaging systems to determine in two cases the following variables:

- Replication of refrigerated vehicle situation: verification that the fish internal temperature is between 0 and 4°C, for 72h (maximum time for the distribution of this type of product).
- Replication of non-refrigerated vehicle situation: maximum time that the product maintains a temperature of -18ºC inside.

For this purpose, climatic tests have been designed to reproduce the company's transport temperature conditions, being able to analyze the evolution of the temperature in the product, as well as in the packaging, using temperature sensors.

The result of the study shows the capacity of each packaging system to ensure the maintenance of the product conservation temperature throughout the distribution cycle, being able to identify the most suitable distribution cycles and applications for each of the selected packaging, depending on whether the product is refrigerated or frozen.

As a result of the comparison of the different packaging systems, it has been estimated the following information:

- Technical KPI; based on the laboratory test results.
- Environmental KPI; conducting the carbon footprint of the packaging systems and theoretical recyclability.

With all these issues, the selection of the most appropriate sustainable packaging according to the requirements of the product and the characteristics of the distribution cycle has been covered.

**Keywords:** sustainable packaging, fresh products, temperature control procedure, climatic test, technical and environmental indicators.

**Notes:**

# 106 Effect of Moisture Absorption and Drying on the Compression Strength of Corrugated Fiberboard Boxes

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**Abstract:** This study investigates the effect of direct water exposure on the compression strength of corrugated fiberboard boxes (CFB). Weather conditions, such as condensation and rain can lead to the presence of water on the surface of the boxes. This moisture results in a loss of compression strength, potentially causing damage to the boxes and compromising the stability of unitized loads. Similar conditions may also arise during the transportation and storage of empty flat boxes. Once dried these boxes in the absence of visible abnormalities are typically filled with products and used for storage and transport. The aim of this study is to determine the impact of drying on the compression strength of CFB boxes after water exposure. Physical experiments were conducted using various corrugated fiberboard materials, each representing common variations in box construction. After immersion in water for a specified period the boxes were removed allowed to dry under controlled conditions and then subjected to Box Compression Tests (BCT) to evaluate changes in their compression strength. The results show that the average decrease in compression strength ranged from 14% to 45% with variations depending on the material type and exposure duration. The analysis showed that while drying partially recovered some of the compression strength, the loss due to water exposure remained significant for certain materials. The study provides valuable insights for packaging engineers, particularly in contexts where boxes may be exposed to moisture during storage and transportation prior to use. By understanding the effects of moisture on compression strength, more robust packaging solutions can be developed, ensuring better protection of products and more efficient handling of unitized loads.

**Keywords:** corrugated fiberboard box, BCT, water exposure, compression strength

**Notes:**

# 107 Measurement and Analysis of Trailer Location Effects on Vibration in Canadian Cold Chain Long-Haul Trucking

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**Abstract:** This study investigates vibration hazard variability in three positions within a 53-foot refrigerated trailer, transporting frozen dairy food products. The trailer was equipped with modern air-ride and air-slider suspensions and pulled by a Class-8 tractor operating in the Canadian distribution environment. The objective was to examine how trailer position and suspension types influence vibration characteristics and to assess the Canadian distribution environment against international testing standards from the International Safe Transit Association and the American Society for Testing Materials (ISTA, ASTM). Using triaxial accelerometers, vibrations were measured at the front, middle, and rear positions of the trailer during three replicated trips along a 700 km route from London, Ontario, to Lachine, Quebec, via the 401 Macdonald-Cartier Freeway, North America's busiest highway. The findings revealed that vertical vibrations dominated across all trailer positions, with the front recording the highest number of vibration events, the rear experiencing the most intense and powerful vibrations, and the middle showing the most stable vibration profile. Load weight further impacted vibration intensity, with lighter loads amplifying vibration power and overall energy. Comparison with ISTA and ASTM standards revealed frequent vibration exceedances, highlighting their inadequacy in representing the Canadian vibrational environment. This study proposes a new vibration test spectrum tailored to these conditions, offering a more accurate framework for packaging design.

**Keywords:** Trailer location effects, power spectral density, frozen food distribution.

**Notes:**

# 108 Experimental Validation of The Hilbert Envelope Road Vehicle Shock Detection Algorithm

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**Abstract:** This paper deals with the validation of an algorithm, first proposed by Rouillard & Lamb [1], for detecting shocks and transients that are occasionally produced by road vehicles. The paper includes a review of the original paper by Rouillard & Lamb and describes the experimental evaluation of the algorithm by using a specially built single wheeled vehicle placed on a computer-controlled road simulator. Several artificially generated road profiles of varying roughness levels were created onto which aberrations of varying length (effective frequencies) and diminishing amplitudes were superimposed. Results show that shocks of significant magnitudes were consistently detected, especially for smooth to moderate roads whereas smaller shocks become increasingly drowned-out by the vibration response as the underlying road roughness is increased. The ability of the shock detection algorithm to properly allocate shocks to the correct frequency band corresponding to the two natural frequencies of the vehicle was confirmed. The results confirm the previously published reliability and sensitivity of the algorithm and pave the way for application on multi-wheeled road vehicles travelling on real roads. The algorithm's capabilities for detecting shocks during road transport is expected to prove to be valuable in the characterisation of transport channels as well as for laboratory simulation for stress-testing of products and packaging systems.

**Keywords:** shock detection, road vehicles, vehicle vibrations.

**Notes:**

# 109 Empirical Validation of the Horizontal Transient Response Study on Braking and Stability Testing for Palletized Loads

**Manuel García-Romeu, Phd.**
**Enrique de la Cruz, MEng.**

**Abstract:** The stability of the loads in transport is a must. Different testing methods are applied for the study and validation of the palletized load stability. On IAPRI 2019, at Twente, 'Emergency braking and Stability testing, Response Analysis' presentation explained theoretically the dynamic response of different stability testing methods. Tilt testing and horizontal stability testing by trapezoidal pulses using different dwell time. Twente's presentation demonstrates that the dynamic response depends on the natural frequency of the tested sample. This work is the empirical demonstration of the previous study. This paper shows the results of testing the same sample at different dwell times. Comparing the experiment result with the theoretical study demonstrates how it matches with the response predicted on Twente 2019.

**Keywords:**

**Notes**

# 110 Cargo-vehicle Coupling Jumping Generated by Road Hump and Hole

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**Abstract:** The transport of cargo by vehicle is the most common mode of logistics distribution, it is very important to investigate its dynamic response to ensure the safety of cargo and improve the transport system. Due to the complexity of cargo-vehicle dynamic coupling and the excitation of road hump and hole, it is very difficult to analyze the response of cargo-vehicle coupled system in jumping off state. Based on the coupling model of cargo-vehicle suggested by the authors, a 19 degrees of freedom coupling dynamic model of cargo-vehicle for a three-axis heavy vehicle is developed in non-jumping and jumping off states. The cargo-vehicle jumping program is written by using the MATALB platform, where the stiffness matrix, damping matrix and force vector in jumping off state need to be modified in real time. The cargo-vehicle dynamic response when crossing the road obstacle is obtained, and compared under jumping off and non-jumping states. The results show that the acceleration and displacement of vehicle in jumping off state under the road hump excitation is more than twice that in non-jumping state. The cargo response in jumping off is 80% higher than that in non-jumping. When crossing the hole, the maximum acceleration is greater than that crossing the bump, the second jumping of each wheel axle is caused by the shock, and the jumping off time is shorter than that crossing the bump. The vehicle speed has a significant influence on the acceleration of the vehicle body in jumping off.

**Keywords**: jumping off, coupling model, dynamic response, road hump, road hole.

**Notes:**

# 111 Investigating the Impact of Multi-Axis Vibration on Strain Levels in an Aluminum Rod Structure During Road Transportation

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**Abstract:** In engineering, fundamental studies often employ simplified structures such as rods or beams to establish theoretical frameworks, which can then be extended to more complex systems like airplane wings. This study employs an aluminum rod specimen to directly measure structural dynamic strain under realistic multi-axis excitations, offering a foundational model for capturing strain responses applicable to more intricate packaging structures. While single-axis vibration testing is a common practice, this research explores the limitations of this approach in accurately replicating real-world stress-strain conditions applied to the structures. As a fundamental study, this research employs a rod specimen with an attached strain gauge to measure strain responses—comparing vertical strain induced by single-axis (heave in vertical direction) and three-axis (heave, roll, pitch) real road vibration signals. Results demonstrate that multi-axis vibration generates significantly higher strain levels compared to single-axis vibration, with peak strain magnitudes reaching nearly 18 times greater than those observed under vertical-only excitation. While this amplification is partially attributed to the slender geometry of the rod—having a relatively long length compared to its cross-sectional dimensions—it effectively highlights the critical role of multi-axis excitation in packaging design and testing. This study introduces a new perspective on multi-axis vibration in packaging transportation by focusing on strain analysis, directly linked to structural fracture, to bridge the gap between conventional vibration analysis and product response to vibration-induced damage. It emphasizes the importance of considering multiple aspects of complex multi-axis dynamics in developing packaging vibration testing standards, from energy levels assessed through Power Spectral Density (PSD) analysis to strain analysis as a direct indicator of structural failure, to ensure the effectiveness of protective measures during transportation.

**Keywords:** Multi-Axis Vibration, Strain Analysis, Transportation, Package Failures, Package Distribution Testing.

**Notes:**

# 112 Measurement and analysis of shock events generating by various vertical speed calming elements

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**Abstract:** In the recent years, the volume of the parcel delivery shipments is increased, due to the pandemic and rise in popularity of e-commerce. As a result, delivery vans are doing a lot of mileage on urban roads every day, it is therefore inevitable that these vehicles do not pass through any speed calming element during deliveries. When passing through the vertical speed calming elements, shock events may occur on the loading surface of the delivery vehicles, which may cause damage to the transported packaged products This research paper focuses to measure, analyse the shock events which generated by different speed calming elements. For the field measurements, an empty FIAT Ducato delivery van was used, which equipped with a Lansmont Saver 3X90 data collector to measure the acceleration on the platform above the rear axle. The vertical acceleration was measured when the van pass through four type of speed calming elements with various speed between 5 – 30 km/h. The collected data was analysed to determine the typical waveform, amplitude and duration of generates shock events of each speed calming elements. The results show the speed hump, speed bump and speed table generate shocks with different characteristics when the speed of the delivery van is the same. The results of measurements were compared to the currently available test procedures and previous results of other studies. The result of the comparison shows the intensity of the measured shocks are significantly lower than the suggested shock test parameters by IEC 60068-2-27 and MIL-STD 810 standard's transportation shock test procedures.

**Keywords:** Speed calming elements, shocks, shock testing, parcel delivery.

**Notes:**

# 113 Method for Measuring Friction Performance for Tertiary Packaging under Dynamic Loading Representative of Transport Conditions

**Antonin Géhin[1], André Bégin-Drolet[1] and Julien Lépine[2*]**

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**Abstract:** A critical function of tertiary packaging is to ensure cargo stability and security during transportation, preventing load shifts that may cause accidents or damage. This paper addresses the complexities of securing loads, particularly focusing on the coefficient of friction between the load and the transport vehicle's surface, which plays a crucial role in load stability and packaging system design. Anti-slip mats, widely used in securing cargo, rely on a well-defined friction coefficient. However, this coefficient varies with transport conditions and is rarely characterized under dynamic loading scenarios. The primary objective of this study is to introduce an innovative experimental method to study the friction coefficient of anti-slip mats under conditions that replicate real transportation dynamics. To establish a foundation, we first analyzed typical accelerations encountered in road transportation. Using a custom GPS-accelerometer sensor embedded, we captured in situ acceleration data. These measurements offer insights into the frequency spectrum and amplitude of transport-induced accelerations, vital for replicating such conditions in laboratory settings. Subsequently, we present the design of a testing machine that simulates the variation of normal load under a cargo caused by the transport vehicle dynamics and vibration. This compact system uses two symmetrical motors that oscillate masses at desired positions to produce a varying normal force. By measuring both normal load and traction force required to move the machine, it enables the calculation of friction coefficient variations as the applied load changes dynamically. The results contribute to establishing a more accurate characterization of anti-slip materials behavior under realistic dynamic transport conditions.

**Keywords:** anti-slip mats, coefficient of friction measurements, freight stability, slip-preventing materials, tertiary packaging, dynamic transport conditions.

**Notes:**

# 114 Predicting the thermal performance of bio-based cold chain packaging systems through finite element modelling for passively cooled containers

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**Abstract:** This study investigates the performance of insulated shipping containers (ISCs) for temperature-sensitive products through the development of a finite element model (FEM) to optimize the verification processes. ISCs are critical for transporting sensitive goods such as pharmaceuticals and perishable foods, yet traditional preliminary performance evaluation methods are both time-consuming and resource intensive. Additionally, the extensive use of non-biodegradable insulation materials exacerbates environmental concerns, emphasizing the need for sustainable alternatives. This research establishes a material analysis foundation for FEM-based heat transfer modelling by characterizing the thermal properties of ISC components. Differential Scanning Calorimetry (DSC) and the Heat Flow Meter methods were used to characterize the thermal properties of the components used to build the ISCs. This characterization provides critical input parameters for FEM simulations to replicate the thermal performance across various supply chain scenarios. This study includes analysis of corrugated packaging components, and Phase Change Materials (PCMs) while exploring the integration of eco-friendly insulation alternatives to ensure optimal shipment conditions and sustainability. Results demonstrate strong correlation between FEM simulations and experimental validations, with mean prediction deviations ranging from 4% (double-wall corrugated insulation) to 8% (honeycomb insulation) when maintaining temperatures below critical thresholds (8°C). These results confirm that FEM-based predictions provide high accuracy for bio-based insulated shipping container performance, significantly reducing prototyping and verification resources compared to traditional methods. Furthermore, the incorporation of biodegradable insulation materials addresses environmental challenges by promoting eco-friendly cold chain packaging solutions. This research provides a robust framework for material analysis and thermal modelling, offering practical and scalable solutions to enhance cold chain efficiency while minimizing environmental impact.

**Keywords:** cold chain, insulated shipping container, insulation, phase change material (PCM), finite element modelling.

**Notes:**

# 115 High-Performance and Recyclable Cellulosic Packaging Structures via Wet Coating and Plasma Polymerization Technologies

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**Abstract:** INNCELPACK project aimed to develop sustainable and recyclable cellulose-based packaging solutions to replace traditional plastic-based flexible packaging, particularly for applications in food and e-commerce sectors. Given the environmental challenges posed by single-use, non-recyclable packaging, INNCELPACK was focused on paper-based structures, enhanced with innovative barrier coatings applied via wet rotogravure and plasma polymerization techniques. These coatings provided essential functionalities such as oxygen, moisture, grease resistance, and sealability, achieving properties suitable for applications like snacks and cacao pouches and mailing envelopes. Plasma polymerization technique produced ultra-thin, solvent-free coatings that maintain substrate biodegradability while providing essential hydrophobic and oleophobic properties. Recyclability testing, based on UNE-EN 13430 and ATICELCA methods, confirmed that over 95% in weight of the tested structures could be efficiently recycled in existing paper recycling facilities.

To sum up, INNCELPACK's innovative, eco-friendly packaging solutions align with the European Union's circular economy goals offering materials that enable replacement of plastic materials with high-performance, recyclable, and compostable alternatives.

**Keywords:** sustainable packaging, cellulose based packaging, Paper, cellulose, converting, plasma polymerization, recyclability, gravure printing, barrier properties.

**Notes:**

# 116 Development of Low-Cost Bio-Binder for Biochar Based Sustainable Thermal Insulating Packaging

**Elena Merle, Bindu Etukulapati, Bilge Altay, Burak Aksoy, Raymond Francis, Carlos Diaz**

**Abstract:** Packaging for temperature-sensitive products, such as vaccines or frozen food, relies heavily on Expanded Polystyrene (EPS) due to its low thermal conductivity. However, EPS is known to have negative environmental impacts, and few options exist for re-use or recycling. Thus, there is an immediate market need for new materials that reduce greenhouse gas (GHG) emissions and other negative impacts, while also simplifying end-of-life handling. Previous research demonstrated the ability to create thermal insulation panels with a thermal conductivity similar to EPS by combining biochar with a biobased binder. Although the concept was demonstrated, the high cost of the medical-grade commercial bio-binder has limited its economic feasibility. This research focuses on finding a cost-effective bio-binder derived from organic by-products. Using a thermal conductivity tester and a 3-point bend test, various combinations of biochar and bio-binders were evaluated to achieve low thermal conductivity while maintaining adequate structural strength. The two bio-binders studied in this work were cassava sour starch and Modified Agri Waste Binder (MAWB). In the starch-based formulations, an increase in starch resulted in a decrease in thermal conductivity but compromised flexural strength. The samples with MAWB demonstrated lower overall density and thermal conductivity, particularly when foaming agent was introduced into the formulation. However, the flexural strength was reduced. This research emphasizes the importance of optimizing bio-binder formulations to develop a cost-effective and sustainable alternative to EPS for thermal insulation applications.

**Keywords:** Biochar, Bio-binder, Thermal Conductivity, Starch, Modified Agri Waste Binder

**Notes:**

# 117 Effect of converting steps on dissolved cellulose coated carton board barrier properties

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**Roman Lev, Panu Tanninen and Ville Leminen [2]**

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**Abstract:** Reduction of fossil based raw material usage together with environment concerns are main drivers for researching the alternatives for plastics in packaging applications. Also, legislative efforts have been set up to limit certain single-use plastics. Being both bio-based and bio-degradable, transparent cellulose films and cellulose-based coatings are an example of novel technology with potential to impact global packaging market as an alternative for petroleum-based materials. A Films for Future (F3) project is a collaboration between research (VTT, LUT) and industrial partners, established to explore the possibilities of such cellulose-based films and coatings.

VTT has been working on cellulose dissolving chemistries and regenerating cellulose for over a decade with earlier focus on filament manufacturing. Recently, research has been predominantly concentrated on packaging solutions with a special focus on barrier development. Based on laboratory experiments, transparent regenerated cellulose-based coatings on carton board provide an excellent barrier against both oxygen and water vapor in addition to being grease-proof.

After material manufacturing, the performance of a package is affected by further converting steps. Creasing, folding, pressing and gluing must be tolerated by packaging material to maintain the quality of food packed inside the package. Therefore, the purpose of LUT was to evaluate surface damage induced by one of the most demanding converting operations – creasing. In this work, material samples were creased with a laboratory creasing device imitating industrial conditions of the packaging production.

LUT and VTT evaluated the performance of commercial carton board coated with dissolved cellulose in the conversion process. The effect of converting on package performance was evaluated by utilizing methods such as microscopic analysis and barrier measurements.

**Keywords:** dissolved cellulose, coating, converting, creasing, barrier properties, OTR, WVTR, OGR.

**Notes:**

# 118 Experimental and Numerical Investigation of OTR through inorganic barrier

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**Abstract:** The transition to a circular economy for flexible packaging requires innovative solutions to prevent downcycling and ensure the production of high-quality recycled materials. Monomaterial packaging films enhance recycling efficiency; however, their barrier performance is often limited. Metallized monomaterial films present a promising solution, providing oxygen and water vapor barriers without significantly compromising recyclability. Therefore, the quality of the thin metallization layer is a critical factor, as defects induced during the manufacturing process can significantly affect barrier performance.

This study investigates the oxygen transmission rate (OTR) of plastic through inorganic model barriers, simulating metalized films, utilizing both experimental and numerical methods. The investigation assumes that oxygen permeation is mainly driven by the defects present in the metal layer. Key defect parameters affecting oxygen barrier performance - namely areal and number density and average size- were experimentally replicated at the millimeter scale. Numerical models, using Fick's diffusion law and incorporating the precise 3D geometries of the experimentally tested samples, were employed to replicate the experimental findings and extrapolate them to the microscopic scale of actual packaging films.

The results from both experimental and numerical analyses identified several critical parameters that must be controlled to achieve optimal laminate structures. These optimal packaging structures can be designed to minimize plastic usage while maintaining adequate barrier performance.

This research provides valuable insights into the design and optimization of recyclable flexible packaging materials.

**Keywords:** Barrier, defect, simulation, experimental.

**Notes:**

# 119 Prediction modelling of pallet overhang on box compression strength

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**Abstract:** Accurate estimation of box compression strength is vital for optimizing the performance and safety of global distribution operations, yet the impact of pallet overhang remains relatively underexplored. This study aimed to advance predictive capabilities for box compression strength loss due to overhang on a pallet by leveraging an expanded experimental data set and developing a robust predictive model. The research involved extensive laboratory testing of five distinct boxes sizes using three types of corrugated boards: nominal 32 ECT B-flute, 44 ECT C-flute, and 61 ECT C-flute. A space-filling design determined box dimensions (lengths from 25.4 to 60.9 cm and widths/heights from 25.4 to 50.8 cm), while overhang ranged from 0.635 to 8.25 cm, examining effects on width, length, or both sides. The study combined data from previous initial study, encompassing a total of 2723 compression tests. The multiple linear regression model was developed, achieving an R-squared of 0.867, demonstrating unbiased predictions with normally distributed residuals. Key findings indicated that box height and edge crush test (ECT) value had minimal impact on compression strength loss within the studied ranges. Validation with 30 commercially available box designs yielded an R-squared of 0.707, confirming the model's reliability. Beyond this, the research explored various machine learning algorithms, including decision trees, random forest, gradient boosting and neural boosted for model evaluation. Regularization techniques such as ridge and lasso were applied to prevent overfitting. This exploration aims to enhance model accuracy and robustness. These models support packaging designers in effectively estimating strength loss due to overhang. The findings contribute to more sustainable and efficient packaging strategies, supporting high-performance distribution systems by offering actionable insights into overhang effects and optimizing packaging design.

**Keywords:** box compression strength, pallet overhang, predictive modelling, machine learning algorithms.

**Notes:**

# 121 Optimization of properties of industrial compostable materials for flexible and rigid food packaging.

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**Abstract:** The aim of this work was to design novel formulations of industrial compostable materials to develop new packaging materials by using melt blending extrusion. The first step was to determine the most compatible polymers and maximize the degree of mixing a custom-designed screw simulation tool was used. To achieve food packaging requirements and concretely to improve barrier properties other technologies such coating application and the design of laminated structures have been implemented. Flexible and rigid packaging solutions were obtained, achieving properties suitable to maintain and even to extend the current shelf life of specific food products, comparing with their current non-recyclable packaging.

By applying these techniques, the first flexible packaging type was produced by laminating novel flexible structures with a barrier coating and a cellulose base film. The materials developed showed excellent performance for flow pack packaging in semi-industrial conditions. This material was used to develop two demonstrators and the products selected for these tests were bakery food (wholemeal bread rolls) and nuts (fried cashew nuts). The results obtained for the samples packaged in the developed material were compared with those packaged in the current conventional material, tests done with wholemeal bread showed a better preservation of the product in the compostable material increasing the shelf life up to 5 months. Regarding the fried cashew nuts, the results obtained were similar to those of the current packaging, preserving the product up to 6 months after being packaged.

For rigid packaging, the focus was on the development of industrial compostable materials for thermoforming applications with excellent mechanical and barrier properties. The shelf life of two types of food, fresh sausages and a ready-to-eat rice dish, was evaluated. Fresh sausages were evaluated up to 13 days, obtaining similar results to those observed in the current packaging. Finally, the ready-to-eat rice achieved a shelf life up to 29 days. It should be noted that this material is suitable for contact with all types of foodstuffs under prolonged storage conditions, so it has the potential to be evaluated for use in other food applications.

**Keywords:** industrial compostable, packaging, flexible, rigid, flow pack, tray, bakery, nuts, ready-to eat dish, shelf life, food safe compostable packages.

**Notes:**

# 122 Polyethylene Terephthalate-Based Heat Sealable Packaging Film Without Heat Sealing Layer

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**Abstract:** The food packaging industry is evolving to meet demands for circularity, cost-effectiveness, lower carbon footprint and higher production efficiency with polyethylene terephthalate (PET) emerging as a preferred material for packaging. Despite its advantages, PET faces two main challenges in flexible barrier packaging applications, such as flow packs or form-fill-seal pouches. First, PET films for flexible packaging often lack adequate moisture and oxygen barriers, limiting their range of applications. Second, the high melting temperature of PET of around 250°C complicates the sealing process, causing deformation and poor-quality seals. Traditional solutions involve multilayer films, in which PET is laminated with a superior permeation-barrier layer and a lower melting-temperature heat-sealing layer. This results in non-recyclable packaging, posing sustainability issues. In the present work, PET-based heat sealable films were developed to address these issues. Specifically, a water-based organic–inorganic hybrid nanocomposite sol–gel coating was applied to one side of the 23-µm thick PET film, followed by drying and curing. The thickness of the subsequent coatings was approximately 2.3 µm. The sol–gel's rheological properties allow for a microscopically thin application that hardens into a micrometre-thick, flexible, transparent and abrasion-resistant coating with a decomposition temperature well above melting temperature of PET. The wettability of the coating was slightly higher than that of PET. The result of the pencil hardness test indicates tight bonding of the coating to the PET film. Mechanical tests of the coated and uncoated PET indicate that the mechanical properties of the bulk PET were retained after the application and curing of the coating, and the reinforcing effect of the coating was confirmed by the measurement of the Young's moduli and the puncture resistance test. Characterization using Fourier transform infrared spectroscopy confirms that the film contains organo-silicon compounds and aluminium oxides. Uncoated sides of a pair of PET films were faced and heat-welded at 250°C, demonstrating significantly reduced deformation around the welding portion. The coating reduced oxygen and water vapour transmission rates by more than a factor of 3 and 4, respectively.

**Keywords:** heat sealing, heat welding, organic inorganic hybrid sol–gel coating, polyethylene terephthalate, shrinkage.

**Notes:**

# 126 How Patents Providing a Functional Invention Prevent Competition from Stealing Market Share

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**Abstract:** This paper covers how a packaging invention that is designed to provide a 'function' that did not exist before, such as a unique way of dispensing, preventing spills, maintaining temperature over a more extended period of time (cold or hot), as well as an improved delivery mechanism of the product that allows mixing without stirring, are examples of packaging forms that were given patents. However, not all inventions are accepted by the consumer. Often, most patents yield little revenue due to a lack of consumer acceptance and are not used by the competition. With a clear value proposition, an inventive packaging system will likely generate strong market interest, impacting sales and overall revenue potential. This paper provides a unique look at packaging engineers who work hard to develop new packaging systems or components and how to make inventions that offer innovation and prevent imitation. This paper and presentation at IAPRI are the second in a series following last year's paper on design patents. The authors will cover packaging trademarks and copyright work in the previous paper next year. Keywords: Packaging Patents, Function, Process, Intellectual Property, Prior Art, Packaging Invention.

**Keywords:**

**Notes:**

# 127 Industrial-Scale Processing of PHA/HPMC Multilayers Using Aqueous Spray-Coating Technology

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**Abstract:** The fabrication of bioplastic multilayer films has often relied on organic solvent casting methods, which are not suitable for mass production. It results from chemical composition, different polarity, limited processability, and poor thermal compatibility of bioplastics. To overcome these technical drawbacks, this study introduces a scalable, aqueous-based approach to fabricate multilayer structures using a novel spray-coating process. It instantly eliminates the need for organic solvents while enhancing interfacial adhesion and other physico-chemical properties. Hydroxypropyl methylcellulose (HPMC) was used as the base film, onto which aqueous polyhydroxyalkanoate (commercially called, emulsion PHA) was deposited via spray-coating, followed by hot pressing under controlled pressure conditions. This approach successfully improved structural uniformity, feasibility for mass production, and interfacial adhesion, addressing key challenges in bioplastic multilayer films. Surface roughness was significantly reduced from 5.66 μm to 0.08 μm at 5 MPa, and the oxygen transmission rate (OTR) decreased from 120.49 $cm^3/m^2 \cdot day$ to 52.24 $cm^3/m^2 \cdot day$, demonstrating a substantial enhancement in gas barrier performance. Additionally, tensile strength increased from 42.3 MPa (pure HPMC) to 70.2 MPa (5 MPa), confirming improved mechanical integrity. These findings suggest that this organic solvent-free, scalable process can bridge the gap between lab-scale bioplastic film development and industrial application, offering a promising route for sustainable packaging solutions.

**Keywords:**

**Notes:**

# 128 Novel Spray Coating Process to Develop Bioplastics onto Paper-Packaging Material

**Chenxi Cao, Kihyeon Ahn**

**Abstract:** The growing demand for sustainable packaging solutions has driven the development of environmentally friendly alternatives to synthetic plastics. This study proposes an advanced spraying method to press a blend of polylactic acid (PLA) and hydroxyalkenoate (PHA) onto Kraft pulp-based paper, aiming to enhance mechanical strength, oxygen barrier performance and surface hydrophobicity while maintaining its biodegradability. PLA and PHA are derived from renewable resources. They are mixed in different proportions, evenly sprayed through atomizing spray guns, and then subjected to hot pressing treatment. Morphological analysis indicates that with a certain increase in PHA content, the surface uniformity and permeability are improved, which is attributed to its lower crystallines and higher flexibility. The measurement of the water contact Angle indicates a significant improvement in hydrophobicity, with the hydrophobicity of the pure PHA coating reaching its peak. Mechanical tests show that the tensile strength and elongation have improved, especially in the 50:50 PLA/PHA blend. Thermogravimetric analysis indicates that increasing the PLA content can improve thermal stability. It is worth noting that the 50:50 blend achieves the best oxygen barrier performance, indicating the optimal interaction between the polymers. These findings highlight the potential of PLA/PHA coated molded fiber substrates as high-performance, biodegradable packaging materials suitable for functional and environmental applications.

**Keywords:**

**Notes:**

# 129 Descriptive study and evaluation of shrink hoods with recycled content for regulatory compliance

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**Abstract:** In preparation for the European Commission's Packaging and Packaging Waste Regulation (PPWR), mandating 35% recycled content in tertiary plastic transport packaging by 2030, distributors are already producing films with similar content. As part of the TETRA-CORNET MultiRec project (HBC.2023.0176), funded by VLAIO VLAIO and in collaboration with industry partners, this case study evaluates shrink hoods with 30% and 35% post-consumer recycled (PCR) content, designed to protect palletised loads of 1.3 tons of bricks. This study provides a framework for systematic assessment of these films, enabling their improvement in a later phase, aligning with regulatory requirements and ensuring transport performance, and identifying correlations between mechanical, thermal, and chemical properties as well as transport performance. Key mechanical properties, such as coefficient of friction (dynamic COF: 0.19–0.25), tensile stress, and thermal shrinkage, were analysed, revealing notable variability between films. Differential scanning calorimetry (DSC) and gel permeation chromatography (GPC) assessed thermal transitions (melting peaks: 118–124 °C) and molecular weights, while gas chromatography-mass spectrometry (GC-MS) identified additives. PCR granulates exhibited notable variability, including lower melt enthalpy (95-103 J/g) compared to the full films (>108 J/g), indicating reduced crystallinity. Granulate colour varied noticeably, with lighter ones having lower molecular weight (199.6 kg/mol) than darker ones (275.3 kg/mol). Transport simulations further highlighted performance differences between films, emphasizing the need for tighter control over variables such as PCR composition, compensatory measures in virgin fractions, and production parameters. In conclusion, this study highlights the variability in both PCR granulate and film properties, emphasizing the need for systematic and open research to address performance challenges and support the transition to circular materials while maintaining sufficient transport protection in demanding applications.

**Keywords:** shrink hood films, polyethylene, post-consumer recyclate, transport simulation, additive screening.

**Notes:**

# 201 Circularity and Active and Intelligent Packaging

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**Abstract:** In a circular economy, food production and distribution are conceptually designed to extend resource use, minimize waste and environmental impact, and drive economic growth. Circular-economy studies often employ systems thinking to evaluate complex processes—for example, supply chains—though this approach can be applied to many other interconnected systems as well. In this study, we investigate active and intelligent packaging by analysing existing agri-food and packaging system data. We quantify potential efficiency gains by linking this data to greenhouse-gas emissions and water-use metrics, and demonstrate significant reductions in both emissions and water consumption, as well as potential for benefits like enhanced consumer confidence in food safety—offering a clear market advantage. Concurrently, we examine how these innovations align with industry regulations and standards to enable circularity and foster sustainable investment and ensure equitable access to advanced packaging solutions and related training programs. This study provides insights for the future development of circular-economy practices in agri-food and packaging systems.

**Keywords:** Active packaging, circular economy, intelligent packaging, supply chain efficiency.

**Notes:**

# 202 Study on the Properties of PLA- and PP-Based Films for Food Applications Incorporating Orange Peel Extract from Agricultural By-Products

**Ana Maria Tone [1*], Nuria Herranz Solana [1], Muhammad Rehan Khan [2], Angela Borriello [2], Elena Torrieri [2], Carmen Sánchez Reig [1] and F. María Monedero Prieto [1]**

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**Abstract:** The aim of this work was to develop active packaging based on polypropylene (PP) and polylactic acid (PLA) matrices using a high value by-product extracted from orange peel as an active compound for food packaging applications. Different films with and without orange peel extract (OPE) based on PP and PLA were obtained via cast extrusion and characterized in terms of their mechanical, thermal, optical, and sealing properties. The films obtained were transparent, but when OPE was incorporated, the transmittance spectrum decreased, causing slight coloration. Mechanical properties were affected by the incorporation of OPE, as elongation at break and tensile strength increased in the cross-direction of the PP film, although the main differences found were related to the polymer itself. In addition, sealing strength also increased via the incorporation of OPE in the PP matrix. However, thermal properties were not affected by OPE in the PP matrix but slightly de-creased stability in PLA. Finally, antioxidant activity was observed in in vitro studies with 2,2-Diphenyl-1picrylhydrazyl (DPPH) radical. The results of this study showed that the obtention of materials with OPE incorporated into the PLA and PP matrix is feasible. The new materials obtained can be used for ap-plications of oxidation-sensitive fresh products.

**Keywords:** active packaging; antimicrobial activity; antioxidant activity; polylactic acid; extrusion; orange peel extract; food loss; food contact material; NIAS; migration

**Notes:**

# 203 Best methods for incorporating nano ZnO into polyhydroxyalkanoates to obtain antimicrobial packaging films

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**Abstract:** Innovation in food packaging is driven by making packaging more sustainable without compromising food safety, quality or convenience. Among the alternatives to conventional plastics, polyhydroxyalkanoates have emerged as promising candidates. For example, biobased and biodegradable poly(3-hydroxybutyrate-co-3-hydroxyhexanoate) (PHBHHx) can be processed into packaging materials with good mechanical properties and moderate gas permeability. Attractive strategies to increase their application potential include the fabrication of ZnO/PHBHHx nanocomposite materials with antimicrobial functionality. However, which approach is the best for incorporating ZnO nanoparticles (NPs) efficiently to obtain active films with good packaging performance? While early research focused on solvent-assisted methods, this study explores novel technologies for the production of ZnO/PHBHHx nanocomposites that offer advantages with regard to industrial upscaling, eco-friendlier or cheaper processing, and more specific incorporation of ZnO NPs in the polymer matrix. More specifically, we compare bulk mixing versus surface coating, using melt processing and ultrasonic spray coating of water-based inks, both in combination with miniemulsion encapsulation of the ZnO NPs. The thermal, mechanical, oxygen and water vapor barrier, UV barrier, and antimicrobial properties of the modified PHBHHx films are thoroughly analyzed. Our results show that surface-coated PHBHHx films (with less total ZnO wt.%) exhibit better gas barrier properties and enhanced antibacterial activity against S. aureus and E. coli compared to bulk-mixed films. The observed functionality results from a complex interplay between intrinsic ZnO NP properties, dispersion quality, matrix–filler interactions, and crystallinity. We conclude that coating with PHBHHx-encapsulated ZnO NPs might be the best approach to confer close interaction between ZnO and bacteria on the one hand, while minimizing the amount of active NPs on the other hand. Further research is necessary to determine whether annealing the coated film can prevent or reduce the potential migration of encapsulated ZnO NPs into packed food.

**Keywords:** polyhydroxyalkanoates, ZnO, extrusion, ultrasonic spray coating, active packaging.

**Notes:**

# 204 Cellulose-based trays with plastics for food packaging: A case study on modified atmosphere packaging of chicken fillets

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**Abstract:** Cellulose-based materials face limitations in fresh meat packaging applications, which require resistance to moist and fatty foods and high environmental humidity, as well as sufficient gas barrier properties for modified atmosphere packaging (MAP). Even with conventional plastic coating, such materials can encounter practical challenges regarding sealability and structural stability during storage. Given the need to reduce plastic use, this study aimed to evaluate the performance of two different cellulose-based tray solutions: (i) corrugated board trays coated with film consisting of polyethylene (PE) /ethylene vinyl alcohol (EVOH)/PE *(Corr-Barr),* and (ii) carton tray consisting of a combination of 50% cellulose and 50% polyethylene terephthalate (PET) *(Cart-PET),* in comparison to mono PET trays (*Mono-PET).* The primary objective was to assess whether any of the cellulose-based trays could preserve food quality and shelf-life as effectively as conventional plastic trays. Additionally, the study aimed to test the structural integrity and ability to maintain the gas barrier properties of the cellulose-based trays during storage, which is essential for preserving food quality. The performance was evaluated using chicken fillets, and food quality was analyzed throughout the expected shelf-life. Compression strength of trays was also assessed. The results indicated that the quality of chicken packaged in both cellulose-based trays (*Corr-Barr* and *Cart-PET)* was comparable to that in *Mono-PET* trays. However, there were some indications of Corr-Barr maintaining the quality of chicken slightly better compared to the *Cart-PET* trays, possibly linked to their barrier properties. Additionally, the appearance of both cellulose-based trays changed substantially during storage, as well as the compression strength of *Corr-Barr*. These aspects may be useful to better understand possible barriers to the implementation of these trays at large scale.

**Keywords:** cellulose-based packaging, gas barrier properties, modified atmosphere, compression strength, food quality preservation.

**Notes:**

# 206 Artificial Intelligence as a Catalyst for Advancing Circular Bioeconomy in Packaging

**Alina Kleiner [1] and Markus Schmid [1*]**

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**Abstract:** The transition towards a circular bioeconomy is essential for the packaging industry as it seeks to reduce resource consumption and environmental impact. This paper explores how Artificial Intelligence (AI) is playing a pivotal role in driving this transition. AI can be used along the entire value chain to develop optimal packaging and act as a catalyst for advancing circular bioeconomy in packaging. By optimizing material selection, enhancing recycling processes, and improving lifecycle analysis, AI is enabling more efficient, sustainable packaging solutions that align with circular economy principles. Key strategies include the integration of AI-driven tools for "design for recycling," improving recyclate quality, and supporting decision-making processes in packaging research and development. This paper provides insights from the KIOptiPack project, which focuses on developing AI-powered technologies that optimise the design of packaging with high recycled content. Digitalisation forms the basis for the successful use of AI, as it enables the necessary data collection and analysis as well as automated processes. Nevertheless, there are challenges to the use of AI in the packaging industry, including the availability and security of data, the limitations of AI models and technologies and the lack of qualified personnel. A comparison of CO2e emissions from deforestation or food wastage with CO2e emissions from AI use and the relativisation of the increase in work efficiency through AI invalidates the CO2e emissions associated with the use of AI that are currently being criticised. These advancements are critical for helping the industry meet increasing demands for sustainable, circular solutions while maintaining product performance and safety. The research presented provides a roadmap for stakeholders in packaging to embrace AI-driven innovation, which is crucial for creating regenerative packaging systems that contribute to a more sustainable, circular bioeconomy.

**Keywords:** circular bioeconomy, artificial intelligence (ai), sustainable packaging, packaging optimization.

**Notes:**

# 207 Can Packaging Prevent Food Waste in Homes?

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**Abstract:** Our research investigates the underexplored potential of food packaging design as a strategic intervention to reduce household food waste (HFW). Despite global initiatives aimed at diminishing food waste, HFW remains stubbornly high, accounting for nearly half of all food waste in the United States. While sensory cues predominantly guide consumer perceptions of food edibility, the role of packaging in extending food lifespan and reducing waste is critical yet inadequately studied. Our research uniquely addresses this gap by focusing on specific packaging features-resealability, transparency, and size suitability-and their impact on HFW through a mixed-methods approach comprising expert Delphi surveys, household recall surveys, and framed field experiments. The findings reveal that certain packaging features, notably resealability and appropriate sizing, significantly reduce food waste, with resealable packaging reducing HFW by up to 6.21%. Conversely, transparency tended to increase waste under certain conditions, indicating that visible food cues can influence consumption but do not always prompt conservation. This nuanced understanding underscores the complexity of consumer interactions with food packaging, which can either enhance or undermine its effectiveness in waste reduction. Our study enhances operational and behavioral insights into food waste management by emphasizing tailored packaging strategies. By optimizing packaging design, we align with global sustainable consumption goals. This research advances academic understanding and practical approaches for policymakers, manufacturers, and consumers to reduce household food waste effectively.

**Keywords:**

**Notes:**

# 208 PackMit: Empowering the Transition to Sustainable and Circular Packaging in the Food Industry

**Markus Schmid [1*] and Alina Kleiner [1]**

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**Abstract:** When conceptualising more sustainable and circular packaging solutions, conflicting objectives often arise, for example between the material efficiency of composite packaging and its recyclability or between the use of innovative biopolymers and the functionality and price of the packaging. Therefore, the transition to more sustainable and circular packaging solutions is a key challenge in the food industry. The PackMit project supports this transition by equipping future packaging experts with the knowledge and tools needed to guide companies towards more circular packaging practices. This project focuses on developing a comprehensive training program that empowers experts to offer tailored, holistic consultations to food industry stakeholders. PackMit addresses critical areas such as the comparison of conventional and bio-based materials, the optimization of packaging processes and equipment, adherence to sustainability criteria, and alignment with the latest regulatory frameworks. This paper examines the opportunities presented by the training program and the barriers to the use of these opportunities by packaging experts and the packaging industry, as well as barriers to the implementation of more sustainable packaging concepts. Supported by funding from the German Ministry of Food and Agriculture, PackMit is paving the way for the future of sustainable food packaging by fostering expertise that is critical to achieving a more sustainable, circular bioeconomy.

**Keywords:** more circular packaging practices, comprehensive training concept, packaging experts, customized packaging solutions.

**Notes:**

# 210 Review of passive packaging solutions for transport and their thermal characterization

**Sibylle Blaise[*1,2,3], Victor Huart [1], Jean-Charles Candore[3], Nicolas Krajka[1], Jerome Pellot[1] and Damien Erre[2,3]**

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**Abstract:** Since 2020, following the COVID-19 crisis, thermosensitive products have become widespread in e-commerce. Today, consumers can buy fresh products such as meat, fish, and vegetables directly online. Given the large volume of these goods, active transportation is becoming increasingly complex and costly. Additionally, these goods are shipped through conventional logistics networks. During transportation, these products need protection not only against mechanical factors (shocks, shaking, vibration, etc.) but also against temperature fluctuations. The packaging of these thermosensitive products must maintain the freshness of the product. Adopting passive distribution solutions is therefore essential in the current context. To address this need, it is crucial to understand the various thermal phenomena at stake, the existing solutions, and how they can be characterized. In this work, we will present a state-of-the-art review of the main passive solutions used in the transport of thermosensitive products, including materials, applications, and so forth. A comparative study of two packaging systems will be conducted to assess the impact of design on thermal properties, beyond the inherent performance of the materials used. The results will demonstrate that the design of passive thermal packaging should consider both the material properties and the packaging design itself. Understanding the influence of geometry on a package's thermal behaviour is therefore a key factor, especially before studying the impact of mechanical stresses during transport on its properties.

**Keywords:** thermal packaging, transport, cold chain, sensitive goods.

**Notes:**

# 211 Steps towards a template for fair comparisons between single use and reusable items

**Mieke van den Berg, Roland ten Klooster**

**Abstract:** In this paper the factors taken up in LCA studies comparing single-use to reuse are evaluated. Based on literature research, the insight was obtained that there are many single-use vs reuse comparisons that do not take into account the full picture of a reuse system. These factors are defined and further explored using single-use/reuse system comparison case-studies. A method to calculate the impact of reuse systems and to compare it to single-use systems is presented in terms of equations based on the case studies. The equations are used to show the relevance of taking up specific parameters using different input values. Significance is shown for the following factors: - Single-use components in a reuse system - Constant factors in a reuse system - Pool size compared to system size in a reuse system - Loss percentage With this method, several factors are taken up outside of LCA Software in order to determine a break-even point or to understand the trajectory of the system impact over rotations. Together with inventory reporting according to ISO 14040/14044 this can be the basis for transparent reuse system impact calculations and its fair comparison to single-use system impact.

**Keywords:**

**Notes:**

# 212 Understanding the Nexus of Plastic Packaging and Atmospheric Pollution for Greener Tomorrow

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**Abstract:** Polymeric materials have revolutionized various industries, particularly packaging, which has driven significant advancements in plastic packaging technology. However, the widespread use of plastics has resulted in serious environmental concerns in relation to sustainable packaging and zero-waste solutions. The packaging industry, fueled by increasing demand for groceries and delivery services, is expected to reach a market value of $291.5 billion by 2026. Unfortunately, environmental issues arise from plastic packaging manufacture, usage, and disposal processes, where microplastics (MPs) could be emitted into the workplace and the atmosphere. These emissions contribute to the growing problem of plastic waste and pose significant risks to both human health and the environment. The sources and environmental fate of atmospheric MPs are still not clearly defined and explored. Few studies have fully explored the complex sources of plastic-derived contaminants during and after plastic production from a sustainability perspective. In the United States, hazardous air pollutants are regulated by federal law, including National Emission Standards for Hazardous Air Pollutants (NESHAP), which apply to the polymer and resin processing industries. In April 2023, the U.S. Environmental Protection Agency proposed strengthening NESHAP regulations for industries handling polymers such as polyethylene, polypropylene, polystyrene, and polyethylene terephthalate, however, the atmospheric MPs are not listed. This paper critically reviewed the point sources and emissions of packaging-derived anthropogenic air pollutants, i.e., atmospheric MPs, throughout the lifecycle of packaging, from production and processing to disposal and recycling. It also investigated the pathways through which the pollutant is exposed to human beings. Fundamental solutions, i.e., source characterization, are crucial to mitigate these issues, emphasizing sustainability and providing a framework for the plastic packaging industry to address environmental challenges.

**Keywords:** sustainable plastic manufacture, atmospheric microplastics, microplastic sources.

**Notes:**

# 213 Circular and Sustainable Packaging Challenges for US Military versus Consumer Packaging

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**Abstract:** This paper covers how the US Military drives its use of packaging materials like all other global, private, and consumer industries to circular packaging choices, thereby reducing the use of single-use plastic packaging materials and setting more authoritarian mandates and sustainability targets for 2025 and 2050. Developing biodegradable or non-toxic packaging that can be safely abandoned without leaving environmental hazards is a goal but remains technically and logistically challenging. For the U.S. Army, an executive order has set recycling targets at 50% for fiscal year 2025 and 75% for fiscal year 2030. In remote or combat environments, recycling infrastructure is nonexistent. Packaging left behind could impact the environment or even provide intelligence to adversaries. Creating truly sustainable packaging means addressing the entire life cycle of military packaging systems, from raw materials to end-of-life-and back again. In addition to investing in circularity, the US Military has a strategy and a plan introduced in September 2024 to reduce, recycle, and eliminate packaging waste. US consumer goods and industry have similar objectives. While it varies across the applications for food, pharmaceutical, equipment, health, and beauty aids, etc., the general target is to make sure at least half of all plastic packaging is made with 100% recycled content for packaging to consumers by 2025, and for packaging to businesses by 2030. The presentation in June 2025 will cover how the US military and private industry performed and if they met the 2025 target material reductions, improved recycling rates, and elimination or reduction of packaging waste. Keywords: US Military, Circular Packaging, Sustainability, Single Use, Food, Pharmaceutical and Medical.

**Keywords:**

**Notes:**

# 214 ECOTRON: New technologies for one-pot glycolysis of printed electronics

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**Abstract:** With the aim of promoting sustainable technologies within conventional electronics and mitigating the environmental impact of electronic devices, technologies for chemical recycling of polymeric substrates of these devices have been developed. The initiative stems from the need for a paradigm shift in electronic design and manufacturing processes to reduce the environmental footprint of electronic products.

In order to evaluate recyclability of polymeric substrates two methodologies were tested: alkaline hydrolysis and catalyzed glycolysis. The hydrolysis process has been performed with the aim of recovering Ag-ink while achieving PET substrate recycling towards terephthalic acid (TPA) in the same process step. Analogously, catalyzed glycolysis processes have been investigated with the aim of recovering Ag-ink and simultaneously PET substrate recycling towards bis (2-hidroxyethyl) terephthalate (BHET). Ag-ink can be easily recovered during a first filtration step, while all the other reactants and products remain on the liquid phase IF 100% PET substrate conversion is achieved.

In this study we have first analyzed the chemical recycling processes of PET substrates by means of energy and environmentally friendly technologies, with special focus on the recovery of Ag-inks. Specifically, we began by evaluating alkaline hydrolysis using water and NaOH as the reaction medium (with good ink separation), although we had to be applied by more intensive technologies to obtain good conversions of the PET substrate and high-value products for the industry (BHET). Moreover, glycolysis reaction parameters were optimized with commercial catalysts and different inks and polymeric substrates to evaluate and define the best strategies for the glycolysis process. Characterization of all fractions produced was carried out to check the efficiency of the separation process of the metallic inks, the depolymerization of the PET substrate and the purity of the BHET obtained.

**Keywords:** PET, solvolysis, BHET, depolymerization, printed electronic

**Notes:**

# 216 The Role of Packaging Engineers in Informing Evidence-Based Policy Making to Minimize Export Market Disruptions in the Face of Foreign Sustainable Packaging Regulations

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**Abstract:** U.S. food and beverage exporters are facing increasing demands from foreign regulators and consumers to distribute products in sustainable packaging or free of packaging. In response, the U.S. Department of Agriculture (USDA) Foreign Agricultural Service (FAS) is collaborating with Michigan State University and other stakeholders to ensure that emerging foreign sustainability regulations are informed by private sector and university packaging experts to optimize sustainability within practical constraints. Furthermore, to accelerate the implementation of compliant sustainable technologies, FAS is providing $10 million for packaging innovation through a new program implemented by Clemson University and the Foundation for Fresh Produce (FFP).

Sustainable packaging regulations are emerging worldwide, and the trend is expected to accelerate. With the passage of the Packaging and Packaging Waste Regulation, the European Union will implement comprehensive regulations requiring recyclability and recycled content and establish quotas on reusable packaging. Canada has issued broad framework proposals, including the voluntary phase-out of most single-use plastic packaging for fresh produce. In the United Nations negotiations on an international instrument on plastic pollution, 175 countries are considering binding obligations that could dramatically restrict the use of plastic packaging. These regulations will require significant innovations in packaging, yet regulators often overlook the challenges in developing new sustainable packaging, leading to unrealistic timelines and requirements.

In this presentation, we will present, past, and future opportunities for collaboration, including prior meetings between Canadian and European regulators and packaging engineers helping to inform the current state of regulations, as well as pathways for future meetings in the United States and worldwide to support the packaging community to inform and collaborate with the specialty crop industry. We will also provide an update on the first round of packaging innovation funding administered by Clemson University and FFP.

**Keywords:** Regulations, emerging technologies, sustainability.

**Notes:**

# 217 Thinking models for recycling information in packaging design

**Roland ten Klooster [1*] and Eric Lutters [1]**

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**Abstract:** With the aim of achieving higher recycling rates, especially for plastics, many recycling design guidelines have been published, such as those from Recyclass, KIDV Recyclechecks, and APR. Despite these guidelines, many design projects still result in packaging designs that, for a variety of reasons, cannot be recycled or cause issues during recycling. For example, some cannot be sorted, are not large enough, or produce chemicals in the recycling process. Packaging design methods are not complete in taking up recycling information to become more circular, especially for plastic packaging.

In order to gain insight into the most important questions relevant to closing the plastics material chain, the Dutch research institute TNO conducted an intensive round of interviews with 44 people who are stakeholders in the plastics recycling chain. This research was done on behalf of the Innovation Growth Fund Circular Plastics NL, which aims to enhance the circularity of plastics. The Netherlands Institute for Sustainable Packaging KIDV wanted to get insight in lacks of knowledge at companies concerning packaging design and conducted a round of interviews. The results of both studies show that decision makers in packaging design want to get understanding in sustainable packaging design, do not always know where to find guidelines, and are missing an overview of new legislation and what this means to them.

Recycling of plastic packaging at high scale is new and design methods do not integrate issues from the end of the chain in detail. A thinking model is set up to handle information during packaging design decision taking processes to help decision makers and to get better understanding of the steps and the mutual influences. The thinking model takes the material chain as starting point, pictured as a circle. A layer around this chain is made to illustrate the input of needed information in every step, with help of scenarios to be able to get insight in the consequences for recycling. The thinking model is proposed as a starting point for further development towards packaging design methods in which recycling information is integrated.

**Keywords:** sustainability, packaging design, decision making process, recycling, plastic packaging, thinking model.

**Notes:**

# 218 Leveraging LCA for Informing Eco-Design and Eco-Modulation to Promote Sustainable Production

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**Abstract:** Traditional Life Cycle Assessment (LCA) approaches for estimating the potential environmental impact (PEI) of product/packaging systems often overlook key supply chain stages, such as loss rates, the use phase, and secondary and tertiary packaging. These omissions can lead to incomplete insights for reducing the PEI of these systems. To address these gaps, we conducted four LCAs using ISO14040/44-2006 for cement, milk shampoo, and bottled water, focusing on market-representative systems to provide actionable strategies for reducing PEI across the supply chain. We employed SimaPro-v9.6.0.1 software, US-LCI, Ecoinvent-v3.10, and DataSmart-v2023 databases, along with selective TRACI-v2.1 impact categories. These served as midpoint indicators and, along with the inventory, calculated the impact assessment, analyzing the system's contributions, comparison, and uncertainty. The life cycle inventory was based on North American supply chain data from 2022 to 2024, with cradle-to-grave scope; these LCAs examined product and packaging systems. Functional units (FU) included three systems delivering 13,431 kg of cement, five delivering 7,602 kg of milk, four delivering 23,728 kg of shampoo, and four delivering 18,000 kg of bottled water. For instance, alternative cement packaging systems showed minimal differences in global warming potential (GWP); however, reducing product loss by ~50% could lower life cycle GWP by ~3.5%. Reducing product loss by ~50% for milk could lower life cycle GWP by 4-5%. The key contributors to shampoo systems include packaging, transportation, and water used for hair washing, with the greatest reductions achievable by reducing product loss by ~50%, using 50% PCR content, and increasing the recycled rate. The most significant GWP contributors for bottled water products are transportation, product, and packaging production. System targeting loss minimization and identifying hot spots can reduce PEI, guiding eco-design and eco-modulation strategies.

**Keywords**: environmental footprint, cement, milk, bottled water, shampoo.

**Notes:**

# 219 New requirements and methodologies for the evaluation of packaging recyclability

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**Abstract:** New legislation has been published in the area of packaging sustainability. For instance, the new European Packaging regulation has established a calendar on packaging reduction, reuse, recyclability, recycling content and compostability. In the area of recyclability this new standard has stablished that all packaging should be recyclable by design in 2030 (design aligned with existing recycling technologies) and recyclable at scale by 2035 (the technologies are well extended and in operation).

In order to evaluate recyclability two methodologies are available: theoretical and practical. Theoretical procedures evaluate the recyclability based on the analysis of the life cycle of the packaging and therefore considering design, manufacturing, use, collection, sorting and recycling stages. Practical methodologies evaluate the recyclability based on a reproduction of the complete recycling process in laboratory trials (recycling protocols). Moreover, all these methodologies can be completed with the technical information described in new recycling guidelines that are being prepared by packaging material.

In this study we have firstly analysed the new legislation in application in Europe in the area of packaging sustainability, with a special focus on the new Packaging and Packaging waste Regulation. Concretely, we have described the new requirements, with a special focus on recyclability (objectives and dates). Moreover, we have identified and described the different methodologies for the recyclability evaluation: theoretical (ISO18604:2013), practical (Recyclass Recycling Protocols for plastic packaging, CEPI method for paper packaging). Moreover, the different recycling guidelines for the diverse packaging materials have been described. Finally, we have developed two case studies in which we have applied these methodologies in two packages (bottle and tray), to better understand their application.

**Keywords:** Packaging, recyclability, recyclability by design, recyclability at scale, theoretical recyclability, practical recyclability, design, manufacturing, use, collection, sorting, recycling technologies, recycling protocols

**Notes:**

# 220 Enhancing Freshness and Sustainability Through a Monitoring and Traceability System

**Juan Granados[1] and Pablo García[2*]**

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**Abstract:** The aim of this work was to develop a monitoring system to address the challenges of preserving and transporting fresh fishery products. With increasing global demand and the need for sustainable practices, ensuring product quality and traceability throughout the supply chain is crucial for consumer trust and food safety.

Besides the commonly use temperature and humidity sensors, gas sensors were chosen to monitor the degradation of fishery products, particularly focusing on trimethylamine (TMA) and bacterial activity. As fish begin to spoil, bacteria break down trimethylamine oxide (TMAO), producing TMA, which causes the characteristic "fishy" odor, as well as gases like $NH_3$ (ammonia) and $H_2S$ (hydrogen sulfide). Furthermore, carbon dioxide ($CO_2$) is released during bacterial respiration, while methane ($CH_4$) is produced by certain bacteria under anaerobic conditions. By continuously monitoring these gases and tracking the product's location via GPS, the system provides real-time insights into the freshness of the product, helping to detect the onset of spoilage and improve the management of storage and transportation conditions.

To complete the value chain, ITENE collaborates with INFOTEAMS on the development of a website and mobile app serving as an integrated platform. This platform connects all data from the devices, including product tracking and quality measurements, with manufacturing data such as production date, batch, and other relevant attributes. Users can access real-time data and historical records, offering complete traceability and product quality insights. This data integration enhances transparency and trust in the supply chain while providing a more informed and user-friendly experience.

**Keywords:** fishery products, gas sensors, GPS tracking, real-time monitoring, online marketplace.

**Notes:**

# 221 Packaging Impact on Consumer Experience: Voice of the E-Customer

**Daniel Hellström [1,2*], Yulia Vakulenko [1,2], Diogo Figueirinhas [1,2] and Henrik Pålsson [1, 2]**

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**Abstract:** With the growth of e-commerce, understanding the nuances of packaging performance and consumer expectations has become essential to enhancing the customer experience. In e-commerce, packaging is a key component of the overall consumer experience, directly influencing perceptions and expectations. Despite its importance, packaging often remains overlooked and is significantly understudied. This exploratory study aims to bridge the gap by investigating the impact of packaging on consumer experience, using text mining techniques to analyse online consumer reviews. Drawing from a comprehensive dataset of Amazon reviews spanning from 1995 to 2016, the study identifies key packaging facets that influence consumer perceptions, including quality, aesthetics, and protection. The findings demonstrate that positive packaging experiences are associated with higher consumer ratings, enhancing the overall shopping experience. In contrast, negative packaging experiences, such as damage or poor design, have a disproportionately large impact, often leading to significantly lower ratings. The study also reveals that packaging failures tend to drive consumer dissatisfaction more than positive experiences drive satisfaction, highlighting the greater weight of negative experiences. Additionally, the research identifies nine distinct facets of the packaging experience, each contributing to the consumer's cognitive, emotional, and sensorial evaluations. When executed well, these facets serve as latent differentiators that support positive consumer experiences. This study provides an initial framework for businesses to improve packaging design, aligning it more closely with consumer expectations and reducing negative experiences. By enhancing the design and functionality of packaging, businesses can improve customer experience and influence purchasing decisions, underscoring the strategic role of packaging in e-commerce.

**Keywords:** customer satisfaction, e-commerce, packaging performance, product reviews, text mining.

**Notes:**

# 222 Real-time optimization of reusable package transportation

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**Abstract:** Our study introduces an analytical framework to optimize the transportation operations of reusable packages through a dynamic vehicle routing problem with backhauls (DVRPB). The increasing demand for on-demand delivery services necessitate shifting from static vehicle routing problems (VRPBs), where all parameters are predefined, to dynamic settings (DVRPBs) that adapt to real-time data such as customer requests and locations. This research develops a model integrating real-time data acquisition, decision-making for accepting or rejecting service requests based on resource constraints, and route optimization to accommodate newly accepted requests. Our research presents a dual case study in collaboration with industry, revealing the trade-offs between transportation cost and service responsiveness in dynamic routing environments. We quantitatively assess the impact of various factors like urban density, customer location accessibility, the proportion of online customers, and vehicle capacity on the DVRPB's effectiveness. The methodology relies on computational experiments using two simulated geographic networks representing urban and rural settings, highlighting the challenges and efficiencies in each. The results demonstrate that dynamic routing significantly enhances the responsiveness of reusable package delivery services, reducing material usage and waste. This approach not only addresses environmental concerns but also meets the growing consumer demand for swift and efficient delivery services. Future directions include refining the real-time decision-making processes and expanding the model's applicability to other dynamic routing scenarios.

**Keywords:**

**Notes:**

# 226 Optimizing Oblong Cutout Shapes in Ventilated Food Packaging Designs

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**Abstract:** The protection of postharvest fruits and vegetables during transportation and storage is critical to extending their shelf life, reducing waste, and ensuring consumer satisfaction. Ventilated corrugated packaging plays a crucial role in achieving these goals by facilitating airflow and maintaining the produce's quality. However, incorporating ventilation cut-outs often compromises the structural integrity of the packaging, reducing its compressive strength and increasing the risk of mechanical damage. This study investigates the balance between enhancing ventilation and maintaining packaging strength, focusing on oblong-shaped cut-outs in corrugated paperboard plates. Using a combination of experimental buckling tests conducted with an Instron Universal Testing Machine and finite element analysis (FEA), we validate how varying the size, orientation, and width-to-length (W/L) ratios of cut-outs affect the critical buckling force of the plates. The experimental tests, conducted under controlled conditions using corrugated C-flute plates, demonstrated that increasing W/L ratios of cut-outs generally reduces the critical buckling force. Larger cut-outs provide better airflow but significantly diminish structural stability. The orientation of cut-outs also plays a pivotal role, with vertically oriented oblong shapes retaining more compressive strength than horizontal ones but being less ergonomic. FEA simulations, validated against experimental results, provided further insights into stress distribution and buckling behavior across different cut-out configurations, confirming the reliability of the simulation approach in predicting structural performance. This study emphasizes the importance of optimizing cut-out designs to create durable, ergonomically efficient, and ventilated packaging solutions. The findings provide actionable design guidelines to improve the safety and sustainability of fresh produce transportation. By aligning ventilation and strength requirements, this research contributes to reducing food waste, enhancing cold chain efficiency, and fostering consumer confidence in postharvest supply chains.

**Keywords:** Food packaging, fresh produce packaging, oblong cutouts, Box compression, Shel-Life.

**Notes:**

# 227 Visible light responsive packaging material for broad-spectrum antibacterial control on food and contact surfaces

**Zhiyuan Xu, Zunhuang He, Yilin Li, Hongchen Shen, Young-Teck Kim, Danmeng Shuai, Yun Yin, Haibo Huang, Monica Ponder**

**Abstract:** Antibacterial packaging holds promise in reducing bacterial growth in foods, but current solutions are often limited to materials embedded with antimicrobial or harmful chemicals, raising concerns about antimicrobial resistance and chemical residuals in foods. Therefore, there is an urgent need to explore alternative approaches for developing effective and safe antibacterial packaging materials. This project focuses on developing a visible-light responsive antibacterial packaging material that incorporates dye-sensitized titanium dioxide (TiO2) into cellulose nanofibrils. The developed film can produce reactive oxygen species (ROS) under visible light, inactivating bacteria on food and contact surfaces. The light absorbance properties of the conjugates were characterized using UV–Visible spectroscopy, while the quantity of reactive oxygen species (ROS) generation under varying light intensities was also analyzed using electron paramagnetic resonance (EPR). The antibacterial efficacy of the films was evaluated by measuring log CFU reduction of both gram-negative and positive bacteria such as multidrug-resistant Salmonella enterica, methicillin-resistant Staphylococcus aureus (MRSA) under different light intensities. On Salmonella contaminated mango slices, the film achieved a 3.0 ± 0.07 log CFU/g reduction under 6000 lux light within 48 hours. When the light intensity was lowered to 1000 lux, the population of Salmonella was still reduced by 1.87 ± 0.57 log CFU/mL. However, it showed limited efficacy on contaminated chicken breast. The film also reduced MRSA by 0.97 ± 0.25-log CFU/mL after 2 hours of 3000 lux exposure on stainless steel surfaces. These results demonstrate the potential of developed visible-light-responsive film as an effective solution for inactivating pathogens on both food and food contact surfaces, offering a promising strategy for novel antibacterial packaging to enhance food safety.

**Keywords:**

**Notes:**

# 301 Plastic packaging and freshwater a commodity that is fast decreasing and its impact on natural disasters and wars

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**Abstract:** This paper covers the impact of a rising temperature on earth that will impact the use of plastic materials in packaging, and an essential human requirement to have fresh water will be a challenge for future research. The presentation will show trends in making plastic materials in packaging to be eliminated. The production and recycling of plastics divert resources from sustainable water management practices. However, the requirement for fresh and clean water, produce, and perishables is a fundamental human need and cannot be eliminated. Mismanaged plastic waste contaminates freshwater sources, affecting aquatic ecosystems and making water unsafe for consumption. Microplastics are increasingly found in rivers, lakes, and groundwater. Future research should aim to reduce the wasteful use of these two critical needs, replace them with a new generation of plastics, recover fresh water, and decrease the reliance of the affluent society on such needs. Examples are shown for humanitarian missions, war zones, natural disasters, and the role of packaging for human survival.

**Keywords:** Sustainability, Plastic Packaging, Fresh Water, New Biomaterials, Future Research, Inventions.

**Notes:**

# 305 Using Real-World Data to Predict Failure Modes for Repackaging Sensitive Molecules: A Risk-based Approach

**Mercy Okezue [1*] and Stephen Byrn [2]**

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**Abstract:** Manufacturers conduct stability assessments in the container closure systems designed to market a drug product. Therefore, inherent risks are associated with repackaging moisture and oxygen-sensitive products in other systems, which may not be equivalent to their original primary and auxiliary containers. Consequently, we assessed the risk of repackaging certain pharmaceutical products using a representative oxygen and moisture-sensitive drug formulation prone to potency loss.

Quality parameters per USP were conducted on three brands of levothyroxine and carbamazepine tablets based on their trend analysis from FDA Enforcement Reports (ER). The samples were repackaged and stored at ambient (~ 23◦C), accelerated mode 40◦C / 75% RH, and withdrawn for testing at 0-, 3-, and 6-month intervals. Control samples were kept in the original manufacturer's container closure systems. We further investigated levothyroxine products' potencies stored under the recommended ambient temperature and refrigerated conditions of 2◦C to 8◦C.

From 2012 to 2024, approximately 78% of all levothyroxine recalls were due to chemistry manufacturing and control (CMC) issues; sub-potency accounted for about 54%. Approximately 55% of all carbamazepine recalls were due to CMC; dissolution failure accounted for about 83%, and potency failures were only 7%. From the stability assessments, all brands of levothyroxine had satisfactory potencies after 1.5 months of accelerated conditions. However, failures were documented for two brands after 3 months of stability; at the 6th month, all brands were below the USP assay limits. The potency was mostly retained for the samples kept in their original containers under ambient normal room temperature, ~ 23◦C at 6 months.

The results from levothyroxine tablets suggested that repackaging drug molecules highly prone to various degradation pathways can cause them to lose efficacy before their affixed expiry date. However, a similar trend was not observed in carbamazepine tablets repackaged in polypropylene primary containers void of auxiliary components.

**Keywords:** repackaging, stability, subpotency, levothyroxine, degradation.

**Notes:**

# Poster 105P Eco-design based on distribution risks as a key tool to develop a sustainable packaging system for bathroom sector

**Patricia Navarro, Marta Garrido Hieskar Stwolinsky, Ariana Gómez, Víctor Gallego, Nuria Herranz.**

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**Abstract:** The objective was the selection, development and validation of a sustainable packaging system at a technical and environmental level, carried out with packaging eco-design based on distribution risks, through the development of a customized test protocol. The development of testing protocols based on standards, as a key tool, to develop a sustainable packaging system for the companies, to improve their alignment with environmental requirements, ensuring product protection throughout the distribution cycle. The technical validation of packaging systems, through transport simulation test protocols, has become an essential phase in the development of sustainable packaging systems. Because of environmental legislation, companies have to reduce and implement easily recyclable materials, with recycling percentage and finally significant changes in packaging design that may affect product protection. For this reason, the development of ad – hoc test protocols based on standards, becomes a necessity, to ensure the efficiency of the new packaging systems. As a case study, a company in the bathroom sector was selected. This company, because of the acquisition of different international plants, needed to standardize the packaging system for shower trays, considering the requirements of product protection, risks of different types of distribution, customer requirements and of course environmental requirements, among others. As a result of the case study, the following indicators have been estimated: Technical Kpi, based on the results of the test protocols applied on the current packaging systems of the different plants compared to the new standardized sustainable solutions. Environmental Kpi, based on the recyclability, packaging reduction and % of recycling rate materials of the different packaging systems. With these final indicators, the selection of the most appropriate sustainable packaging has been covered.

**Keywords:**

**Notes:**

# Poster 402 Uncovering UTSA-280 A Metal Organic Frameworks as A Safe Bioactive Food Packaging Material

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**Abstract:** Metal-organic frameworks (MOFs) represent a novel class of highly tunable materials with promising applications in food preservation and packaging. This study explores the potential of UTSA-280, a calcium-based MOF, for moisture management in food packaging. UTSA-280 was synthesized using a mechanochemical method and characterized by its high crystallinity and microporous structure. Water sorption isotherms were measured to assess its moisture adsorption capacity, revealing that UTSA-280 adsorbs up to 80 $cm^3/g$ of $H_2O$-2.5 times more than bentonite desiccants, though 150% less than silica gel. Despite its lower overall adsorption capacity compared to silica gel, UTSA-280 offers several distinct advantages for food packaging. These include its selective adsorption properties, which prevent over-drying and maintain the desired moisture balance, essential for preserving food quality. Additionally, UTSA-280's structural integrity, thermal stability and regenerability make it a sustainable and cost-effective solution for long-term food storage. The findings demonstrate that UTSA-280 is a promising candidate for enhancing food safety and extending shelf life in packaging applications.

**Keywords:**

**Notes:**

# Poster 403 Analysis of pallet stability and mechanical properties under horizontal constraints

**Nolot Jean-Baptiste [1*], Le Baillif Marie [1,3], Delloque Philippe [1], Huart Victor [2], Odof Serge [1,3], Meuret Mikael [1] and Erre Damien [1,3]**

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**Abstract:** The transportation of goods by truck is a critical sector of the global economy, ensuring the distribution of products over long distances and across various environments. However, this mode of transport poses numerous technical and safety challenges. Among the primary concerns are the horizontal constraints associated with handling, braking, cornering, roundabouts, and the stability of cargo inside the truck. Abrupt braking or improper negotiation of a turn can cause cargo to shift, increasing the risk of pallet overturns and potentially leading to severe accidents. Such incidents can not only damage the transported goods but also endanger drivers and other road users. To mitigate these risks, special attention must be given to load distribution, braking techniques, and the stability of goods during transit. This study focuses on analyzing the stability of pallets. The objective is to characterize the mechanical properties of pallets using various experimental methods. To this end, we instrument the pallets with sensors (an input accelerometer at the base and an output accelerometer at the top of the pallet) to measure physical quantities potentially correlated with their stiffness and elasticity under horizontal constraints. Vibration transmission measurements are performed using sinusoidal sweep and multi-level spectral excitation to analyze the frequency response and overall system behavior. Free damped oscillation tests are conducted by tilting the pallet flat or on its base edge to study the damping phenomena. A horizontal traction test applied to the top of the pallets evaluates their structural resistance. Horizontal shock tests with durations ranging from 10 to 400 ms and constant intensities (0.15, then 0.21, 0.40, 0.50, and 0.65 g) are applied to the pallet to calculate the shock amplification at the top of the pallet relative to the base. Finally, shock wave propagation speed is measured to determine the dynamic transmission properties and rigidity of the system. The transfer functions of the "pallet system" in response to horizontal vibrational stimuli are highly dependent on the excitation level. The system exhibits non-linear behavior. At very low excitation levels, the first and second vibration modes are clearly identified. The first mode occurs at a frequency close to the natural oscillation (relaxation) frequency. Both the frequency peak (first and second modes) and its intensity decrease as the excitation level increases. Shock amplification at the output/input ratio stabilizes when the duration of the input shock increases. However, when the intensity of the input shock rises, the amplification decreases (e.g., ×2 at 0.15 g, ×1.4 at 0.65 g). This study demonstrates that a pallet's mechanical properties can be characterized through a series of relatively simple tests.

**Keywords:**

**Notes:**

# Poster 404 Corrugated Packaging Manufacturing Evaluation: Laser Cutting vs. Traditional Methods

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**Abstract:** Corrugated cardboard packaging is widely used for transporting and protecting goods across various industries. Its popularity is driven by its adaptability and eco-friendly qualities, making it the material of choice for packaging. This trend has accelerated with the rapid growth of e-commerce, where most shipments rely on corrugated cardboard.

Traditional manufacturing methods for cardboard packaging involve cutting and scoring sheets of material using mechanical pressure. While effective, these methods have notable limitations, including the inability to achieve fine details, material deformation from pressure, and relatively high dimensional tolerances.

Laser cutting has emerged as a viable alternative, offering significant advantages over conventional techniques. This modern process provides greater dimensional accuracy, eliminates mechanical stress on the material, and supports cleaner, more sustainable production methods. Additionally, it contributes to a more attractive work environment, appealing to younger workers who value modernity and sustainability.

The study aimed to compare the performance of corrugated cardboard specimens prepared through traditional methods (mechanical cutting and scoring) with those produced using laser cutting and scoring by material removal. Tests conducted included: Edge Crush Test (ECT – ISO 3037) to measure the vertical compression strength of the flute, Score Quality Test (TAPPI T829) to assess scoring quality, Compression Resistance Test (ASTM D642) to evaluate box strength, and Drop Tests (ISTA 2A) simulating a 970 mm fall with a 2 kg internal weight.

Boxes were manufactured using the FEFCO 201 standard design for both processes. For laser scoring, material was removed to half the thickness of the cardboard, with two variations: one removing only the inner layer and the other removing of the flute "head" as well.

The results show identical ECT performance between laser cutting and Billerud cutting (single-bevel utility knife blade). In compression resistance tests on the boxes, the performance is statistically identical. However, when the laser scoring design is modified, improved performance can be observed. This suggests a need to adjust the designs of FEFCO standards.

The folding force required for laser-scored lines is lower than for traditional scoring, which can be advantageous for packaging processes on automated closure lines. Drop tests reveal that tearing at the score lines (in laser-cut boxes) occurs only if the outer cover paper is of poor quality.

**Keywords:**

**Notes:**

# Poster 405 Impact of cellulose dimensions on the crystalline structure and properties of thermoplastic starch composites

**Dasom Son, DongHo Kang, Junhyuk Lee, Jin Kie Shim, EunAe Shin**

**Abstract:** Thermoplastic starch (TPS) is increasingly recognized as a promising solution for sustainable and biodegradable materials in various applications. In this study, we investigate the impact of filler dimensions on inducing crystalline types during the gelatinization and retrogradation processes of TPS. By systematically varying the dimensions of cellulose nanomaterials (CNM) through acid hydrolysis while maintaining other formulation parameters constant, we confirmed changes in the ratio of B and Vh-type of TPS crystalline structures induced by the CNM dimensions using X-ray diffraction (XRD) analysis. Differential scanning calorimetry (DSC) further revealed that the melting temperatures varied with the crystalline structures, reflecting differences in chain structure. The transition of crystalline structures in TPS composites caused by systematically controlled CNM dimensions led to improvements in toughness. Toughness increased by up to 34% compared to neat TPS, particularly at intermediate CNM dimensions, which promoted a balance between strength and elongation. The addition of CNMs also enhanced the barrier properties of TPS composites by reducing the water adsorption by approximately 20% and significantly decreasing oxygen permeability from 46.3 $cm^3 \cdot m^{-2} \cdot day^{-1} \cdot atm^{-1}$ to 6.96 $cm^3 \cdot m^{-2} \cdot day^{-1} \cdot atm^{-1}$ with varying CNM dimensions. Analysis of the induced crystalline types according to filler dimensions and their associated properties enables precise tailoring of TPS composite properties to meet various application requirements.

**Keywords:**

**Notes**:

# Poster 406 Exploring Packaging Solutions for Vegan Meat Alternatives: Towards More Circular and Sustainable Designs

**Alina Kleiner and Markus Schmid**

**Abstract:** Packaging, especially when used for food, fulfils important packaging-specific functions, the most important of which is product protection and thus makes a significant contribution to reducing food wastage. For optimal product protection the knowledge of the product specific requirements towards the packaging is essential. Currently, the specific packaging requirements of vegan meat alternatives are underexplored in the literature. Despite their unique properties, vegan meat alternatives are often packaged using materials and designs developed for conventional animal meat products, potentially overlooking opportunities for packaging optimization and sustainability improvements This study addresses this gap by investigating how tailored packaging solutions, adapted to the distinct needs of vegan products such as oxygen, moisture, and light barriers, can enhance circularity. Furthermore, the research explores innovative strategies for up-cycling production residues and by-products into bio-based packaging materials, thus creating integrated circular systems. Particularly in the production of vegan meat alternatives, significant by-products, such as starch from the extraction of plant protein, are generated. These by-products, which are often unsuitable for direct food processing due to limited functionality and off-flavors, represent a valuable resource for developing bio-based packaging materials. This approach not only mitigates environmental impact but also adds value through the creation of sustainable, circular packaging solutions for vegan meat alternatives. The outcomes of this research have the potential to drive significant advancements in the packaging industry by promoting more eco-friendly and resource-efficient designs.

**Keywords:**

**Notes:**

# Poster 407 Lignin as a Compatibilizer for Biodegradable Polymer Blends: Enhancing Compatibility and Barrier Properties for Sustainability

**Sung Kyu Kim, DongHo Kang, Junhyuk Lee, and Jin Kie Shim**

**Abstract:** The utilization of renewable resources in the development of sustainable materials has gained significant attention in recent years. In this study, lignin, a multifunctional by-product from forest resources, was employed as a reactive compatibilizer to enhance the interfacial compatibility between polylactic acid (PLA) and polybutylene adipate-co-terephthalate (PBAT). Functionalization of lignin through a tailored chemical reaction enabled its integration as a compatibilizer, promoting in situ interactions between PLA and PBAT phases. The resulting biodegradable polymer blend exhibited improved morphological stability and mechanical properties, indicating enhanced compatibility between PLA and PBAT. Additionally, the incorporation of lignin significantly enhanced UV and water barrier properties, making the blend suitable for sustainable packaging applications. This study demonstrates a novel approach for developing high-performance, eco-friendly polymer blends by leveraging the unique properties of lignin, paving the way for innovative applications in sustainable packaging and materials science.

**Keywords:**

**Notes**:

# Poster 409 Enhancing Moisture Barrier Properties of Poly(lactic) Acid Films with Beeswax for Sustainable Packaging Applications

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**Abstract:** Over 140,000 tons of poly(lactic) acid (PLA) is produced each year and is expected to increase by 30% in the next two years due to its growing use in packaging applications. The biodegradability of PLA attracts food packaging applications, but its use is limited due to its poor water barrier properties. Its moisture barrier has been improved by incorporating additives and coatings, typically through solution casting. Unfortunately, this methodology reintroduces environmentally toxic components as it uses organic solvents and challenges the biodegradability of PLA. To emphasize sustainability, this study explores approaches to enhance resistance to moisture permeation by adding beeswax through co-extrusion without solvents while maintaining the biodegradability of PLA films. Beeswax, a complex mixture of fatty acids, long-chain hydrocarbons, and esters, is hydrophobic and a promising additive to increase the moisture resistance of PLA films. A 10% wt./wt. beeswax/PLA masterbatch was experimentally selected as the optimal mixture ratio and manufactured by twin-screw extrusion. Results showed the addition of beeswax improved the moisture barrier from 5.86 to 1.64 (x 10^-16 (kg·m/(m2·s·Pa)) due to the hydrophobic nature of the dispersed beeswax. After film processing using cast extrusion, the impact of annealing (120 °C) was examined. Although annealing increased the crystallinity of the films, it also decreased their structural integrity because of phase separation during heating. The different temperature profiles of beeswax and PLA contribute to the degradation under post-thermal treatment. Nuclear magnetic resonance analysis was used to monitor the loss of beeswax and the final film composition for each processing step. Our study demonstrates that beeswax could be effectively incorporated into PLA through thermal mixing, resulting in cast extruded films with enhanced moisture barrier properties. This approach will offer a potentially sustainable solution for developing PLA films suitable for packaging moisture-sensitive products.

**Keywords:**

**Notes:**

# Poster 411 Improving the recyclability of flexible packaging for meat: a comparison of conventional and new designs

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**Abstract:** Flexible plastic packaging for fresh meat products plays a critical role in preserving product quality through its moisture and oxygen barrier properties. However, the complex multilayer structure of these packages, often incorporating materials like PVDC, significantly complicates recycling. This study investigates a new design for multilayer flexible packaging aimed at improving recyclability while maintaining essential functional properties. Five commercial vacuum-packed meat samples were characterized using FT-IR, DSC, and microscopy to determine their material composition. The packaging structures were found to consist of PE, EVA, and PVDC. Using the RecyClass tool, these packages were classified as "Not Recyclable", indicating that they are not recyclable due to fundamental design issues, primarily the inclusion of PVDC. In response, we propose a redesign of the packaging structure, replacing PVDC with EVOH (≤ 5%) and PA layers, resulting in a new multilayer configuration. According to RecyClass, this new design would be classified as "CLASS C", indicating that it is recyclable, but with some recyclability issues, with potential improvements in recycling processes and the possibility of closed-loop schemes. While recyclability improves with the new design, both the PVDC-based and the EVOH+PA-based packaging were analysed for their barrier properties and mechanical performance to ensure that product shelf life is not compromised. The PVDC-based packaging showed superior mechanical performance, but the redesigned sample (EVOH+PA) performed better in terms of barrier properties, especially against oxygen. These results suggest that the redesigned packaging has strong potential to replace the conventional packaging used in commercial samples, providing a better balance between recyclability and product performance. Achieving this balance is critical to ensuring environmental benefits without contributing to food waste. This work offers a promising approach to redesigning flexible meat packaging, combining sustainability advantages with technological feasibility for the meat packaging industry.

**Keywords:** Flexible packages, multilayer films, design for recycling, circularity, meat products packaging.

**Notes:**

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