

# 19th IAPRI WORLD CONFERENCE ON PACKAGING

15-18 JUNE, 2014  
MELBOURNE, AUSTRALIA

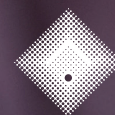
Responsible Packaging for the Global Market

## PROGRAM AND ABSTRACTS

Hosted by the  
Engineered Packaging and Distribution Research  
Group at Victoria University.

[vu.edu.au/iapri-2014](http://vu.edu.au/iapri-2014)

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**VICTORIA  
UNIVERSITY**

MELBOURNE AUSTRALIA

## Welcome

We are delighted to have the opportunity to welcome the international community to Victoria University in Melbourne for the 19<sup>th</sup> IAPRI (International Association of Packaging Research Institutes) World Conference on Packaging. The conference is organised by the Engineered Packaging and Distribution Research Group at Victoria University and supported by the College of Engineering and Science and the Office for Research at Victoria University.

The IAPRI conference has become an important and prestigious forum where leading researchers and global experts gather to share their research findings in the field of packaging, distribution and logistics. IAPRI is the global peak body for packaging research, and is responsible for fostering the exchange of research initiatives by more than 1,000 experts from 80 packaging research institutes.

We welcome you, in this 25<sup>th</sup> anniversary of packaging and distribution research at Victoria University, to share your work and make new friends while experiencing the unique and evolving city that is Melbourne - a city where modern architecture and design is juxtaposed with heritage buildings reflecting Australia's cultural history.

On behalf of Victoria University and the Organising Committee, we welcome you to the 19<sup>th</sup> IAPRI Conference in Melbourne.

**M.A. Sek, S.W. Bigger and V. Rouillard**  
Chairs, Organising Committee



## **IAPRI 2014 Organising Committee**

### **Co-Chairs**

**A/Professor Michael Sek**

Engineered Packaging and Distribution Research Group, Victoria University

**A/Professor Vincent Rouillard**

Engineered Packaging and Distribution Research Group, Victoria University

**Professor Stephen Bigger**

College of Engineering and Science, Victoria University

### **Committee Members**

**Dr Matthew Lamb**

Engineered Packaging and Distribution Research Group, Victoria University

**Dr Anthony Parker**

Engineered Packaging and Distribution Research Group, Victoria University

**Dr Marlene Cran**

Engineered Packaging and Distribution Research Group, Victoria University

**A/Professor Karli Verghese**

Program Director, Sustainable Products, RMIT University

**Gavin Williams**

CEO, Packaging Council of Australia

**Stan Moore**

CEO, Australian Packaging Covenant

**Adele Elice-Invaso**

Executive Director, Australasian Pulp and Paper Industry Technical Association (APPITA)

**Professor Gil Garnier**

Australian Paper and Pulp Institute, Monash University

### **Conference Secretariat**

**Luba Schnitzer**

Victoria University

**Sue Davies**

Victoria University

### **Conference Ambassador**

**Dr Mervyn Minett**

## IAPRI 2014 Scientific Committee

<b>Rafael Auras</b>	Michigan State University	USA
<b>Greg Batt</b>	Clemson University, NC	USA
<b>Carlos Bernad</b>	Instituto Tecnologico de Aragon	Spain
<b>Stephen Bigger</b>	Victoria University	Australia
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<b>Vanee Chonkenchob</b>	Kasetsart University	Thailand
<b>Marlene Cran</b>	Victoria University	Australia
<b>Damian Erre</b>	Reims University	France
<b>Mikael Gallstedt</b>	Innventia	Sweden
<b>Manuel Garcia-Romeu</b>	ITENE	Spain
<b>Rafael Gavara</b>	IATA-CSIC	Spain
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<b>Soren Ostergaard</b>	Danish Technological Institute (DTI)	Denmark
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<b>Panuwat Suppakul</b>	Kasetsart University	Thailand
<b>Michael Sek</b>	Victoria University (Chair)	Australia
<b>Jay Singh</b>	Cal Poly State University	USA
<b>Thomas Trost</b>	Innventia	Sweden
<b>Diane Twede</b>	Michigan State University	USA
<b>Mika Vaha-Nissi</b>	VTT, Technical Research Centre	Finland
<b>Karli Verghese</b>	RMIT University	Australia
<b>Jun Wang</b>	Jiangnan University	China
<b>Fredrik Wikstrom</b>	Karlstad University	Sweden
<b>Yves Wyser</b>	Nestle Research Centre	Switzerland
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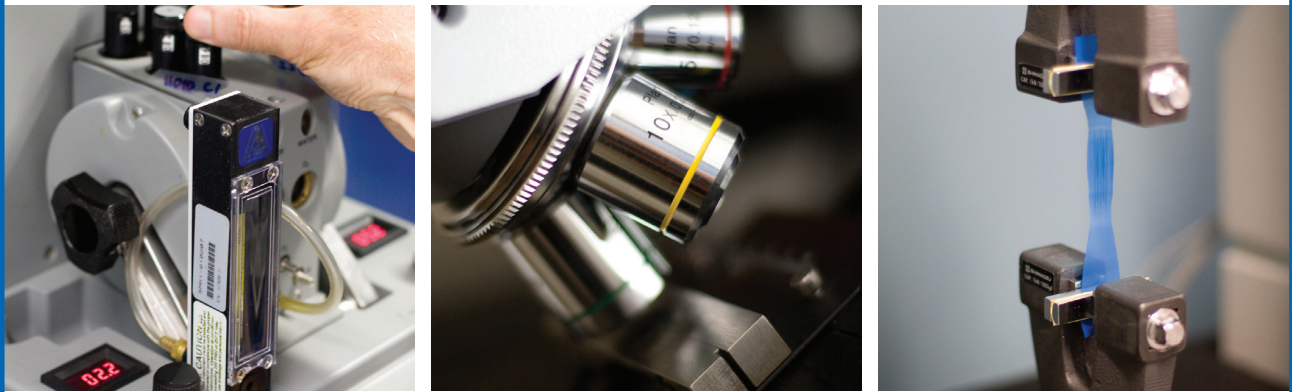
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## INDEPENDENT MEASUREMENT OF PACKAGING PERFORMANCE



- Permeability testing - oxygen transmission and water vapour transmission.
- Analysis to determine what types of plastic materials are present in a sample, including structures of multilayered packaging.
- Mechanical testing of plastic films – tensile strength and related properties, tear resistance, puncture resistance, dart impact resistance and others.
- Plus many other tests.



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### Research funding opportunities at Victoria University

**Victoria University offers funding for industry linked projects.**

**These include:**

- Scholarships for research students.
- Industry Postdoctoral Fellowships (4 year appointment).
- Collaborative Grants (grants up to \$20,000 for a 12 month research project).

**These opportunities are co-funded by the University and industry**



For more information contact Dr. Patrick-Jean Guay  
 Email: [research.COES@vu.edu.au](mailto:research.COES@vu.edu.au) Phone + 61 3 9919 2993

## Institutional Sponsors



## Conference programme at a glance

### Sunday 15 June 2014

**17:00** Registration. Level 12, VU Conference Centre, 300 Flinders St.

**18:00** Welcome function - Cocktail Event. Level 12, VU Conference Centre, 300 Flinders St.

### Monday 16 June 2014

**8:00** Registration. Foyer, Level 11, VU Conference Centre.

**9:00** Opening session. Room 1101

Parallel / keynote sessions

Break

Parallel / keynote sessions

Lunch Level 9, VU Conference Centre

Parallel / keynote sessions

Break

Parallel / keynote sessions

**18:30** Social Dinner Carlton BrewHouse. Busses leave VU Conference Centre (street level) at 6:30 pm

### Tuesday 17 June 2014

**9:00** Parallel / keynote sessions

Break

Parallel / keynote sessions

Lunch Level 9, VU Conference Centre, 300 Flinders St.

Parallel / keynote sessions

Break

Parallel / keynote sessions

**19:00** Conference dinner. Coral Atoll room, Melbourne Aquarium, Corner Flinders t. And King St.

### Wednesday 18 June 2014

**9:00** Parallel / keynote sessions

Break - Level 12, VU Conference Centre, 300 Flinders St.

Poster session. Level 12, VU Conference Centre, 300 Flinders St.

Lunch Level 12, VU Conference Centre, 300 Flinders St.

Conference closing session. Level 12, VU Conference Centre, 300 Flinders St.

IAPRI General meeting. Level 12, VU Conference Centre, 300 Flinders St.

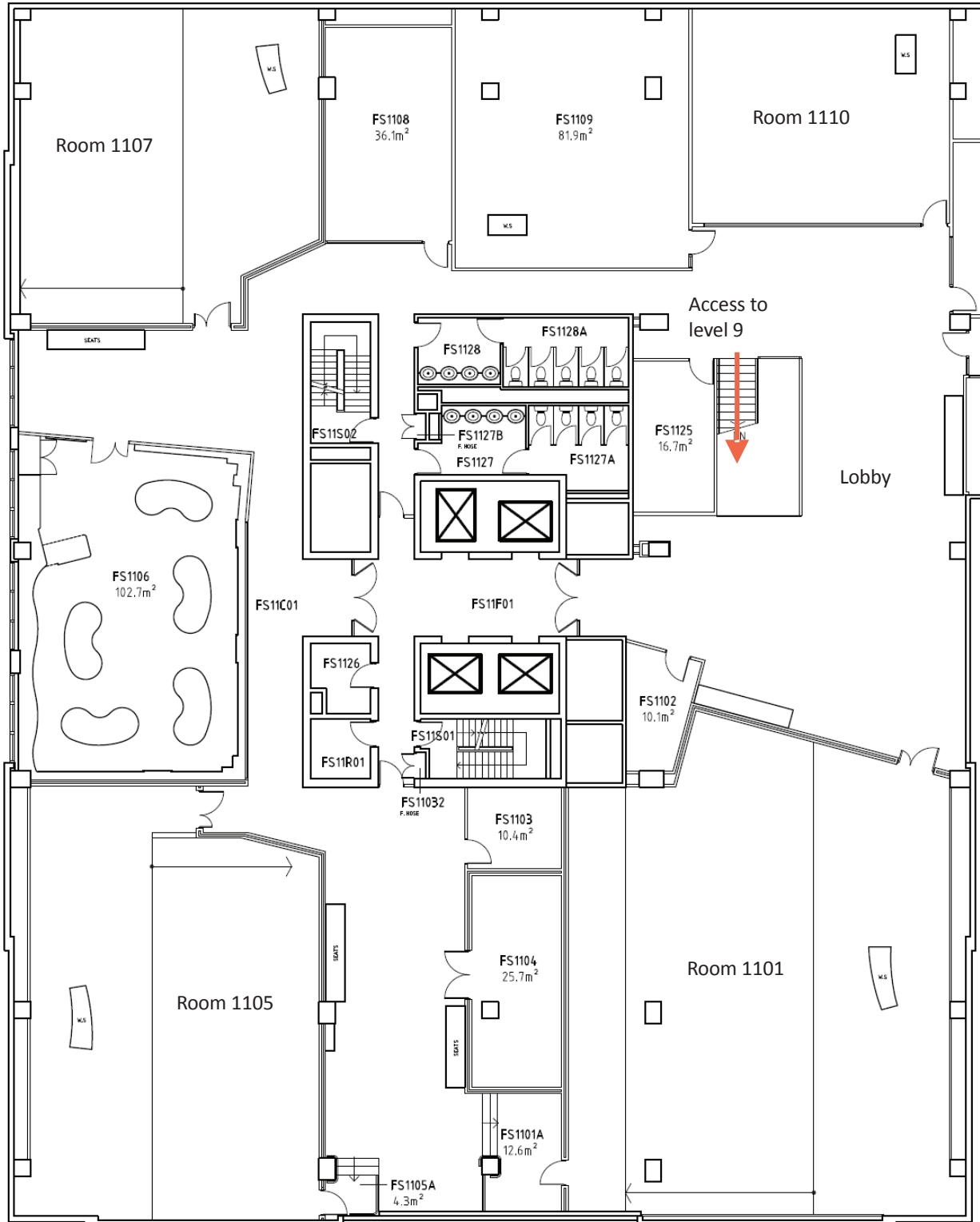
**14:00** IAPRI Working Groups meetings

### Thursday 19 June 2014

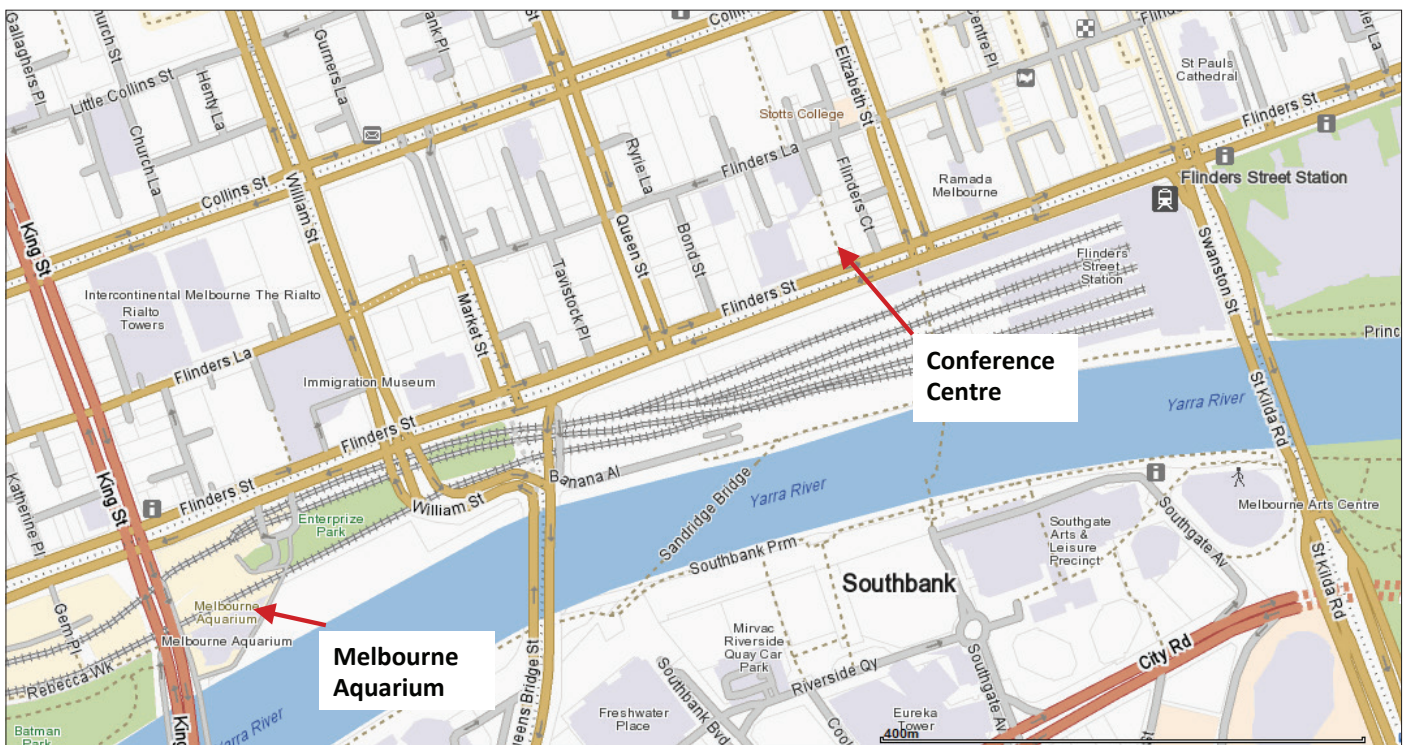
**9:00** Workshop: Measuring and simulating hazards in the distribution environment: From field data to packaging optimization

### Conference Venue Floor Plans

#### Level 11



### Conference Venue Precinct Plans



## Some helpful information

### Conference venue

The Conference will be held on Levels 9, 11 and 12, at the Victoria University City Convention Centre, 300 Flinders St, Melbourne. The Conference administration desk is located in Room 1110, Level 11.

### Catering

#### Lunch

All registrations include lunch as well as morning and afternoon teas. On Monday and Tuesday, lunches will be served on Level 9. This is accessible from Level 11 *via* the main staircase or *via* the lifts. On Wednesday, lunch will be served on Level 12. This is accessible from Level 11 *via* the lifts or stairwell.

#### Social dinner (Monday evening)

Location: Carlton BrewHouse.  
Corner of Thompson and Nelson Streets,  
Abbotsford, Victoria, 3067.  
Tel: +61 9420 6800  
Time: 19:00 – 22:00.  
Transport: Buses leave VU Conference centre (street level) at 6:30 pm.

#### Conference Dinner (Tuesday evening)

Location: Coral Room, Melbourne Aquarium,  
Flinders St, Melbourne.  
Time: 17:00 – 23:00  
Transport: Nil. Accessible by foot from the Conference venue (see Conference venue precinct plan).

**Partners' room** Delegates' partners can meet in Room 1110 on Level 11.

**Internet access** Wireless internet access is available throughout the conference centre.

ID: **Guest VU**

Password: **M0th3rsD@y**

### Discover Melbourne

We invite you to enjoy the conference while experiencing the unique and evolving city that is Melbourne - a city where modern architecture and design is juxtaposed with heritage buildings reflecting Australia's cultural history. The dynamic and spectacular new developments like Federation Square, Melbourne Docklands and Southbank will ensure your experience goes beyond the conference activities.

Melbourne is one of Australia's most popular destinations for business events - and is host to many international conferences, sporting events and art, music and comedy festivals. Melbourne is yours to discover with many of the city's top attractions within walking distance of the Convention Centre. From stylish fashion boutiques, laneway cafes and trendy bars, to botanic gardens, sports stadiums and elegant architecture, Melbourne has something for everyone. Discover what Melbourne has to offer by visiting: [www.visitmelbourne.com](http://www.visitmelbourne.com).

Assistance and advice is available the Melbourne Visitor Centre located at Federation Square (Corner Flinders and Swanston Streets).

# ENGINEERED PACKAGING AND DISTRIBUTION

## CAPABILITIES STATEMENT

The mission of the Engineered Packaging and Distribution Research Group (EP&DRG) at VU is to provide a local, national and international focus for high-quality applied scientific research aimed at developing environmentally sound and optimized solutions to support the distribution of products and produce.

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## Keynote speakers

### John Kettle

#### ***International Development Manager, Technical Research Centre of Finland (VTT)***

#### **Keynote address: The tyranny of distance and packaging's pervasive role in daily life**

Dr John Kettle has been working in the pulp and paper related industries since 1983. His career started in English China Clays (ECC) R&D labs and whilst at ECC he obtained a PhD (1996) from the University of Plymouth. The focus of the PhD work was on the "Pore-structure characterisation and simulation of paper coatings" under the supervision of Professor Peter Matthews and Professor Patrick Gane. In 1997 John moved to Sundsvall, Sweden to work for SCA Graphic Research. In 2006 he moved on to work for Oy Keskuslaboratorio - Centrallaboratorium Ab (KCL) in Espoo, Finland and in 2008 he became a Research Area Director of the area called 'Sustainable Production Technologies'. In 2009 KCL was merged into VTT and after this fusion he has had the role of an International Development Manager within VTT. His present focus is on the development of VTT's business internationally and with particular focus on Australia. John has been active in the TAPPI organization for many years and is a reviewer for a number of international journals and has published in the fields of porous materials, coating and printing technologies, and foresighting.

### Nina Cleeve-Edwards

#### ***Packaging Specialist, Nestlé Australia***

#### **Keynote address: Packaging paradoxes: laminating perception and reality**

Nina is responsible for the innovation, design, safety, compliance, and environmental performance of Nestlé Oceania's packaging. Nina commenced in the packaging field in 2006 and completed the Packaging Diploma course from the Institute of Packaging UK in 2008. She spent four years based in the Nestlé Research Centre in Lausanne, Switzerland, where she was an Ecodesign Specialist and rolled out a packaging ecodesign tool throughout the company and performed research on bioplastic applications for Nestlé packaging. She has a Bachelor of Science and a Master of Commerce from the University of New South Wales.

### Tim Woods

#### ***Managing Director, IndustryEdge***

#### **Keynote address: Fibre resources reaching peak recovery - the implications for packaging**

Tim Woods is Managing Director of IndustryEdge, Australia's leading trade data and market analysis and intelligence firm in the fibre resources, wood processing, pulp, paper and paper products sectors. Tim is publisher of the monthly subscription publication, *Pulp & Paper Edge* and the annual *Pulp & Paper Strategic Review*, as well as a range of multi-client sustainable procurement guides and forestry and wood products publications and data. He leads the firm's multi-client and client specific consulting services supplied to business, industry and government clients in Australia and across Asia. IndustryEdge plays a significant role in product stewardship, in particular in verifying the recovery, recycling and alternative use of fibre resources. Tim is a Trustee Director of Monash University's Australian Pulp & Paper Institute, an independent non-Executive Director of a financial services company, Chair of a not-for-profit employment and training service and Chair of the national Timber Communities Australia. Working with its parent company, Fitzpatrick Woods Consulting, of which Tim is Principal, IndustryEdge supports clients with integrated market intelligence and advisory services.

### Diana Twede

#### ***Professor, School of Packaging, Michigan State University***

#### **Keynote address: The Sacks of Rome**

Diana Twede is a Professor in The School of Packaging at Michigan State University, where she teaches courses in Packaging Development and Packaging Economics. She is the lead author for the textbook *Cartons, Crates and Corrugated Board*, and co-editor of the international journal *Packaging Technology and Science*. Her Ph.D. is in the field of Logistics Management. Her research interests are logistical packaging and the history of packaging, with a special emphasis on the history of shipping containers. In a search for "universal principles," she has published about the packaging technology, production organization and economics of ancient commercial amphorae, wooden barrels, tea chests and corrugated boxes. Dr. Twede will present an archaeological mystery: Were sacks used for the ancient grain supply chain from Egypt to Rome? Archaeologists have conflicting opinions, which lead to very different assumptions regarding the nature of the supply chain. This presentation investigates the question from a logistical packaging paradigm perspective. Combined with the known history of ancient grain trade and textile technology, this physical exploration of the supply chain suggests surprising new theories. This research sheds new light on the history of packaging technology and deepens our understanding of the relationship between packaging, economics and supply chain management.

## Sunday 15 June 2014

17:00 – 18:00 Registration. Level 12, VU Conference Centre, 300 Flinders St

18:00 – 20:00 Welcome function - Cocktail Event. Level 12, VU Conference Centre, 300 Flinders St

## Monday 16 June 2014

8:00 - 9:00 Conference registration. Foyer, Level 11, VU Conference Centre, 300 Flinders St

**OPENING SESSION (1101) Chair: Michael Sek**

9:00 - 9:30 Welcome remarks, IAPRI President. Formal opening, Brad Battin MLA, Parliamentary Secretary for the Environment

9:30 - 10:00 Keynote address: The tyranny of distance and packaging's pervasive role in daily life. John Kettle, VTT. Room 1101

10:00 - 10:30 Keynote address: Packaging paradoxes: laminating perception and reality. Nina Cleeve-Edwards, Nestle. Room 1101.

10:30 - 11:00 Break

	<b>Session MA1: ACTIVE &amp; INTELLIGENT PACKAGING (1101)</b>	<b>Session MA2: DISTRIBUTION PACKAGING (1105)</b>	<b>Session MA3: DESIGN, ERGONOMICS &amp; HUMAN FACTORS (1107)</b>
	<b>Chair: Stephen Bigger</b>	<b>Chair: Dan Goodwin</b>	<b>Chair: Soren Ostergaard</b>
11:00 - 11:20	Controlled Release of Mangiferin Using Ethylene Vinyl Acetate Matrix for Antioxidant Packaging - Vanee Chonhenchob (P2)	An Introduction to Next-Generation Loggers for Measuring Distribution Hazards on the Product and Package - Changfeng Ge (P27)	An Empirical Study for Exploring Reusable Packaging Attributes - Ahmed Babader (P53)
11:20 - 11:40	Reduced liquid loss and extended shelf life of chicken filets by the use of carbon dioxide emitters and modified atmosphere packaging - Marit Kvalvag Pettersen (P3)	Issues with Combining Road Elevation Spectral Models and Vehicle Vibration Response to Estimate Vehicle Dynamic Characteristics - Daniel Ainalis (P19)	Relationship Between Peel Angle and Peel Force in Peelable Semi-rigid Packaging Comprising Tyvek® and PETG - Javier de la Fuente (P54)
11:40 - 12:00	Nanoiron Based Composite Oxygen Scavengers - Zenon Foltynowicz (P7)	Measurement and Analysis of Vibration Levels in 2 and 3 wheel Delivery Vehicles in South East Asia - Paul Singh (P25)	An Eye-Tracking Methodology for Testing Consumer Preference of Display Trays in a Simulated Retail Environment - Andrew Hurley (P55)
12:00 - 12:20	Effect of Storage Conditions and Sulphur Compounds on the Activity of Palladium Based Oxygen Scavenging Films - Selcuk Yildirim (P8)	New Standardized Package System for Imported Fresh Mangos to the United States from Mexico and Guatemala - Koushik Saha (P26)	A review of thermoplastic composites vapour permeability models: Applicability for barrier dispersion coatings - Gonzalo Hermosilla (P56)
12:20 - 13:40	<b>Lunch Level 9, VU Conference Centre / PTS Editorial Board meeting (D. Shires Chair) Room 906 Level 9, VU Conference Centre</b>		
	<b>Session MB1: PACKAGING MATERIALS (1101)</b>	<b>Session MB2: PACKAGING FOR FOOD AND AGRICULTURE (1105)</b>	<b>Session MB3: DISTRIBUTION PACKAGING (1107)</b>
	<b>Chair: Diana Twede</b>	<b>Chair: Jay Singh</b>	<b>Chair: Greg Batt</b>
13:40 - 14:00	Outdoor weathering of HDPE containers filled with Nitric acid - Anja Geburtig (P87)	Packaging for Controlling Texture of Frozen Microwaveable Sandwiches - Alexander Bardenshtein (P75)	Indirect Inverse Sub-structuring Theory for Coupling Dynamic Stiffness Identification of Complex Interface between Packaged Product and Vehicle Transport System - Jun Wang (P28)
14:00 - 14:20	Preparation and Characterization of Low Methoxyl ectin/Carboxymethyl Cellulose-based MMT Composite Films - Zhi-Wei Wang (P91)	Development of a freshness indicator for monitoring chicken meat freshness - Teresa Calvo (P79)	Damage to carton board packages subjected to concentrated loads - Daniel Eriksson (P31)
14:20 - 14:40	New bio-based plastics, from a non-edible plant oil side-stream, for film extrusion - Mikael Gällstedt (P92)	If at first you don't succeed: Older consumers & hospital food & beverage packaging – a matter of try, try and try again! - Alastar Yoxall (P80)	Comparison of two vibration recording methods depending on the data-recorder position - Victor Huart (P35)
14:40 - 15:00	Characteristics of Poly(lactic acid) Composites Reinforced with Natural Fibres - Intan S. M. A. Tawakkal (P94)	Development of Time-Temperature Indicator Based on Polydiacetylene/Silica Nanocomposite for Monitoring Fresh Skinless Chicken Breast Quality - Atchareeya Nopwinyuwong (P82)	Influence of corrugated cardboard corners in shock damping: Case of a 100% cardboard packaging. - Philippe Delloque (P39)
15:00 - 15:30	Break		
	<b>Session MC1: ACTIVE &amp; INTELLIGENT PACKAGING (1101)</b>	<b>Session MC2: PACKAGING MATERIALS (1105)</b>	<b>Session MC3: SUSTAINABILITY / PRINTING &amp; GRAPHICS (1107)</b>
	<b>Chair: Vanee Chonkenchob</b>	<b>Chair: Damien Erre</b>	<b>Chair: Karli Verghese</b>
15:30 - 15:50	Development of an intelligent packaging device for the monitoring of ready-to-eat salad spoilage - Anne Maltais (P5)	Evaluation of Static and Dynamic Cushioning Properties of Polyethylene Foam for Determining its Cushion Curves - Michael Sek (P86)	Plasma enhanced surfaces for sustainable fiber based packaging - S. Vikram Singh (P112)
15:50 - 16:10	Methodology to evaluate the performance of active ingredients as oxygen scavengers - Angela Garcia Mora (P13)	The effect of heating speed on the expression of heat seal strength in plastics packaging materials. - Kazuo Hishinuma (P89)	Film performance of Poly(lactic acid) blends for packaging applications - Carlos Diaz (P114)
16:10 - 16:30	Developments in Antimicrobial Food Packaging Research - Stephen Bigger (P14)	Development of biodegradable Starch-Based Cushions with high shock absorption - Georges Abinader (P98)	The Study on Symbol Contrast of Inks and Paper Liners for Barcode Printing on Corrugated Box - Pakapol Kittipinyovath (P107)
16:30 - 16:50	Effect of Nano-Semiconductors and Sacrificial Electron Donors on Color Transition of a Novel UV-Activated Oxygen Bio-Indicator - Surachai Khankaew (P16)	Evaluating the Dynamic Characteristics of Starch Based Loose-Fill - Vincent Rouillard (P99)	Trends and drivers influencing papermaking and its products towards the future - Marco Lucisano (P115)
18:30 - 22:00	<b>Social Dinner Carlton BrewHouse. Busses leave VU Conference Centre (street Level) at 6:30 pm</b>		

## Tuesday 17 June 2014

Session TA1: DESIGN, ERGONOMICS & HUMAN FACTORS (1101)		Session TA2: DISTRIBUTION PACKAGING (1105)		Session TA3: PACKAGING FOR FOOD & AGRICULTURE (1107)	
Chair: David Shires		Chair: Katsuhito Saito		Chair: Zhi-Wei Wang	
9:00 - 9:20	The Functional Analysis Methodology for Environmentally Conscious Packaging Design - Jeeranuch Buddeejeen (P57)	Reduced-Order Modeling of the Linear Vibration Response of Expanded Polymer Cushion Material - Gregory Batt (P20)	Migration of plasticizers from paper and board into food simulant Tenax and olive oil during microwave cooking - Yumei Wu (P67)	9:20 - 9:40	Easy Opening or a lost 16 per cent sale - Soren R Ostergaard (P58)
9:40 - 10:00	Packaging for Personalized Food for Nutrition of Elderly Consumers Made Using Rapid Manufacturing - Alexander Bardenshtein (P59)	Vibration Transmissibility of Packaging in Three-Substructures Coupled Product Transport System - Yuan-Biao Zhang (P24)	Estimation of the dynamic properties of nonlinear packaging materials using an optimised reverse multiple input/single output based approach - Matthew Lamb (P21)	10:00 - 10:20	Attention Grabbing Power of Branded vs. Unbranded Packaging - Patricia Huddleston (P61)
10:20 - 10:50	<b>Break</b>		How to choose the resistance to vertical crushing of stacked cardboard box suitable for your trip. - Jean-Baptiste Nolot (P38)	10:20 - 10:50	Glucosylase Time-Temperature Indicators Based on Fat Oxidation of Chilled Pork - Jing Qian (P72)
<b>Session TB1: PACKAGING SUSTAINABILITY (1101)</b>		<b>Session TB2: DISTRIBUTION PACKAGING (1105)</b>		An innovative corrugated shipper to improve palletized load airflow for fresh produce - Ray Kisch (P78)	
Chair: Javier Zabaleta		Chair: Jun Wang			
10:50 - 11:10	Qualitative Analysis of Coverage Value Transfer in Modern Packaging Printing Workflow - Diana Milčić (P104)	Future Demands In Distribution Dynamics Research - Ed Church (P22)	11:10 - 11:30	Implementing Packaging Sustainability Metrics in a Developing Economy - Siddhant Dwivedee (P109)	The Application of Computational Methods to the Analysis of Unitized Load Performance - Dale Knochenmuss (P23)
11:30 - 11:50	Green Fibre Bottles - Soren R Ostergaard (P111)	Carton Clamp Test Methodologies and the Effects on Load Containment and Retention - Jay Singh Koushik Saha (P29)	11:50 - 12:10	The greenhouse gas profile of a "Hungry Planet"; quantifying the impacts of the weekly food purchases including associated packaging and food waste of three families - Karli Verghese (P113)	Transport simulation testing for stretch wrap film optimisation and palletised load safety (DUOPLAST Business Case) - Manolo Garcia-Romeu (P36)
12:10 - 13:30 <b>Lunch Level 9, VU Conference Centre</b>					
<b>PLENARY SESSION (1101) Chair: Thomas Goedecke</b>					
13:30 - 14:00 Keynote address: Fibre Resources Reaching Peak Recovery - The Implications for Packaging. Tim Woods					
14:00 - 14:30 Keynote address: The Sacks of Rome. Diana Twede					
14:30 - 15:00 IAPRI travel scholarships presentation					
15:00 - 15:30 <b>Break</b>					
<b>Session TC1: PACKAGING FOR FOOD &amp; AGRICULTURE (1101)</b>		<b>Session TC2: DESIGN, ERGONOMICS &amp; HUMAN FACTORS (1105)</b>			
Chair: Yves Wyser		Chair: Manuel Garcia-Romeu			
15:30 - 15:50	Determination of Ti in Nano/submicro-TiO <sub>2</sub> -plastic Composite Food Packaging by Microwave Digestion and Inductively Coupled Plasma Atomic Emission Spectrometry or Inductively Coupled Plasma Mass Spectrometry - Qin-Bao Lin (P69)	The study of uncertainty elements related to heat seal strength by comparison of standard testing methods - Chana Yiangkamolsing (P52)			
15:50 - 16:10	Effect of propolis extract on physical and antioxidant properties of chitosan film - Ubonrat Siripatrawan (P76)	Is Your Package Pro-LOHAS? – Findings of the Finnish LOHASPAC Study 2011-2014 - Virpi Korhonen (P63)			
16:10 - 16:30	Effects of in-package atmosphere on temporal changes in the fractionation of oxygen isotopes during respiration in tomatoes - Yoshio Makino (P77)	Material Identity in a Packaging Context - Mikael Gällstedt (P64)			
16:30 - 16:50	Equilibrium Modified Atmosphere Packaging for Preserving Quality and Extending Shelf-life of Longan - Chaos Sripethdee (P81)	Crumpling of paper sheet and packaging - Jean-Baptiste Nolot (P65)			
19:00 – 23:00 <b>Conference dinner. Coral Atoll room, Melbourne Aquarium Cnr. Flinders St. and King St.</b>					

## Wednesday 18 June 2014

Session WA1: PACKAGING FOR FOOD AND AGRICULTURE (1101) Chair: Marit Petersen	Session WA2: PACKAGING MATERIALS (1105) Chair: Thomas Goedecke	Session WA3: DISTRIBUTION / LOGISTICS (1107) Chair: Edward Church
9:00 - 9:20 Modelling of migration from printing inks on paper packaging and its verification - Zhi-Wei Wang (P71)	The Effect of A Vibration Force Field on The Crystallization and Barrier Properties of Polymer Nanocomposites - Yuejun Liu (P88)	RFID tag characterization by studying their backscattering response - S. Vikram Singh (P43)
9:20 - 9:40 The flexible packaging line – PickNPack - Soren R Ostergaard (P73)	Maximum Gauge Pressure in Dangerous Goods Packagings Under Normal Conditions of Carriage - Comparison of Direct Measurement and Calculations - Eva Schlick-Hasper (P90)	A method review and a case study of packaging design difference of automobile KD parts and after-sale parts with an application on transport - Binglin Lu (P45)
9:40 - 10:00 Response Modelling of Time-Temperature Indicator Based on Polydiacetylene/Silica Nanocomposite - Atchareeya Nopwinyuwong (P83)	Designing polypropylene lidding film with combined peelable and antifogging properties for food packaging - Charinee Winotapun (P100)	Shock Analysis during Fruits Export from Japan to Neighbouring Regions - Hiroaki Kitazawa (P34)
10:00 - 10:20	Microperforation of three common plastic films by laser and their enhanced oxygen transmission for fresh produce packaging - Wannee Chinsirikul (P101)	The Status of Wood Pallet Repair Operations in the United States: A Survey Study - Laszlo Horvath (P46)
10:20 - 10:50 Break - Level 12, VU Conference Centre, 300 Flinders St.		
10:50 - 12:15 Poster session. Level 12, VU Conference Centre, 300 Flinders St.		
12:15 - 13:30 Lunch Level 12, VU Conference Centre, 300 Flinders St. - Includes Conference closing session		
13:30 - 14:00 IAPRI General meeting. Level 12, VU Conference Centre, 300 Flinders St.		
IAPRI WORKING GROUPS. LEVEL 12, VU CONFERENCE CENTRE, 300 FLINDERS ST.		
14:00 - 15:00 Distribution Packaging, Room 3 / Sustainability Packaging, Room 4.		
15:00 - 16:00 Dangerous Goods Packaging, Room 3 / Consumer and Packaging, Room 4.		
16:00 - 17:00 Research Networking, Room 3 / Flexible Packaging, Room 4.		

## Thursday 19 June 2014

WorkSHOP: MEASURING AND SIMULATING HAZARDS IN THE DISTRIBUTION ENVIRONMENT: FROM FIELD DATA TO PACKAGING OPTIMIZATION
8:30 - 9:00 Bus from VU Conference Centre (street level) to Werribee Campus
9:00 - 10:30 Fundamentals of protective packaging and distribution hazards
10:30 - 11:00 Break
11:00 - 12:30 Collecting and analysing field data using Lansmont's Savers
12:30 - 13:30 Lunch
13:30 - 15:00 Review of shock and vibration testing standards and protocols
15:00 - 15:30 Break
15:15 - 17:00 Analysis and laboratory simulation of realistic distribution shock and vibrations
17:00 - 17:30 Transport back to Melbourne City (IAPRI 2014 Conference venue)

## Posters (Wednesday 18 June 2014 10:50 - 12:15)

- Microwaveable packaging for heating and crisping a food product - Eric Martine (P4)
- Determination of Four Types of Hazardous Chemicals in Food Contact Materials by UHPLC-MS/MS - Qin-Bao Lin (P70)
- ULab© Cloud Testing System for Flexible Plastic Packages - Yuan Su (P110)
- Degradation of Steel Packages in Tropical Environments – Results After 10 Years of Discarding - Sylvia Dantas (P93)
- Development and Properties of High Density Polyethylene (HDPE) and Ethylene-vinyl Acetate Copolymer (EVA) Blend Antioxidant Active Packaging Films Containing Quercetin - Tiantian Han ? Lixin Lu (P6)
- Sulfide black in canned meat - Sylvia Dantas (P74)
- Elastic Modulus of Corrugating Medium under Different Temperature and Relative Humidity - Hongge Guo (P44)
- Microbiological stability of shampoo stored in polymeric packaging modified with nanosilver - Zenon Foltynowicz (P48)
- Combination Cushioning Pad Design and Drop Simulation - To be confirmed and paid in Melbourne (P30)
- Evaluation Method of Abrasion Damage on Corrugated Board - Meishu Piao (P32)
- Time-domain Inverse Sub-structuring Method for Product-transport-system - Jun Wang (P33)
- Opening status comparison with model PTPs between ordinary people and patients with Rheumatoid Arthritis - Kiyomi Sadamoto (P60)
- Objective evidence of opening status contribute development of up grading PTP - Mikio Murata (P49)
- Possibility of electric devices and devices with drug packaging in medical and health care - Kiyomi Sadamoto (P9)
- A Method for General Printing Anti-counterfeiting by Moiré Patterns - To be confirmed and paid in Melbourne (P105)
- Properties of Corrugated Liner Made from Musa sapientum Linn Banana Pulp and Recycled kraft Pulp - Nucharin Luangsa-Ard (P95)
- The extent of rice straw mushroom's shelf life by using paper made from petiole of Nipa palm mixed with ash from power plant - Nucharin Luangsa-Ard (P10)
- Evaluation of opening status of PTPs with three element from push to go out from package - Kiyoshi Kubota (P50)
- Effects of active packaging on the physico-chemical properties of fresh-cut cantaloupe (cucumis melo l. var. glamour) - Zuhair M Nor (P11)
- Release of Oregano Essential Oil and Green Tea Extract from Ethylene Vinyl Alcohol Copolymer Films - Marlene Cran (P12)
- Effect of Compatibilizer on Physical and Rheological Properties of PLLA/PPC Binary Blends - Jin Kie Shim (P96)
- Influence of reprocessing on mechanical properties of SAN copolymers in injection molding - Damien Erre (P97)
- Biodegradable cross-linked gliadin films with antifungal activity for active packaging of bread - Javier Zabaleta (P15)
- Thermoforming in-mould labelling - Outi Kaikkonen (P106)
- The Design Development of Perforation Rule for Retail Ready Packaging - Pakapol Kittipinyovath (P62)
- Development of a biodegradable coating based on seaweed extracts and starch for food packaging applications. - Teresa Calvo (P84)
- Vibration Performance for Biocushion Materials - Daniel Goodwin (P37)
- The Study on Packaging Cushioning Performance and Physical property of Poly (vinyl alcohol) Sponge - Guo Hongge (P102)
- Impact of Liquid Nitrogen Dosing on Application and Removal Torque of Wine Bottle - Koushik Saha (P40)
- Effect of Photoinitiator and Binder Concentration on Color of Methylene Blue-based Oxygen Indicator  
Effect of photoinitiator and binder concentration on irradiation time and properties of methylene blue-based oxygen indicator - Chana Yiangkamolsing (P17)

## **ACTIVE & INTELLIGENT PACKAGING**

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## CONTROLLED RELEASE OF MANGIFERIN USING ETHYLENE VINYL ACETATE MATRIX FOR ANTIOXIDANT PACKAGING

Vanee Chonhenchob - Kasetsart University, Thailand  
Rungkan Boonnattakorn - Kasetsart University, Thailand  
Muhammad Siddiq - Michigan State University, United States  
Sher Paul Singh - Packaging Forensic Associates Inc, United States

This study investigated the use of ethylene vinyl acetate (EVA) matrix in controlled release packaging. Mangiferin, a rich source of antioxidant activity, was incorporated into the EVA matrix with different vinyl acetate (VA) contents. Mangiferin release rate increased with increasing VA content (decreasing crystallinity). Linear relationship between mangiferin release rate and VA content was observed in the range of 18% to 40% VA. The diffusion coefficients of mangiferin released from the EVA matrices containing 12, 18, 25 and 40% VA were 0.005, 0.079, 0.281 and 5.87 ( $\times 10^{14} \text{ m}^2 \cdot \text{s}^{-1}$ ), respectively. Partition coefficients decreased with increasing VA content. The enhancement factors of 22.32-fold and 7.22-fold were observed in the 12 and 18% VA matrices, respectively when using triethyl citrate as a plasticizer. EVA film containing 40% VA had the highest antioxidant activity (81.90 % RSC) since the highest amount of mangiferin was released in the food simulant (84.66 g.mL<sup>-1</sup>). Plasticizer and mangiferin had no significant effect ( $p > 0.05$ ) on mechanical and barrier properties of the films. The results of this study demonstrated that EVA matrices with different degree of crystallinity, could potentially be used to control mangiferin release rate for antioxidant packaging.

**Keywords:** Active packaging; Mangiferin; Antioxidant; Controlled release; EVA matrix; Release kinetic

Paper ID = 21, Session MA1, Room 1101

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## REDUCED LIQUID LOSS AND EXTENDED SHELF LIFE OF CHICKEN FILETS BY THE USE OF CARBON DIOXIDE EMITTERS AND MODIFIED ATMOSPHERE PACKAGING

Marit Kvalvag Pettersen - NOFIMA, Norway

Oddvin Sorheim - NOFIMA, Norway

Marie H. Moen - Nortura SA, Norway

Askild L Holck - NOFIMA, Norway

The consumption of poultry meat has increased over the last decades in many countries, and is nowadays a very popular food commodity around the world. Fresh chicken meat is a highly perishable product due to its high content of nutrients and water. Modified atmosphere packaging (MAP) is widely used for extending shelf life of fresh meat. High concentrations of CO<sub>2</sub> in the headspace of meat packages inhibit or reduce microbial growth. Active packaging by adding CO<sub>2</sub> emitter sachets to packages of meat is an alternative to traditional MAP. The purpose of the study was to investigate the effect of different CO<sub>2</sub> concentrations on the shelf-life of chicken filets, at 4 °C storage. The inhibition of microbial growth was proportional the CO<sub>2</sub> concentration. Storage in 100 % CO<sub>2</sub> resulted in a microbial shelf life of approximately 25 days, that is a 6-7 days extension compared to 60 % CO<sub>2</sub>. The dominating species were *Carnobacterium divergens*, *Carnobacterium* sp. and *Lactococcus* sp. Drip loss was highly affected by the gas atmosphere within the packages. CO<sub>2</sub> dissolved in the meat during storage, and storage in pure CO<sub>2</sub> caused collapse of the packages. The resulting so called vacuum –effect or squeeze of the packages lead to a severe increase in liquid loss. The liquid loss was reduced profoundly by using a CO<sub>2</sub> emitting sachet in the packages. Addition of CO<sub>2</sub> emitters can easily be implemented at industrial packaging lines without reductions in production efficiency.

**Keywords:** Active packaging; CO<sub>2</sub>-emitter; Chicken breast; Drip loss; Extended shelf-life; Modified atmosphere packaging.

Paper ID = 22, Session MA1, Room 1101

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## MICROWAVEABLE PACKAGING FOR HEATING AND CRISPING A FOOD PRODUCT

Eric Martine - HEIG-VD, Switzerland

Didier Louvier - HEIG-VD, Switzerland

The susceptor is a technology widely used since about 15 years ago. A wide range of products is today packaged worldwide with susceptor: French fries, pop-corn, sandwiches, pizzas, etc. A susceptor is an artificial film slightly vacuum-metallized (the thickness of the metal layer is in the order of the nanometer). The susceptor, placed around the food, concentrates the microwave energy onto the product surface, crisping it. Its main role is to transform the microwaves into infrared waves, able to crisp or even brown-crisp the food. The maximal temperature allowed by a susceptor must be reached as quickly as possible and avoiding a thermal boom; then the food surface will be crispy and the food won't overcook. One of the most appreciated Swiss foods is the "raclette" a special cheese. Usually, this cheese is heated inside a special oven by an electrical resistance, whose heat first melts the cheese and then crisps the surface of the melted cheese. The aim of this project is to package a raclette-cheese portion with a specially designed packaging, able to melt and crisp the cheese in a common microwave oven. To realize this, one primary packaging and a secondary packaging have been developed. Concerning the primary packaging is involved the use of two technologies: susceptor and micro-rite. The optimal packaging was found testing 16 different types of raclette cheeses and several different packaging designs. About the secondary packaging, the main role is to avoid the occurrence of a hot spot during the cooking of the cheese in the microwave oven. To judge the potential success of this packaging, the degree of satisfaction of potential clients is assessed by organizing two separate public organoleptic tastings in Swiss supermarkets. Different criteria of satisfaction, such as fat separation, creaminess, unctuousness, consistency "gummy", crispness... were considered. Both tasting gave satisfactory results on all organoleptic criteria.

**Keywords:** susceptor; aluminized container; active packaging; raclette cheese; microwaveable food; convenience food; sensory analysis.

Paper ID = 23, Poster session

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## DEVELOPMENT OF AN INTELLIGENT PACKAGING DEVICE FOR THE MONITORING OF READY-TO-EAT SALAD SPOILAGE

Anne Maltais - ITEGA, Canada

Mina Zitouni - Université de Sherbrooke, Canada

An intelligent packaging prototype to detect freshness level of ready-to-eat lettuce was developed in this study. In order to develop such a system, the first step was to investigate quality index markers in lettuce. Ethanol and total volatile basic amine (TVBN) were found to slightly increase in ready-to-eat romaine lettuce as a function of time when packed in polyethylene (PE) bags conditioned with 100% nitrogen. In ventilated PET boxes with atmospheric oxygen conditions, no ethanol accumulation was detected in salad mix containing baby lettuce leaves (arugula, spinach and chicory). However, in the same packaging conditions, TVBN reached 35 mg nitrogen equivalents (N) per 100 g of salad mix after 11 days at 5°C in response to aerobic spoilage flora. These findings were used to develop colorimetric devices responsive to the accumulation of such metabolites. The device developed was based on color change as a response to accumulation of basic pH molecules (TVBN) in package headspace. Bromocresol purple (BCP) was chosen as the active molecule for the freshness detection in the prototype developed. In presence of TVBN vapors corresponding to concentrations found in salad mix after days of storage, BCP color changed from yellow to purple. Different strategies were tested to increase sensitivity to TVBN of the intelligent device and to limit leaching of the active molecules. The final prototype developed showed the ability to successfully detect TVBN levels as low as 5 mg N/100 g of salad, which corresponds to mid-shelf life of this specific produce. Smart packaging device developed in this study represents a great alternative to 'best before' labels which cannot precisely inform the consumer as to freshness level of ready-to-eat vegetables.

**Keywords:** Intelligent packaging; Freshness indicator; Color indicator; Food spoilage; Ready-to-eat salad; Volatile amines.

Paper ID = 51, Session MC1, Room 1101

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## DEVELOPMENT AND PROPERTIES OF HIGH DENSITY POLYETHYLENE (HDPE) AND ETHYLENE-VINYL ACETATE COPOLYMER (EVA) BLEND ANTIOXIDANT ACTIVE PACKAGING FILMS CONTAINING QUERCETIN

Tiantian Han - Jiangnan University, China

Li-Xin Lu - Jiangnan University, China

Changfeng Ge - Rochester Institute of Technology, United States

Yali Tang - Jiangnan University, China

Antioxidant active packaging is a promising technology for extending shelf life of lipid-rich food products. In order to secure the safety of the active package, the using of natural antioxidants is the trend. In this study, high Density Polyethylene (HDPE) and ethylene-vinyl Acetate Copolymer (EVA) blend films incorporated with quercetin as the bioactive antioxidant were successfully developed by the method of flat compression. The mass ratio of HDPE/EVA was 65:35. The addition percentages of quercetin were 0.74% and 1.23%, respectively. This film making method could keep the quercetin retention percentage in a higher level which was 96.75% in this study. The addition of quercetin did not modify greatly the film's thermal stability. In addition, the barrier performance for water vapor and oxygen of the active films were kept well with the presence of quercetin. Release quantity of quercetin from the active antioxidant films into 50% (simulant for high alcohol containing products and milk and some dairy products) and 95% ethanol (simulant for fatty food products) at 37 was periodically measured by HPLC system for 45 days. In 50% ethanol and 95% ethanol, the release extent and kinetics of quercetin differed largely. The ultimate release content of quercetin in 50% ethanol and 95% ethanol were 70% and 10%, respectively. The diffusion of antioxidant showed a Fick's behavior with its diffusion coefficient (D) falling in 10-13 and 10-15 m<sup>2</sup>/s and partition coefficient in 44 and 5863. The obtained films showed good release profiles. Packaging applications of these films can improve food stability and provide another method for adding bioactive compounds and making films.

**Keywords:** HDPE; EVA; quercetin; antioxidant; food packaging; simulant.

Paper ID = 55, Poster session

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## NANOIRON BASED COMPOSITE OXYGEN SCAVENGERS

Zenon Foltynowicz - Poznan University of Economics, Poland

Wojciech Kozak - Poznan University of Economics, Poland

Man has grappled with the problem of food spoilage since the beginning of time. Thanks to serendipitous observations and methodical research, we have known for more than a century that the presence of oxygen is one of the key factors affecting food quality. The amount of oxygen in the packaging can be reduced by increasing the concentration of carbon dioxide and/or another gas (e.g. nitrogen), using modified atmosphere packaging, vacuum packaging or active packaging with oxygen scavengers. Traditional commercial oxygen scavengers are based mainly on iron or its compounds. So far, known oxygen absorbents based on iron and its compounds may be used only when at least small amounts of water are present in the packaging, which is a factor limiting their application.

In this study new type of oxygen scavengers based on nanoiron will be presented. Why nanoiron? Nanoscale particles have a much larger surface area available for interaction with reagents than bulky particles leading to higher surface reactivity. The iron nanoparticles were synthesized by reducing the iron salts with the reducing agent, e.g. sodium tetraborohydride. As results of investigation shows water or humidity as well as activators are not necessary for oxygen fixation by nanoiron. The simultaneous presence of CO<sub>2</sub> and moisture has no negative influence of the oxygen absorption process. The study also shows that nanoiron can be an active component of oxygen scavenging composites based on polymers commonly applied in packaging industry.

**Keywords:** oxygen scavenger; nanoiron based oxygen scavenger; nanoiron composites oxygen scavenger.

Paper ID = 58, Session MA1, Room 1101

## EFFECT OF STORAGE CONDITIONS AND SULPHUR COMPOUNDS ON THE ACTIVITY OF PALLADIUM BASED OXYGEN SCAVENGING FILMS

Selcuk Yildirim - Zurich University of Applied Sciences, Switzerland

Nadine Renke - Zurich University of Applied Sciences, Switzerland

Palladium catalysis the oxidation of hydrogen in the presence of oxygen. In a previous work, palladium was coated on a film using magnetron sputtering technology and the oxygen scavenging activities were tested. In this study the influence of temperature and relative humidity on the scavenging activity of palladium coated films has been evaluated. Oxygen scavenging rates increased from  $145 \pm 20$  to  $2653 \pm 172$  ml/(m<sup>2</sup>\*h) as the temperature increased from -10°C to 60°C. On the other hand increase in relative humidity from 15% to 90% did not have a significant influence on the oxygen scavenging rates of the films. A very significant reduction in the oxygen scavenging activities has been observed when the active films were introduced into the packaging of different food systems. Storage of oxygen scavenging films in the presence of wine, coffee beans, grains of corn, sauerkraut and onion resulted in deactivation of the oxygen scavenging films within 5 to 10 minutes. It has been shown that sulphur compounds may lead a significant degradation of performance of palladium based catalysts [2,3]. Therefore, the influence of different thiols, dimethyl sulfide (DMS) and sulphur dioxide (SO<sub>2</sub>) naturally found in tested foods were evaluated. Ethanethiol, and furfrylthiol resulted in a very fast deactivation of the catalyst at concentrations above 0.1 mmol/L. Propanthiol and DMS had a similar effect at concentration above 0.01 mmol/L. Concentrations of 1 µmol/L of thiols and DMS did not have a significant effect on the oxygen scavenging activity of the films. Wine containing 30 mg free SO<sub>2</sub> also deactivated the catalyst whereas SO<sub>2</sub> free wine did not show any significant influence on the activity.

### References:

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- [2] Graviil P.A., Toulhoat H. "Hydrogen, sulphur and chlorine coadsorption on Pd(111): a theoretical study of poisoning and promotion" Surface Science 430, 176–191,1999
- [3] Bartholomew, C. H., Agrawal, P.K., Katzer, J.R., "Sulphur Poisoning of Metals", Advances in Catalysis, Volume 31, 135-242, 1982

**Keywords:** Oxygen scavenger; Active packaging; Sulphur compounds.

Paper ID = 65, Session MA1, Room 1101

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## POSSIBILITY OF ELECTRIC DEVICES AND DEVICES WITH DRUG PACKAGING IN MEDICAL AND HEALTH CARE

Kiyomi Sadamoto - Yokohama College of Pharmacy, Japan

Mikio Murata - Yokohama College of Pharmacy, Japan

Hiroko Takamori - Dainippon Printing Co. Ltd, Japan

We have developed electric devices which are used for supporting drug taking and monitoring disease symptom. It is innovative that the card also play a role of drug packaging. Since the electric card is flexible in arrangement of button and item design, there is a lot of possibility of usage in medical care including drug taking, symptom change, appearing side effects. In addition, it can be used not only disease therapy but also preventive medicine such as health check for elderly, check of food taking, situation of evacuation and some body conditions. So we considered several sample design which has different usage in medical and health care. First one is the card for monitoring mental status for patients with depression, second one is monitoring condition of body for elderly people in the community, and third one is monitoring drug taking with card with packaging type (drug in). To see the potential in using devices, we also tried questionnaire which include usability study of electric devices and their hope to use packaging for patients and pharmacists. Patients are able to understand how to use the card devices in every generation, and as far as users including patients and pharmacists, simply push button and monitoring drug taking just open the package is highly evaluated. Both patients and pharmacists understand simplicity of usage and usability of electric cards for evidence-based drug therapy. We confirm the possibility of usage in several ways, so that it is necessary to consider the reasonable design and easily open packaging in practical use.

**Keywords:** electric devices; health check; preventive medicine; monitoring.

Paper ID = 78, Poster session

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## THE EXTENT OF RICE STRAW MUSHROOM'S SHELF LIFE BY USING PAPER MADE FROM PETIOLE OF NIPA PALM MIXED WITH ASH FROM POWER PLANT

Nucharin Luangsa-Ard - King Mongkut's University of Technology Thonburi, Thailand

Ratsamee Narktubtim - King Mongkut's University of Technology Thonburi, Thailand

This research was aimed to produce paper from petiole of Nipa palm mixed with ash from power plant and use it to absorb the moisture of rice straw mushroom, to compare the moisture absorption ability between the paper mixed with ash that was sprayed with modified tapioca starch after sheet forming and the paper mixed with ash that was added modified tapioca starch before sheet forming as well as to compare moisture absorption ability of petiole of Nipa palm paper that was mixed with different percentage of ash at 0, 50, 100, and 150 % on oven dried weight. The results showed that the paper which was sprayed with modified tapioca starch after sheet forming had higher moisture absorption ability than the paper which was added modified tapioca starch before sheet forming. In addition, the paper which was sprayed with modified tapioca starch at 10% had the best moisture absorption ability. When the rice straw mushroom was kept in the package with the paper that was mixed 50% of ash and sprayed with 10% of modified tapioca starch in three different temperatures, it showed that the packages kept at the temperature of 12 °C could absorb the highest amount of moisture from rice straw mushrooms. Furthermore, the rice straw mushrooms were still in good condition and the paper was also in proper condition for further use.

**Keywords:** Petiole of Nipa Palm paper; Rice Straw Mushroom; Ash from Power Plant; Moisture absorption ability.

Paper ID = 82, Poster session

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## EFFECTS OF ACTIVE PACKAGING ON THE PHYSICO-CHEMICAL PROPERTIES OF FRESH-CUT CANTALOUPE (CUCUMIS MELO L. VAR. GLAMOUR)

Syahidah Kamaruddin - Faculty of Engineering, Universiti Putra Malaysia, Malaysia

Rosnah Shamsudin - Faculty of Engineering, Universiti Putra Malaysia, Malaysia

Anvarjon Ahmedov - Faculty of Engineering, Universiti Putra Malaysia, Malaysia

Zaulia Othman - Horticulture Research Centre, Persiaran MARDI-UPM, Malaysia

Noranizan Mohd Adzahan - Faculty of Engineering, Universiti Putra Malaysia, Malaysia

Mohd Zuhair Mohd Nor - Faculty of Engineering, Universiti Putra Malaysia, Malaysia

One of the most well-known active packaging concepts is gas absorbers or scavengers. In this study, modified atmosphere packagings were developed to investigate the physico-chemical properties of fresh-cut cantaloupe (*Cucumis Melo L. Var. Glamour*) fruit during storage by using oxygen and ethylene absorbers. The fresh-cut cantaloupes were cut into small cubes and immersed in a calcium lactate solution (1%) prior to packing in polypropylene (PP) container that contained ethylene and oxygen absorbers and sealed with low-density polyethylene (LDPE) films. The changes in physico-chemical properties of the packed fruits were determined in terms of colour, pH, texture and total soluble solid (TSS) during storage for 18 days at 2 °C with 87% relative humidity (RH). No overall significant changes were observed on the colour, TSS and pH properties of the fresh-cut cantaloupes. However, the firmness values of the fresh-cut cantaloupes were found to be significantly different ( $p < 0.05$ ) for different absorbers used. The fresh-cut cantaloupes packed with ethylene absorber in the PP container demonstrated better firmness as well as visual appearance than ethylene/oxygen absorbers and control packages. These findings indicate that the shelf life of fresh-cut cantaloupes was extended to a certain period of time due to the presence of the gas absorbers.

**Keywords:** fresh-cut fruit; active packaging; shelf life.

Paper ID = 86, Poster session

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## RELEASE OF OREGANO ESSENTIAL OIL AND GREEN TEA EXTRACT FROM ETHYLENE VINYL ALCOHOL COPOLYMER FILMS

Virginia Muriel-Galet - Instituto de Agroquímica y Tecnología de Alimentos (IATA-CSIC), Spain

Marlene Cran - Victoria University, Australia

Stephen Bigger - Victoria University, Australia

Pilar Hernández-Muñoz - Instituto de Agroquímica y Tecnología de Alimentos (IATA-CSIC), Spain

Rafael Gavara - Instituto de Agroquímica y Tecnología de Alimentos (IATA-CSIC), Spain

Active packaging films containing antimicrobial (AM) and antioxidant (AO) compounds can offer additional protection and extend the shelf life of many perishable food products. The efficacy of any AM or AO additive depends on its ability to be released into the products over time. The aim of this work was to develop a new active film containing a combination of AM and AO agents for food packaging applications. Oregano essential oil and green tea extract were incorporated into ethylene vinyl alcohol (EVOH) copolymer film with 29% of ethylene molar content. Release studies were conducted at 23°C in aqueous food simulants which were selected in accordance with the European Regulations. The food simulants included: (i) 10% (v/v) ethanol for aqueous foods; (ii) 3% (v/v) acetic acid for acidic foods (pH 4.5); and (iii) 50% (v/v) ethanol for lipophilic foods. The major compounds of oregano essential oil and green tea extract were identified and quantified by GC and HPLC respectively. Once the migration reached equilibrium, the total antioxidant activity was measured in the food simulants using a standard antioxidant assay. In addition, the AM capacity of the film was tested in vitro against *L. monocytogenes* and *Escherichia coli* in a liquid media assay as well as in a vapor inhibition assay. The results suggested that the release kinetics of different compounds depend on the affinity between the active agents and the food simulants. In general, higher diffusion coefficients were obtained when films were exposed to 50% (v/v) ethanol. In this simulant, the antioxidant efficiency was observed to be greater. With regard to AM activity, the film showed growth inhibition in both liquid media test and vapor inhibition assay. Overall, the results suggest that the EVOH films with AM and AO agents show strong potential for further development as food packaging films.

**Keywords:** packaging; antioxidant; antimicrobial; EVOH; release kinetics.

Paper ID = 91, Poster session

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## METHODOLOGY TO EVALUATE THE PERFORMANCE OF ACTIVE INGREDIENTS AS OXYGEN SCAVENGERS

Angela Garcia - Universidad de los Andes, Colombia

Jorge Medina - Universidad de los Andes, Colombia

Jacques Verdu - PIMM Arts et Métiers Paristech, France

Bruno Fayolle - PIMM Arts et Métiers Paristech, France

The development of oxygen scavengers for active packaging covers various sources of active components, e.g. inorganic elements, unsaturated compounds, acids, enzymes, clays, and polymers [1-6]. Despite the advances in the formulations of this technology, there is a lack of detailed information concerning the performance of oxygen scavengers for packaging applications. Data provided by manufactures may be limited and generalized [7]. In addition, considerable differences between commercial data sheets and experimental studies have been reported [8]. Thus, there is an increasing need for tools to evaluate performance of polymeric and organic formulations.

In this research, we proposed a new methodology for evaluate the performance of unsaturated-lipid compounds as active ingredients for oxygen scavenging. This methodology is composed of an experimental section and a modeling section completes it. Measurements of oxygen in headspace and thermogravimetric analyses (TGA) performed at different temperatures and atmospheres (nitrogen, air, and oxygen) served to determine the real oxygen scavenging capacity of selected ingredients. The model is based on the oxidation of C-H bonds adjacent to double bonds as active sites. Active ingredients used in this study were unsaturated esters and natural components as linseed oil and soybean lecithin. Oxygen uptake capacity was obtained simultaneously by headspace measurements and TGA. Furthermore, these measurements allow for the identification of the effect of temperature in the thresholds of oxygen scavenging, which is important as triggering method, but also influences in storage or final use conditions of the packaged product. Industries that already use active packaging, and those interested in this developing technology, can use the proposed methodology as a useful and simple tool to evaluate the oxygen scavenging performance in their specific applications and environments. Experimental measurements of oxygen in headspace can be applied to other types of triggering like UV radiation, acidic conditions, and humidity.

**Keywords:** oxygen scavengers; performance; temperature; modelling; unsaturated lipids; TGA.

Paper ID = 96, Session MC1, Room 1101

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## DEVELOPMENTS IN ANTIMICROBIAL FOOD PACKAGING RESEARCH

Marlene Cran - Victoria University, Australia

Stephen Bigger - Victoria University, Australia

Intan S. M. A. Tawakkal - Victoria University, Australia

The distribution of fresh and safe food products to consumers is becoming more reliant on the development of materials that can prevent or minimize food spoilage that occurs due to microorganisms. Antimicrobial (AM) food packaging encompasses a range of materials that incorporate AM agents into their formulations, either directly or in coatings. The preference for naturally derived AM agents has resulted in considerable research with a strong focus on essential oils and extracts that are known to impart AM activity. However, these are typically volatile materials and considerable losses can occur during thermal processing of traditional packaging materials such as extruded polyethylene films. Recent advances to overcome these losses include the use of additives to retain the AM agents and the use of encapsulating technologies such as inclusion compounds that can protect the volatile agents during heat processing. Another important advance in AM packaging is the search for biodegradable materials that can be produced from renewable resources such as starch from wheat and corn. However, for some of these new and emerging materials, the production costs are often higher than those of typical synthetic packaging materials. There are some strategies that can reduce production costs such as the incorporation of natural fibres and fillers and this can offer other advantages including improved mechanical properties and an affinity for some AM agents. However, the biodegradability of many of these materials in certain environments is still under widespread investigation, particularly with the addition of AM agents that may retard biodegradation until the AM agents are dissipated or otherwise inactivated. This paper reports some recent progress in the development and characterization of a range of AM packaging materials at Victoria University.

**Keywords:** antimicrobial agents; active packaging; essential oils; biodegradable materials.

Paper ID = 97, Session MC1, Room 1101

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## BIODEGRADABLE CROSS-LINKED GLIADIN FILMS WITH ANTIFUNGAL ACTIVITY FOR ACTIVE PACKAGING OF BREAD

Mari Pau Balaguer - Instituto de Agroquímica y Tecnología de Alimentos (IATA-CSIC), Spain

Pascale Chalier - CIRAD, INRA, Montpellier SupAgro, Université Montpellier, France

Eva Almenar - Michigan State University, United States

Nathalie Gontard - CIRAD, INRA, Montpellier SupAgro, Université Montpellier, France

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Protein-based bioplastics obtained directly from biomass are renewable and inherently biodegradable. However, some of their functional properties should be improved to be used satisfactorily in packaging applications, especially the mechanical and water resistance, what could lead to a reduction in their biodegradability. Moreover, these materials have a great potential to be used in the development of active films for food packaging applications. Their water sensitivity provides them with a mechanism for triggering the release of active volatile organic compounds that can be previously incorporated into the polymer matrix. In this work wheat gliadin proteins were employed as raw material for the production of films. A chemical treatment which combines cinnamaldehyde with low pH in the reaction medium was used to cross-linking the proteins. Moreover, cinnamaldehyde is a well-characterized natural antimicrobial agent against a wide range of pathogen and food-decay microorganisms. Cinnamaldehyde was incorporated in different percentages. Glycerol was used as plasticizer, and films were produced by casting. Mechanical tensile tests and stability of films in water were evaluated. Biodegradation in compost was also checked. The kinetics release of cinnamaldehyde was evaluated at different relative humidities. Antifungal properties were tested in sliced bread. The results showed that cinnamaldehyde treatment of gliadin films increased their cross-linking density, reducing their solubility in water and improving their mechanical resistance, without comprising their biodegradability. The release rate of cinnamaldehyde increased at high relative humidity conditions, what represents an excellent mechanism to retain the compound before its use, and to trigger and modulate its release rate according to the food product moisture. Gliadin films incorporated with cinnamaldehyde were highly effective against mold growth in bread, increasing the time lag from 4 days to 27. Gliadin films incorporating cinnamaldehyde present improved functional properties, were biodegradable and effective against mold growth in bread, enabling their application in active food packaging.

**Keywords:** protein films; cinnamaldehyde; antimicrobial activity; active packaging; biodegradability; functional properties; bread.

Paper ID = 107, Poster session

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## EFFECT OF NANO-SEMICONDUCTORS AND SACRIFICIAL ELECTRON DONORS ON COLOR TRANSITION OF A NOVEL UV-ACTIVATED OXYGEN BIO-INDICATOR

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The use of oxygen indicator is of increasing interest because oxygen is one of the major causes of food product deterioration. In order to monitor the quality and safety of shelf-stable food products related to either package leakage or gas permeability of packaging materials, oxygen indicator could be possibly employed. As a quality indicator being in a subclass of diagnostic packaging, oxygen indicator is one of the most important gas indicators. Due to the perceived lower risk to the consumer compared to synthetic redox dyes, a bio-redox dye could be used as a visual material in this indicator system. Anthraquinone derivative enables to apply as a colorimetric redox dye in a bio-colorimetric oxygen indicator that comprises nano-semiconductor (nSC), e.g. ZnO and TiO<sub>2</sub>, and sacrificial electron donor (SED), e.g. glycerol and sorbitol, in cellulose-based solution. Effect of nSC and SED on color transition of UV-activated bio-oxygen indicator has been investigated. UV-activated bio-oxygen indicator label was prepared using a casting technique. After UV-activation, leuco-anthraquinone (colorless) changed to anthraquinone (orange-yellowish). It is ready to use as a bio-oxygen indicator label for monitoring the oxygen status. When this indicator label exposed to the air (20.9 %oxygen), the color gradually faded out to the original state of leuco-anthraquinone. The light absorption spectra, the total color differences (TCD), and the times of color changing are also reported.

**Keywords:** Semiconductor; Sacrificial electron donor; Redox dye; Oxygen indicator; UV-activated; Intelligent packaging.

Paper ID = 110, Session MC1, Room 1101

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**EFFECT OF PHOTOINITIATOR AND BINDER CONCENTRATION ON COLOR OF METHYLENE BLUE-BASED OXYGEN INDICATOR**  
**EFFECT OF PHOTOINITIATOR AND BINDER CONCENTRATION ON IRRADIATION TIME AND PROPERTIES OF METHYLENE BLUE-BASED OXYGEN INDICATOR**

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Oxygen indicator is one of the mechanism to ensure that the low oxygen concentration in headspace is maintained. Oxygen indicator based-on methylene blue is effective and being used commercially in the tablet form. The oxygen indicator system consists of methylene blue, photoinitiator and binder. In this study, the objective was to evaluate the effect of methylene blue (redox dye) and 2,2-dimethoxy-2-phenyl acetophenone-benzyl dimethyl ketal (photoinitiator) on the color of the film formed using methylcellulose. Methylene blue concentration (with constant BDK concentration at 0.7%) affected the color of the film before and after UV irradiation as well as the color difference. The lower methylene blue concentration resulted in lighter film that reach its maximum color difference the fastest both for UV irradiation and oxygen exposure steps. MB concentration did not have effect on the magnitude of color difference in the range of 0.021 – 0.049% BDK concentration (with constant MB concentration at 0.021%) had less obvious effect on the color of the film before and after UV irradiation than MB concentration did. Film with 0.35% BDK required the least time to reach saturated color difference point but its magnitude of color difference were slightly (but significantly) less than that of film with 0.7 and 1.4% BDK. BDK concentration in the range of 0.35 – 1.4% had no effect on film color difference.

**Keywords:** oxygen indicator; methylene blue; Irradiation; coating material; leak indicator.

Paper ID = 138, Poster session

## **DISTRIBUTION PACKAGING**

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## ISSUES WITH COMBINING ROAD ELEVATION SPECTRAL MODELS AND VEHICLE VIBRATION RESPONSE TO ESTIMATE VEHICLE DYNAMIC CHARACTERISTICS

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Michael Sek - Victoria University, Australia

The research presented in this paper focuses on the issues associated with the development of an experimental technique to estimate the dynamic characteristics of wheeled vehicles (namely the Frequency Response Function) using only in-service response data. In order to validate the approach and eliminate complexities associated with multi-wheel vehicles, a single-wheeled prototype vehicle was designed and commissioned. The vertical vibration acceleration of the prototype vehicle's sprung mass was measured during normal operation. The Power Spectral Density function was computed and used to estimate the Frequency Response Function of the vehicle. A number of experiments using various configurations of the single-wheeled prototype vehicle were undertaken, along with a series of vibration table experiments were also undertaken to provide a comparison with the estimated Frequency Response Functions. The results show that the best estimate of the Frequency Response Function using the vehicle response data provides reasonable agreement with the measured laboratory experiments when the value of the slope of the spectral function is not set to the value recommended by the International Organisation for Standardisation. Another technique was further developed to estimate the value of the pavement spectral slope using only in-service response data; however this technique does not yield consistent and accurate estimates. Interestingly, the main resonance of the vehicle is in agreement between the vibration table and in-service response data around the sprung mass of all three vehicle configurations when inspected using linear scales (regardless of the variation in the spectral shape of the excitation), although the additional modes (including the unsprung mass) differs for all vehicles.

**Keywords:** Vehicle dynamic characteristics; frequency response function; transmissibility; pavement spectral analysis; laboratory simulation; distribution vibration.

Paper ID = 1, Session MA2, Room 1105

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## REDUCED-ORDER MODELING OF THE LINEAR VIBRATION RESPONSE OF EXPANDED POLYMER CUSHION MATERIAL

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James Gibert - Clarkson University, United States  
Mohammed Daqq - Clemson University, United States

The demand to lower costs and reduce the amount of packaging materials utilized in a packaged-product system has placed increased importance on the development of tools to model the behavior of packaging systems. This manuscript examines the accuracy and convergence of a reduced order model (ROM). The ROM is derived from an idealized packaging system consisting of a rod of polymer foam with an attached end mass. The work begins with an introduction to the complex cyclic softening and the viscoelastic and nonlinear stress-strain behavior exhibited by expanded polymer foam. The partial differential equations (PDE) and associated boundary conditions governing the motion of the system are obtained. The equations are reduced to a ROM using the assumed modes method. Approximate eigenvalues are compared to both exact and experimental eigenvalues reported in literature. Finally, the ROM is compared to the frequency response functions (FRF) of the exact solution and those obtained experimentally. Both results are used to determine the number of modal equations needed for the ROM to accurately capture the steady-state dynamic behavior of the packaging system.

**Keywords:** cushion modeling; viscoelastic; vibration; assumed mode; reduced-order.

Paper ID = 2, Session TA2, Room 1105

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## ESTIMATION OF THE DYNAMIC PROPERTIES OF NONLINEAR PACKAGING MATERIALS USING AN OPTIMISED REVERSE MULTIPLE INPUT/SINGLE OUTPUT BASED APPROACH

Matthew Lamb - Victoria University, Australia

Anthony Parker - Victoria University, Australia

During the distribution phase, packaged consignments are exposed to a variety of environmental hazards (such as vibrations) which, if excessively severe, may cause damage to or even destroy the product. Structural deterioration can be tracked by monitoring variations in the packaging system's modal parameters, particularly its natural frequency (stiffness). Natural frequency estimates are often extracted using a least squares regression curve fit, applied to an estimate of the system's frequency response function (FRF). FRF estimates are generally obtained using the Fourier transform with a single input and single output (SISO). This approach is suitable for many applications; however, as the nonlinearity of the system under analysis increases, the ability of this technique to accurately monitor changes in the system will decrease. In addition, when the excitation to the nonlinear system is varied (increased or decreased amplitude), a SISO based approach may indicate a shift in natural frequency (as a result of the varied input) even though no change in the condition of the system has occurred. This paper discusses an approach which is designed to separate the linear component of the system's FRF using a reverse multiple input/single output (RMISO) algorithm. Such separation will allow traditional modal parameter extraction (curve fitting) techniques to be used to monitor the condition of nonlinear systems. The paper presents the results of experiments in which expanded polystyrene samples were subjected to broad-band random base excitation with a free-moving load placed atop the cushion sample. Continuous acceleration measurements of the vibration table and the free moving load were used to compute the FRFs of the cushions and the differences between a conventional (SISO) approach and the proposed RMISO based parameter extraction technique were evaluated.

**Keywords:** RMISO; reverse path; modal parameter extraction.

Paper ID = 6, Session TA2, Room 1105

## **FUTURE DEMANDS IN DISTRIBUTION DYNAMICS RESEARCH**

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There is risk of damage in every supply chain distribution environment. ISTA exists because hazards are predictable and damage can be prevented. Companies want assurance that they are designing and delivering the distribution packaging that meets the rigors of their supply chain at the lowest cost and smallest environmental footprint. They realize that a properly designed and tested package is a key element in an optimized supply chain. Proven creditability of test protocols and design standards provide confidence in managing supply chain risk and waste, but supply chains are constantly changing and expanding. This presentation will outline the main research ISTA believes needs to be conducted to enable more rapid development of new or updated simulation test methods to reduce the risk of damage and packaging waste. Industry Best Practices needs to be developed for the collection and analysis of distribution hazard data used statistically to create laboratory testing standards. There is also a demand for expansion of distribution dynamic data such as for the E-commerce supply chain, containerized shipments, and unique situations during the “last handlings” segment and other previously unstudied supply chain lanes, all including more temperature and humidity study. The presentation concludes with how others can be involved and contribute in the future.

**Keywords:** Distribution; Dynamics; Test Procedures; Package Testing; Supply Chain; Simulation.

Paper ID = 7, Session TB2, Room 1105

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## THE APPLICATION OF COMPUTATIONAL METHODS TO THE ANALYSIS OF UNITIZED LOAD PERFORMANCE

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Computational methods based on finite element analysis (FEA) are widely used in the engineering and scientific communities but applications in packaging have, to date, been mainly directed toward primary packaging with some limited extensions into secondary packaging. In primary packaging, computational methods utilizing solid modelling and FEA have had a transformative effect on package design, optimization and structural performance prediction – capabilities which can be realized prior to the first physical parts being manufactured. Primary packaging represents only a portion of the larger world of packaging and the global supply chain systems which serve to protect, preserve and transport goods from manufacturer to end user. Opportunities exist to apply computational analysis methods to secondary (individual shipping unit) and tertiary (unitized load) packaging issues but these applications have not been widely explored or presented in the literature. Technical challenges have contributed to the slower adoption of these tools as secondary and tertiary packaging systems are physically larger, incorporate more individual components (which can be geometrically complex), and often utilize multiple materials with anisotropic, nonlinear properties. All of these factors, and the interactions between them in the dynamic transportation environment, serve to increase the difficulty of performing meaningful analysis tasks with computational methods. This paper discusses efforts to expand the use of computational tools to address transportation packaging problems involving full unitized loads consisting of shipping cases, pallets and unitizing films such as stretch wrap. Results of an FEA analysis of a full unit load are presented and examples are provided of the types of unique insights that can be generated from such analysis. Opportunities and challenges for further development are discussed.

**Keywords:** unit load; transportation packaging; finite element analysis (FEA); finite element model; stretch film.

Paper ID = 20, Session TB2, Room 1105

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## VIBRATION TRANSMISSIBILITY OF PACKAGING IN THREE-SUBSTRUCTURES COUPLED PRODUCT TRANSPORT SYSTEM

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Zhi-Wei Wang - Jinan University, China

This paper focuses on the application of three-substructures coupled inverse substructure method in compressor-refrigerator-truck transport system. The compressor-refrigerator-truck system is an actual example of the critical component-product-transport three-substructures multi-coordinate coupled system. It is composed of a compressor, refrigerator and a truck coupled by numerous fixed installation units and packaging units. To obtain the dynamic characteristics for the system, the three-substructures multi-coordinate coupled inverse substructure method is applied in the paper. To evaluate the application, the predicted values and measured values of the substructure-level Frequency Response Functions (FRFs) were compared. The results show that the predicted FRFs of compressor, refrigerator and truck substructure are in accordance with the directly measured. This paper defines the concepts of the vibration contribution, vibration contribution ratio, overall vibration contribution and overall vibration contribution ratio to critical component response through each packaging unit, to evaluate the vibration transmission ability and the cushioning effect of packaging units. The vibration contributions to the compressor through four coupling points almost coincide with each other in the whole frequency domain. However, the vibration contribution ratios are different at a certain frequency. The vibration transmission abilities and the cushioning effects of four coupling points make little difference. Such as, the overall vibration contributions to the compressor on the frequency range 10 to 50 Hz through four coupling points are respectively 18.2327 mm/N, 16.0538 mm/N, 6.8053 mm/N and 10.8630 mm/N, and the overall vibration contribution ratios are respectively 0.3509, 0.3090, 0.1310 and 0.2091.

**Keywords:** frequency response function; critical component-product-transport system; compressor-refrigerator-truck system; three-substructures coupled inverse substructure method; transport packaging; dynamic characteristics.

Paper ID = 31, Session TA2, Room 1105

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## MEASUREMENT AND ANALYSIS OF VIBRATION LEVELS IN 2 AND 3 WHEEL DELIVERY VEHICLES IN SOUTH EAST ASIA

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Sher Paul Singh - Packaging Forensic Associates Inc., United States

Sukasem Sittipod - Kasetsart University, Thailand

Different types of small vehicles, such as three-wheel and two-wheel motorcycles are commonly used for domestic delivery in many countries in Asia, particularly in South East Asia. These types of vehicles exist mostly in the last leg of the supply chain. This study was initiated at the Technical Council meeting at International Safe Transit Association to understand the vibration levels that exist in delivering packages in SE Asia for the "last mile." The delivery process in these countries uses 2 and 3 wheel light vehicles to deliver printers and small packages. However this portion of data and testing has often been overlooked by test standards used in North America and Europe. It has generally been considered the fast, convenient and flexible way of product delivery. This paper presents the vibration measurement and analysis of different types of small vehicles, including three-wheel and two-wheel motorcycles typically being used in Thailand and Indonesia. Recorders were mounted on the vehicle floor to measure acceleration levels during movement in most common routes for the delivery. Measured data shows that lower vibration levels occurred in these vehicles as compared to the other types of vehicle previously studied. Vibration levels in the two-wheel vehicles with trunk containers were higher than those in the three-wheel vehicles. Plastic trunk containers in the two-wheel motorcycles produced lower vibration levels than aluminum containers due to damping structural effects of the plastic materials.

**Keywords:** Vibration; Power spectral density; Small vehicle; Delivery.

Paper ID = 36, Session MA2, Room 1105

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## NEW STANDARDIZED PACKAGE SYSTEM FOR IMPORTED FRESH MANGOS TO THE UNITED STATES FROM MEXICO AND GUATEMALA

Sher Paul Singh - Michigan State University, United States

Koushik Saha - Cal Poly State University, United States

Vanee Chonhenchob - Kasetsart University, Thailand

Jay Singh - Cal Poly State University, United States

This study was conducted in response to the National Mango Board (NMB) and United States Department of Agriculture (USDA) in development of a container for the "Common Packaging Footprint for Mangos." This paper presents the development process for a new corrugated paperboard tray that allows the shipment of an approximate minimum weight of 4 kg of fresh mangos from various countries in Central and South America imported to the U.S. The mango trays currently being used by packing houses in Central and South America were evaluated. This study identified critical design elements which were used to develop a standardized corrugated tray for mangos. In addition, a survey of the retailers and buyers associated with purchasing mango trays in palletized loads in United States was conducted to assess the impact of the proposed tray design on the mango industry. The results indicated that a 14 down common footprint tray did not "best" meet the 40 × 48 Grocery Manufacturers Association (GMA) pallet size. It was capable of holding slightly less than the required 4 kg of mangos and the cooling efficiency was compromised. The two new proposed designs of 12 down and 15 down trays were capable of holding 5 and 3.75 kg of mangos, without affecting current pre-cooling efficiencies during post-harvest processing of the fruit. The survey results further indicated that the retailers are willing to consider a tray design which can hold more than 4 kg/tray, and among the two designs, prefer the proposed 12 down mango tray design.

**Keywords:** Corrugated tray; Common footprint; Standardized package; GMA pallet; Mango.

Paper ID = 38, Session MA2, Room 1105

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## **AN INTRODUCTION TO NEXT-GENERATION LOGGERS FOR MEASURING DISTRIBUTION HAZARDS ON THE PRODUCT AND PACKAGE**

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Saravana Kumar Nadar - Rochester Institute of Technology, United States  
Andrew S Grimaldi - Rochester Institute of Technology, United States  
Robert Brockhurst - Rochester Institute of Technology, United States  
Michael Brockhurst - Rochester Institute of Technology, United States

This paper introduces two working data logger prototypes and the cloud based data analysis system that were trademarked and patented as Pak-Track<sup>TM</sup>-I and Pak-Track<sup>TM</sup>-II. The Pak-Track<sup>TM</sup>-I is designed to wirelessly record and report information in real time about individually packaged products during transit. The system allows the user to immediately view the data with a Global Positioning System (GPS) location via a secured website or Android tablet. The Pak-Track<sup>TM</sup>-II is a standalone device that stores all measurements on internal memory without communicating over a network. The cloud based server and website analyzes and displays the data collected to further study the effects that transportation and handling had on the product and package. The lab obtained vibration and drop data are within expected limits for the purpose of validation. Two field tests were conducted, testing the configuration and setup of the sensors, real time monitoring, display, and analysis. Finally, the collected vibration data was sent to Matlab to generate the PSD chart for validating the FFT algorithm used in the system.

**Keywords:** Data loggers; real time; packaging; transportation.

Paper ID = 39, Session MA2, Room 1105

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**INDIRECT INVERSE SUB-STRUCTURING THEORY FOR COUPLING DYNAMIC STIFFNESS  
IDENTIFICATION OF COMPLEX INTERFACE BETWEEN PACKAGED PRODUCT AND VEHICLE  
TRANSPORT SYSTEM**

Jun Wang - Jiangnan University, China  
Guo-Hua Sun - University of Cincinnati, United States  
Li-Xin Lu - Jiangnan University, China  
Teik C Lim - University of Cincinnati, United States

Inverse sub-structuring method has been recently proposed and applied for inverse analysis of the dynamical response of product transport system. The component-level frequency response functions (FRFs) and the coupling dynamic stiffness for facilitating the cushioning packaging design are all predicted from only the system-level FRFs. However, the system-level FRFs from coupling degree of freedoms (DOFs) may not be measured accurately due to the difficulties of vibration excitation and response measurement for the coupled interface between packaged product and vehicle within the limited accessible space. The aim of this paper is to develop a new FRF-based indirect inverse sub-structuring method for the analysis of the dynamic characteristics of a three-substructure coupled product transport system without measuring system-level FRFs in the coupling DOFs. A closed-form analytical solution to inverse sub-structuring analysis of multi-substructure coupled product transport system is derived. The proposed method is validated by a lumped mass-spring-damper model, and the predicted coupling dynamic stiffness is compared with the direct computation, showing exact agreement. Then, the FRF tests of a physical prototype of multi-substructure coupled product transport system are performed to further check the accuracy of the suggested method. The method developed offers an approach to predict the unknown coupling dynamic stiffness from measured FRFs purely. The proposed method may help to obtain the main controlling factors and contributions from the various structure-borne paths for product transport system.

**Keywords:** Multi-component coupled product transport system; frequency response function; indirect inverse sub-structuring theory.

Paper ID = 41, Session MB3, Room 1107

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## **CARTON CLAMP TEST METHODOLOGIES AND THE EFFECTS ON LOAD CONTAINMENT AND RETENTION**

Jay Singh - Cal Poly State University, United States  
Koushik Saha - Cal Poly State University, United States

A carton clamp is an alternative material handling device for moving packages and material. The need for changing the clamping force for variations in size, shape, and weight of the load creates the potential for under-clamping (slippage) and over-clamping (compressive damage). Currently there are two test standards that provide lab based forklift/clamp testing guidance - ISTA 3B and ASTM 6055. While ISTA provides a stationary simulation of carton clamp handling, ASTM offers a more mobile approach. The ISTA recommended testing equipment tends to be fairly expensive and is not easily accessible in North American test facilities. The ASTM standard proposes the use a carton clamp truck as used in industry, but does not specify any specific parameters making repeatability between laboratories and practitioners ambiguous. This study examined the implementation a carton clamp lift truck as found in industry allowing for mobile (hazard course) testing. A modified version of ISTA 3B was paired off against ASTM 6055 for evaluating both column and cross stack pallet patterns with a variety of treatments. This study attempted to determine if carton clamps as found in industry are capable and repeatable enough to provide consistent data. This study also examined the test methodologies' effect on load containment via stretch film force, load retention via unitized load slippage, and the effects of ride height and driver interaction. The study sought to understand if these effects are uniform across the unitized load, or if particular layers of the load more affected than others.

**Keywords:** Carton clamp; clamp force; unit load; load containment; load retention.

Paper ID = 59, Session TB2, Room 1105

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## COMBINATION CUSHIONING PAD DESIGN AND DROP SIMULATION

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Xie Yong - Hunan University of Technology, China

The combination cushioning packaging has been widely used in large household appliances and instruments in recent years. The combination cushion can not only play the advantages of different materials, but also promote the application of biodegradable material and other traditional plastic cushioning materials. Based on energy equivalent and traditional cushioning design theory, the equivalent cushioning coefficient formula of overlay combination cushion is derived. The formula proposed is very simple in form, and has not made any linear assumption in the derivation process. So it is very universal and can be used for the overlay cushion structure design of linear materials and non-linear materials. In order to verify the validity of the formula and improve the analysis efficiency, simulation and experiment method was both adopted. Firstly, based on static cushioning coefficient - maximum stress curve and the combination cushioning design method, two typical cushioning materials was chosen and the combination cushioning pad was designed. Then, the finite element models of combination cushioning pad structure were established based on ANSYS/LS-DYNA and the cushioning properties were analyzed. Lastly the experiment was carried on with vertical impact machine. Both the simulation and experiment result was close to the theoretical value. The studies show that the equivalent cushioning coefficient formula is validity. The formula can be used to design the combination cushioning.

**Keywords:** Cushioning Design; Simulation Analysis; ANSYS/LS-DYNA; Combination Cushioning.

Paper ID = 71, Poster session

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## DAMAGE TO CARTON BOARD PACKAGES SUBJECTED TO CONCENTRATED LOADS

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Christer Korin - Örebro University, Sweden

Fredrik Thuvander - Karlstad University, Sweden

Carton board packages subjected to concentrated loads near the edges are damaged in a characteristic way. This paper reports an attempt to simulate the damage process in the lab and Package Collapse Loads measured for this load case. Packages were compressed by a concentrated load. The position of load application was varied along a line parallel to a crease and the package was rotated in order to test the influence of the height of the load carrying panel. Force and displacement were recorded and the damage evolution during the test was studied. The damage produced was examined using x-ray tomography. The nature of damage at different stages of damage evolution was studied. Both the visual appearance of the damage and the force-displacement curve were similar in all tests. The Package Collapse Load has little dependence on where along a line parallel to a crease of the package the point load is applied. Damage started developing at the crease and a yield line perpendicular to the crease and parallel to the direction of the load developed. When the displacement increased further, a parabolic yield line, symmetric around the previous one, developed. The start of the damage development was associated with a peak in the force-displacement curve. Stiffness was more geometry dependent than strength. On macro scale, the visual appearance of the damage due to concentrated loads shows no significant dependence on geometry.

**Keywords:** package collapse load; carton board; packaging; strength; concentrated load; x-ray tomography.

Paper ID = 72, Session MB3, Room 1107

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## EVALUATION METHOD OF ABRASION DAMAGE ON CORRUGATED BOARD

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Katsuhiko Saito - Kobe University, Japan  
Akinari Takahashi - Kobe University, Japan  
Akira Higashiyama - RENGO Co. Ltd, Japan

The purpose of packaging research is to improve protection, functionality, convenience and design, and to promote economic and environmental initiatives. Most importantly, proper packaging protects goods from external forces such as vibration, shock and compression. However, products are increasingly being shipped in beautifully printed boxes that advertise the product through images and product information and which will be displayed in shops. Appearance plays a greater role than in the past, and when a corrugated box is abrasion-damaged (even slightly) by vibration during transportation, unspoiled goods may be returned as damaged. Since abrasion damage is visually evaluated by staff, it is subjective and differs among the evaluators. This study proposes an objective and a quantitative evaluation method, and compares the results with those of visual evaluation. First, we reproduce abrasion damage using a friction tester. The abrasion area is filmed as an image of abrasion damage. Analyzing this image, we establish a new standard for evaluating the 'degree' of abrasion damage. Finally, we construct and distribute a questionnaire. From the results of the questionnaire, we confirm the extent to which the method agrees with visual evaluation. The proposed method provides an objective evaluation of abrasion damage that is compatible with visual evaluation.

**Keywords:** corrugated board; abrasion damage; friction test; image analysis; visual evaluation.

Paper ID = 73, Poster session

TIME-DOMAIN INVERSE SUB-STRUCTURING METHOD FOR PRODUCT-TRANSPORT-SYSTEM

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Li-Xin Lu - Jiangnan University, China

Zhi-Wei Wang - Jinan University, China

A time-domain inverse sub-structuring method was suggested for studying the vibration response of product transport system. The formulation of the method was derived based on a new system function, and validated by a lumped parameter model. Finally, the experiment was conducted and the results were compared with the predicted one by the proposed method, showing exact agreement.

**Keywords:** Inverse sub-structuring method; time domain; impulse.

Paper ID = 74, Poster session

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## SHOCK ANALYSIS DURING FRUITS EXPORT FROM JAPAN TO NEIGHBOURING REGIONS

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Yutaka Ishikawa - Food Engineering Division, National Food Research Institute, NARO, Japan

Katsuhiko Saito - Kobe University, Japan

In order to determine measures to prevent damage to fruit from shock during export from Japan to neighbouring regions, we measured the shock frequency and level during the transport of strawberries, cherries, apples, pears, and peaches to Taiwan, Hong Kong, and Thailand by using an acceleration recorder. In addition, we determined the effects of the shock frequency and level on the commercial quality of cherries using two kinds of packaging in order to develop effective cushioning packaging. We compared the shocks to fruit during air and marine transport and found that the former produced higher shock severity and frequency because of the severe shock generated upon loading and unloading at airports. Because the landing shock was very low, we guessed that such severe shock occurred when the samples were handled or loaded on a container dolly. For the cherries, we found that the shock during transport was reduced when several corrugated fibreboard containers were loaded into a larger corrugated fibreboard box (improved packaging) rather than the conventional packaging style of fastening two or three corrugated fibreboard boxes together by plastic bands. This suggests that not only was shock absorbed by the larger box but also that the handling changed. The quality of fruit after transport was better with the improved packaging than with conventional packaging. Based on these findings, cushioning packaging can be designed to reduce the damage to fruit caused by shock during transport.

**Keywords:** acceleration; cushioning packaging; export; fresh produce; shock.

Paper ID = 85, Session WA3, Room 1107

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## COMPARISON OF TWO VIBRATION RECORDING METHODS DEPENDING ON THE DATA-RECORDER POSITION

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Transport measurement is the basis of transport analysis. Its study permits us to detect problems and ensure of the goods safety regarding their packaging. It requires sensors able to record every environmental stress. We generally use a data recorder fixed on the exciter system and then we reproduce the signal on a vibration table in a laboratory. But, can we record stresses by placing the sensor directly on the studied system instead of fixing it on the truck, plane, train... or any exciter system? Indeed, we are not always able to record this way for each case and during the whole transport duration. Transport conditions (changes of means of transport during the journey...) and transporters' notifications (vehicle measurement prohibited directly on the structure, or driver efficiency study...) impose, in some cases, to measure stresses directly on the package. Usually, vibrations tests protocols are based on the exciter system recording and the regulation of the vibration table. But if the record is done directly on the packaging system, how can we realize the simulation on a vibration table? Do these two different ways generate many results differences? And what is the best method to use? In this work, signal of packaging system will be compared to a truck one during the same transportation. PSD signals collected from packaging systems will be compared to PSD collected from the truck. For each measurement point, probability densities of accelerations will also be compared. Overall, this study will allow us to determine if a difference of severity exists between the two recording methods by using an appropriate simulation protocol in laboratory.

**Keywords:** vibration; shock; transport; PSD; severity; measurement; simulation.

Paper ID = 102, Session MB3, Room 1107

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## TRANSPORT SIMULATION TESTING FOR STRETCH WRAP FILM OPTIMISATION AND PALLETISED LOAD SAFETY (DUOPLAST BUSINESS CASE)

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Christoph Graefe - DUOPLAST AG, Germany  
Manuel Garcia-Romeu - ITENE, Spain

Nowadays competitiveness is a must for the subsistence of any company, but it is even more important for European manufacturing companies that have to compete in the global markets with lower cost competitors. Differentiation is a key strategy to achieve that differentiation and that is the strategy that DUOPLAST AG, a German manufacturer of stretch wrap film, has chosen to increase its competitiveness. Palletised loads stability is an issue that is achieving nowadays a high degree of importance. Weight reduction of primary and transport packaging is making tertiary packaging as stretch wrap more and more strategic. Also cost reduction trends put pressure on stretch wrap film optimisation. Besides being a commodity product, stretch wrap film proper application is governed by many parameters that makes it complex. Taking this into account, DUOPLAST AG has converted a commodity product like stretch wrap film in a high value added product by incorporating in-house transport simulation testing to its daily operation. This allows them not just to sell kilograms of film, but film and the most optimised way to apply it to the different product references of its customers. This service improves customer satisfaction by both reducing process complexity and improving performance reliability. The presentation will show how transport simulation testing can be used for stretch wrap film optimisation for safety, stability and cost optimisation. It will show which the minimum equipment is required for that optimisation and how DUOPLAST AG got its own in-house transport simulation centre. It will finally show real cases of stretch wrap film optimisation.

**Keywords:** stretch film; tertiary optimization; stability testing; transport simulation testing; improving performance; blown film.

Paper ID = 105, Session TB2, Room 1105

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## VIBRATION PERFORMANCE FOR BIOCUSHION MATERIALS

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In recent years protective package design considerations have added sustainability criteria to the performance aspects for cushioning material selection. Various biodegradable and renewable materials have been investigated in an effort to design environmentally effective protective packaging systems. Everything from popcorn to mushrooms has received attention in this process. A preliminary study at Rochester Institute of Technology determined the shock and vibration performance characteristics of mushroom-based cushioning. The root-like structure of mushrooms, called mycelium, is used as a binding material for agricultural waste to create an all-natural composite cushioning system. The cushioning material is promoted as 100% renewable and compostable, by Sealed Air Corporation. The study focused on the material performance in reducing transmitted shock levels under ASTM D-1596 Standard Test Method for Dynamic Shock Cushioning Characteristics of Packaging Material. A Lansmont M23 cushion tester was used to compile results. Testing also included the evaluation of the amplification/attenuation characteristics of the materials, using resonance search techniques as a means of assessing performance, under load, with respect to vibration input. Vibration testing required the use of a Lansmont 7000-10 electrohydraulic vibration tester and generated the input through a sinusoidal signal with a spectrum of 3 – 100 Hz. The preliminary study was limited to cushions with thicknesses of 1 and 2 inches (2.54 – 5.08 cm) and was performed under standard laboratory conditions of temperature and relative humidity. Vibration performance testing resulted in inconsistent resonance levels. The current study addressed the inconsistent resonance frequencies found in the preliminary research. The testing protocol for cushion evaluation was modified to include a random vibration signal input. It was found to produce more consistent results. The testing protocol also identified the importance of the fixture for mounting the load.

**Keywords:** biocushions; mushroom cushions; biodegradable packaging; performance curves.

Paper ID = 132, Poster session

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## HOW TO CHOOSE THE RESISTANCE TO VERTICAL CRUSHING OF STACKED CARDBOARD BOX SUITABLE FOR YOUR TRIP.

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Damien Erre - ESIREIMS - ESIEC - Université de Reims Champagne Ardenne, France

In the packaging field, the most widely used material is cellulose: boxboard and corrugated. This material is present in the primary packaging (in a cardboard case) and in grouping case or in pallet boxes. The most common form is the parallelepiped box with contiguous flaps. The main feature of this case is the resistance to vertical crushing (RVC). Usually, this system is studied with static method. (Constant application speed of stress about 10mm/min). However, during transport, systems are subjected to dynamic loads such as shock or vibration. The usual procedure is to determine a static RVC where an empirical coefficient is applied to estimate a dynamic RVC linked to the true transport constraints. This work suggests an alternative approach: First, we record real constraints of shock on current packaging. Then, the data are analyzed to determine the main indicators such as acceleration levels of shocks, frequency, duration... The next step is to define experimentally the limit strength of the cardboard box under dynamic loading using several masses placed on the top of box. Many kinds of shocks are injected. The damage boundary curves of cardboard box are established and compared to the actual data transport discussed above. Following these results, it can be possible to choose the maximum acceptable mass of stacking for a particular packaging and its transport.

**Keywords:** resistance to vertical crushing; stacked cardboard; Shocks on different trip.

Paper ID = 134, Session TA2, Room 1105

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## **INFLUENCE OF CORRUGATED CARDBOARD CORNERS IN SHOCK DAMPING: CASE OF A 100% CARDBOARD PACKAGING.**

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Goods shipped in corrugated box have generally cushioning foams issued from petroleum products (polystyrene, polyurethane, polypropylene,...). However, the use of these materials can have an important environmental impact. For the purpose of eco-friendly conception and matter reduction, packaging developers try to use biomass raw material. They realize also study on matter reduction use in packaging conception. In the one hand, multi-material systems improve complexity of the making process and need the use of different engines. In the other hand, the use of single material gives an easier recycling capacity. So, a single material packaging shows important advantages. Those facts have led us to study a single-material packaging system: a corrugated box with a cardboard cushioning. Cardboard is issued from natural resource and widely used in packaging industry. Moreover, it has recognized mechanical properties. During its life cycle, a shock protective package must ensure products against flat, edge and corner applied stresses. Protocol tests are conformed to those previous observations. The used height fall for packaging conception validation tests are linked product weight, in order to protect it. Flat shock protection conception on box face is mastered by using cushion curves. The corner dynamic is not defined as well.

This study tries to characterize the damping capacity of a cardboard corner. Two specific tests will be realized to determine the corner capacity of a box to dump shocks without cushioning foam adding in this part. The first test use the cushion tester to measure the resistance of a cardboard corner formed in function of different mass. The second test is realized with a drop tester on a complete box containing a prototype with variable mass. This prototype has no influences on the results of the shock corner measures. These two methods allow us to characterise properties of a corner formed cardboard easily as possible.

**Keywords:** shock; cardboard; corner.

Paper ID = 135, Session MB3, Room 1107

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## IMPACT OF LIQUID NITROGEN DOSING ON APPLICATION AND REMOVAL TORQUE OF WINE BOTTLE

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Several studies have been performed that test the finish performance of different types of wine bottles with specific closures systems. However there is a lack of research for closure performance with regard to liquid nitrogen dosing, and its performance within a distribution environment. This study evaluated closure performance of two different types of wine bottles. A standard 750ml glass bottle, produced by 'Verallia Glass Company' and standard 750ml plastic wine bottle produced by 'EnVino Bottles'. Bottles were manually filled to approximate standard fill levels, before they were properly dosed with Liquid Nitrogen as needed and the proper application torque was applied to properly secure the container. The dosing amounts were calculated by measuring the approximate amount of headspace in each type of bottle and then using a Cryotech Calculation chart determining the amount of liquid nitrogen needed to fill that headspace. Glass and plastic bottles were injected with 0.043g and 0.037g of liquid nitrogen respectively. Subsequently, these bottles were subjected to ambient and tropical temperature conditioning prior to simulating a distribution environment as per ISTA 2A test procedure. A Chart Cryotech introducer was utilized for the liquid nitrogen dosing and an Imada DTX-80 table top torque tester was utilized to record the proper application and removal torque of all bottles in the study. The findings of this study can be beneficial to those in the wine industry, to determine how liquid nitrogen dosing, distribution environments and different environmental conditions could affect the performance of screw top closures.

**Keywords:** Finish Performance; Liquid Nitrogen dosing; Application/Removal torque; Wine bottle; Plastic Wine bottle; Distribution testing.

Paper ID = 136, Poster session

## **LOGISTICS & SUPPLY CHAIN**

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## THE SACKS OF ROME?

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While they have long been ubiquitous for shipping granular products, no one actually knows when textile sacks were first used for large shipments of grain, nor is it known when textiles were first used to make shipping sacks. This research is a first attempt to question when the “packaging technology” of shipping sacks was first used on a large scale. Hypothesis: the ancient Egypt-Rome grain trade (after Egypt's annexation in 30 BC) had adequate scale, organization, natural resources, and technological resourcefulness to ship in sacks. Grain and linen textiles were both major exports from Egypt, and most archaeologists and historians assume that sacks were used to ship grain from ancient Egypt to Imperial Rome. Some scholars compare the packaging of wine and olive oil in amphorae, assuming that grain was carried in sacks, even though no actual examples have ever been found (one disadvantage of package biodegradability). The Roman Empire's control of the supply chain also argues for a technical, systemic approach like shipping in sacks. Other archaeologists question the assumption because the evidence produced to support the use of sacks is inconclusive.

This research uses a packaging logistics approach to examine artifacts and research into Egyptian textiles and the Nile-to-Rome grain supply chain. The physical infrastructure ruins at the Ports of Ostia and Trajan's Portus are explored, and artifacts relating to the ancient saccari (porters) are investigated. Evidence is presented to support the (null) hypothesis that the grain was most likely not shipped in sacks, but was stowed and stored in a breakbulk manner. Reasons for the lack of packaging are speculated to include factors relating to the economics of package production, product inspection and distribution. This research sheds light on the history of packaging technology, and deepens our understanding of the relationship between packaging, economics and supply chain management.

**Keywords:** sacks; distribution; grain; distribution packaging; ancient packaging; Roman ports.

Paper ID = 35, Keynote address

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## RFID TAG CHARACTERIZATION BY STUDYING THEIR BACKSCATTERING RESPONSE

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Morten Pedersen - Danish Technological Institute, Denmark  
Alexander Bardenstein - Danish Technological Institute, Denmark  
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There are numerous techniques for measuring radar cross-section of loaded antenna, similar to radiofrequency identification (RFID) tag. These techniques typically involve separate transmitter antenna and receiver antennas and complex RF hardware, especially decoupling (components of transmitter and receiver) equipment. We have been able measure radar cross-section “backscattering” of an RFID tag simply by using two-port Network Analyzer (NA). Here we used one port of the NA as a transmitter antenna, whereas the other port as receiver antenna and the S21 parameters as “backscattering signal” were measured. These measurements are aimed to study ageing of the high-frequency RFID tags and to characterize tags functionality attached to the metallic containers. The measurements were performed on new and used RFID tags from Container Centralen A/S. The transmitter and receiver antenna were placed 1m away from the RFID tag-container (where container is also a part of antenna). By a statistical estimation we decided to perform tests on 120 randomly chosen used container-RFID tag samples and were cross-checked with 23 new sample tags. The measurements showed only a slight ageing effect, however we observed the huge influence of the containers on the measurements. In this connection, the weight, conditions of front frame face (due to paints, stickers, etc.) and even the positioning of the logo of the producers had substantial influence on the backscattered signal. The measurements were performed in 860-875 MHz frequency band. All the measurements were performed within the temperature range of 20-25 C, keeping in with the optimum operation temperature for the NA. An empty hall with wooden floor was chosen for the measurements. This area was less affected from interferences such as reflection from the wall or nearby metal objects. All the adjacent glass windows were covered with wooden plates, it lowered the disturbance. The chosen area provides consistent results.

**Keywords:** Radiofrequency identification (RFID) tag; Backscattering of an RFID tag; S-parameters measured by Network Analyzer.

Paper ID = 62, Session WA3, Room 1107

## ELASTIC MODULUS OF CORRUGATING MEDIUM UNDER DIFFERENT TEMPERATURE AND RELATIVE HUMIDITY

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Hongge Guo - Qindao Science and Technology University, China

The influence of the temperature and relative humidity on the moisture content of corrugating medium was studied by experiments. The ideal three-dimensional diagram between the moisture content and the temperature and relative humidity was constructed by the GAB model. The prediction equation of the moisture content and the relative elastic modulus was fitted after analyzing the test results by Matlab software. The results show GAB model can predict the moisture content of corrugating medium in different temperature and humidity conditions, and the fitting equation can describe the relation between the elastic modulus of corrugating medium and the moisture content. The predicted elastic modulus can be used to evaluate the cushioning properties of corrugated sandwich paperboard.

**Keywords:** Corrugating medium; Moisture content; Elastic modulus..

Paper ID = 63, Poster session

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## **A METHOD REVIEW AND A CASE STUDY OF PACKAGING DESIGN DIFFERENCE OF AUTOMOBILE KD PARTS AND AFTER-SALE PARTS WITH AN APPLICATION ON TRANSPORT**

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Yu Zhao - China Packaging Research and Test Center, China

Binglin Lu - China Packaging Research and Test Center, China

A knock-down package is a packaged kit containing the parts needed to assemble a product. The parts are typically manufactured in one country or region, and then exported to another country or region for final assembly. A common form of knock-down is a completely knock-down (CKD), which is a complete kit needed to assemble a product. An incompletely disassembled kit is known as SKD for semi-knocked-down. Both types of KDs, complete and incomplete, are collectively referred to within the auto industry as knocked-down export. Implementation of an integrated solution to packaging of automobile KD parts is an important issue to automobile exporters in China. Generally, automobile after-sale packaging is used in the domestic auto sale service. The paper compares transport packaging solutions used in the Chinese domestic after-sale service with those adopted for export and investigates their effect on the growth of business. Unitized loads of packaged-parts applied to export which is required to consider with climate environment and available facility of transport system. Both of CKD/SKD packaging process and materials selection play a key role in supply chain management as well as provide cost reduction and damage decline. Packaged after-sale parts are required to match diversity of product and instant customer response management from each manufacturer. A case study will be presented with KD packaging of a China's own-brand vehicle and after-sale parts packaging of an international brand cars.

**Keywords:** KD packaging; Packaging integrated solution; Transport; Supply chain; Automobile export; After-sale part.

Paper ID = 80, Session WA3, Room 1107

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## THE STATUS OF WOOD PALLET REPAIR OPERATIONS IN THE UNITED STATES: A SURVEY STUDY

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There are approximately 1.84 billion pallets in circulation within the United States. Every year, 321 million of these wooden pallets need to be repaired by designated pallet repair facilities. Due to increasing tipping fees by landfills and increasing environmental cautiousness by companies, the amount of pallets repaired significantly increased over the last 15 years. The processes used to repair broken pallets have a crucial importance on the quality of repaired pallets. Meanwhile, increasing environmental awareness and concerns regarding sustainability have resulted in increasing use of quantitative techniques such as life cycle analysis to evaluate the environmental impacts of wood pallets used in the United States supply chain. The reliability of a life cycle analysis depends on the data provided by the life cycle inventory (LCI) database and the construction of an accurate LCI database requires detailed understanding of the types of repair operations used within the wood pallet repair operation. Therefore, the main goal of this study was to investigate the common repair practices used by the U.S. wood pallet repair industry to provide information on the overall status of the industry and to support accurate and comprehensive LCI for the wood pallet repair industry. Data for the study were collected using an online survey of the United States wood pallet repair industry. The study examined the characteristics of wood pallets purchased, received, or repaired by industry participants; the processes used by the industry; and the characteristics of wood pallets repair businesses in general. The results revealed that vast majority of the respondents repaired 48 in x 40 in. stringer class pallets and the main mode of repair was c-block type repair. Results showed that the majority of respondents are using extensive manual labor in their repair processes; however, a higher level of automation has found in notching, trimming, and sorting/stacking processes. Sixty-six percent of the respondents reported grinding unusable wood into chips or mulch and 16 percent of the respondents had a furnace or boiler to utilize wood scrap.

The survey revealed that vast majority of the respondents repaired stringer pallets and the main mode of repair was c-block type repair. Results showed that majority of the respondents are using extensive manual labor in their repair processes; however, higher level of automation has been found in notching, trimming, and sorting/stacking. Sixty-six percent of the respondents reported to ground unusable wood into chips or mulch and 16 percent of the respondents had furnace or boiler to utilize wood scrap.

**Keywords:** pallet repair; wooden pallet; automation; unit processes.

Paper ID = 137, Session WA3, Room 1107

**MEDICAL, COSMETICS & PHARMACEUTICAL PACKAGING**

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## MICROBIOLOGICAL STABILITY OF SHAMPOO STORED IN POLYMERIC PACKAGING MODIFIED WITH NANOSILVER

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Zenon Foltynowicz - Poznan University of Economics, Poland

Microbial stability of cosmetics, provided by preservatives, determines their safe use. However, despite the positive impact of preservatives, they also demonstrate side effects in the form of an allergic reaction to the users. Therefore, alternative methods of preserving cosmetic products are currently investigated. The aim of the study was to replace the preservatives, mainly parabens, contained in cosmetic formulations, through the use of nanosilver, but not entering them into cosmetics, but into its packaging. It is expected therefore to reduce the exposure of users and the aquatic environment on silver nanoparticles, which impact is yet not fully discovered. A shampoo without parabens was stored in nanosilver modified PP and PE containers, as well as in non-modified packaging and glass flasks, as a comparison. Additional reference samples were shampoos with preservatives stored in both non-modified PP and PE containers and in glass flasks. Evaluation of the microbiological stability of the shampoo (with and without parabens) were performed against *Staphylococcus aureus* (Gram-positive bacteria), *Pseudomonas aeruginosa* (Gram-negative bacteria) and *Candida albicans* (fungi). Testing the migration of silver from the packaging into the product as well as the effect of nanosilver particle size and concentration were also done. The results of the investigation confirm that the use of nanosilver immobilized in polymer packaging of selected cosmetic formulation (such as shampoo) can be, in certain circumstances, an effective method of the product preservation.

**Keywords:** nanosilver modified PP and PE containers; parabenes; microbial stability.

Paper ID = 68, Poster session

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**OBJECTIVE EVIDENCE OF OPENING STATUS CONTRIBUTE DEVELOPMENT OF UP GRADING PTP**

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Press through Package (PTP) is one of the most commonly used packaging for medicine. So it is particularly important the usability for every user regardless generation and some handicap. We reported that opening status of PTP is correlated with several factor such as material, shape, structure (including fractional void) and balance of pocket and pill size. In our previous study, we established several useful results in film thickness, and balance of pill size and pocket size. So, using these results, we designed several model PTPs (change in factors: thickness, fractional void, martial) and studied usability and effectiveness of changes of design with them. With collaboration of ordinary young adult (number: 28 average ages: 23.9±5), we studied the opening status in various type model PTPs using Numeric Rating Scale (NRS) and measured individual pinch power simultaneously. From the result of NRS, there is a significant difference of opening status of PTPs. PTP with thick film and hard aluminum, marked worse score in NRS even young adult with sufficient pinch power. On the other hand, PTPs with reasonable balance of fractional void and reasonable material and shape obtain a better score in NRS. The study shows the effectiveness of using data which was collected previous study for developing evidence based PTP design. And there is possibility to propose the standard PTP design with appropriate balance of diameter and thickness for easily-opened PTPs. In addition, using factors which we find in series of studied could be useful to develop higher usability design PTPs as universal packaging.

**Keywords:** PTP; opening status; usability.

Paper ID = 76, Poster session

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## EVALUATION OF OPENING STATUS OF PTPS WITH THREE ELEMENT FROM PUSH TO GO OUT FROM PACKAGE

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In the pharmaceutical packaging, we think the opening characteristics to be extremely important to greatly influence the taking medicine compliance of the patient. We showed that the difference of opening status depend on various PTPs, and the factors which affect the opening status. So we analyze the mechanism of these results with several factors such as material, structure, and balance of fractional void. To analyze the difficulty of opening PTPs, considering all procedure of opening PTPs, and set the three step factors such as push, break aluminum, and go out pill from packages. These steps have following relations for PTP characteristics. \

Step1. Until transforming a pocket and beginning to push the pill: Dimension of pocket , Rigidity of pocket's material, Difference between pocket's height and thickness of pill, Thickness of the top of pocket

Step2. Until breaking aluminum film: Thickness and tenacity of aluminum film, Thickness at the corner of pocket

Step3. Until going out pill: Having stress-relaxation or not after breaking aluminum , Smoothly discharging or not

We should pay attention to these different factors to establish most suitable PTP opening characteristics in the situation that materials or the shape of the PTP pockets were limited. And we devised the method which calculating the area of the radar chart comprised of the sensuality evaluation score of 3 steps as a method to express these elements in one substitute property value. We named this method "The PTP Opening Texture". After evaluating the sample which slightly varied in the molding condition by "The PTP Opening Texture", we knew that we could detect the standards of the parameter functionally.

**Keywords:** PTP; Opening status; Sensuality evaluation.

Paper ID = 84, Poster session

**PACKAGING DESIGN, ERGONOMICS & HUMAN FACTORS**

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## THE STUDY OF UNCERTAINTY ELEMENTS RELATED TO HEAT SEAL STRENGTH BY COMPARISON OF STANDARD TESTING METHODS

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The heat seal technique has been widely used in packaging applications as a plastic packaging material for several decades. The expected functions of heat sealing are package integrity/sealing and opening. Heat seal strength has to balance these two opposing factors; namely, opening and package integrity/sealing. ASTM F88-\*\* attempts this by using the heat seal control.[1] Heat seal strength testing is made from specimens of a certain size, and then heat seal strength is measured by the tension tester. There is "inconsistent expression" (transversely) in the heat seal strength measurement as follows.

1) There is an approximation of heat seal strength value.

2) Results of heat seal strength value and temperature value are inconsistent in all testing at any temperature values.

The cause of inconsistent heat seal strength can be explained by applying the definitions of "heating temperature" and "heating time". The original definitions of testing methodology were defined by ASTM and JIS standard [1,2], but the new definitions differ from the ASTM and JIS standards. These definitions changed to "Heating speed" which greatly influenced the measurement of heat sealing strength and was discovered two years ago. ("Hishinuma Effect") [3,4] It is understood that the "Hishinuma Effect" makes a great difference to the heat seal information. We are deriving 17 categories and 65 items which are the cause of "Uncertainty element" which obfuscates the crossing of the heat seal characteristic.[5] They are reported in this paper based on the examination and the action plan of the influence of "Hishinuma Effect" on "Uncertainty".

**Keywords:** heat sealing; MTMS; "Hishinuma Effect"; sealing; opening; closing; heating temperature; heating time.

Paper ID = 12, Session TC2, Room 1105

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## AN EMPIRICAL STUDY FOR EXPLORING REUSABLE PACKAGING ATTRIBUTES

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Karl Kones - Liverpool John Moores University, United Kingdom

Packaging systems are influenced by many elements throughout their life cycle. The environmental impact of packaging has become an issue in many countries. Much effort has been made to reduce amount of packaging going into landfill. Refillable packaging was discovered as a possible solution in term of reuse packaging; however, packaging used for secondary uses is another reuse technique to deal with packaging which needs investigation. Reusable packaging attributes are the functional characteristics of packaging to be reused as being key benefiting consumers, industries and environment. The paper seeks to address reuse as a sustainable waste route option for open loop system in packaging lifecycle. It specifically proposes to determine reusable packaging attributes in relation to consumers' orientation, to discover the packaging designers' drivers and opportunities related to the design of reusable packaging. An integrated approach is used to identify packaging attributes in literature. An empirical study was conducted to develop and test the design packaging attributes relationship with reusable packaging which identified in extant literature. Qualitative research was conducted to identify the packaging attributes from packaging used for secondary uses using questionnaire. The reusable design packaging attributes model was proposed. The model can be used to help improve the packaging sustainability performance. The model interprets 'BS En 13429:2004 reuse of packaging' standard and helps designers/manufactures in early phases of design packaging to understand the reuse of packaging requirements and procedures.

**Keywords:** reusable packaging; empirical study; waste packaging; reusable packaging attributes.

Paper ID = 17, Session MA3, Room 1107

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## RELATIONSHIP BETWEEN PEEL ANGLE AND PEEL FORCE IN PEELABLE SEMI-RIGID PACKAGING COMPRISING TYVEK® AND PETG

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Testing standards such as ASTM F88 and ASTM F2824 acknowledge the effect of peel angle on peel force during package opening. Understanding the relationship between peel angle and peel force is critical to minimize people's physical effort while opening both semi-rigid and flexible packaging. However, the literature does not provide any mathematical relationship in this regard. In order to start filling this gap, peel force measurements were collected for two test conditions (A and B) of PETG trays and Tyvek® lids at peel angles varying every 15° intervals. Test conditions had different seal geometries and peel directions. In condition A, trays were completely sealed. In condition B, trays were partially lidded and the sealed areas were comprised of two parallel rectangular areas. Experimental data for force vs. angle for both conditions followed a U-shaped pattern with minimum values at peel angle 45°. Beyond 90° peel forces increased rapidly. Statistical analysis of the 0-90° range suggested four homogenous subsets that resulted in statistically differing forces. Classical mechanics was used to derive an equation in which peel force is a function of peel angle. Two approaches were taken to fit the data to this equation: linearization and nonlinear regression. The final equations show good agreement with experimental data. Findings have implications for package design, usability, and peeling simulations. If materials combination and manufacturing process conditions are kept constant, the experimental data suggest that the force needed to peel off a semi-rigid package depends on two factors: peel angle and peel line width.

**Keywords:** Peel angle; Peel force; Usability; Peelable seal; Semi-rigid packaging; Package design.

Paper ID = 18, Session MA3, Room 1107

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## **AN EYE-TRACKING METHODOLOGY FOR TESTING CONSUMER PREFERENCE OF DISPLAY TRAYS IN A SIMULATED RETAIL ENVIRONMENT**

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Rupert Hurley - clemson university, United States

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Display trays have traditionally been used to support distribution packaging and retail stocking. Yet, it is becoming common to find display trays as devices to garner attention and increase the shelf presence of packaging. This paper presents a method for testing consumer preference of display trays for liquid dish soap and canned tomatoes in CUShop™, a consumer experience laboratory, using eye-tracking technology. It was hypothesized that display trays would increase total fixation duration and decrease time to first fixation on the respective products tested. However, it was determined that attention to products in a display tray was less favorable to products not in a display tray. Though an experiment was conducted, the researchers note that many variables exist for display trays and the experimental results are limited. If further studies were to be conducted on a larger variety of display trays using the methodology described, the appeal and attention value display trays could be comprehensively understood. Lastly, this paper describes and defines the various types of display trays used within the packaging supply chain.

**Keywords:** packaging; display trays; CUshop; eye tracking.

Paper ID = 24, Session MA3, Room 1107

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## **A REVIEW OF THERMOPLASTIC COMPOSITES VAPOUR PERMEABILITY MODELS: APPLICABILITY FOR BARRIER DISPERSION COATINGS**

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Behudin Mesic - Scion Research, New Zealand

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One of the purposes of thermoplastic composites films and barrier dispersion coatings is to minimise the permeation of gases. In both cases, fillers and other additives are added during the film preparation to improve barrier properties. A high level of understanding has resulted from the study of the interaction between filler and polymer phases of thermoplastic composites and a number of models have been developed to predict the relative permeability of these materials. However, barrier dispersion coatings have not been modelled in this way. The aim of this review was to discuss similarities and differences of thermoplastic composites and barrier dispersion coatings that may influence the applicability of the models for barrier dispersion coatings applied to paper based materials. The models were developed as a function of the amount of fillers added in thermoplastic composites films and geometrical characteristics of the fillers such as size, thickness, shape, and the distribution of fillers in the film. Two and three dimensional models with oriented and random arrangement of fillers were presented. Due to the parallel orientation and the similar length and width of fillers used in barrier dispersion coatings, three dimensional models were more suitable to predict relative permeability. These models assumed plate or circular shaped fillers with parallel orientation. In order to prove the models, experimental information was required. Very limited data for barrier dispersion coatings with varying the amount of fillers has been reported in the literature. For this reason, further experiments are required under varied combinations of aspect ratio and the volume fraction of fillers.

**Keywords:** Barrier dispersion coating; Thermoplastic composites; Relative permeability; Modelling.

Paper ID = 30, Session MA3, Room 1107

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## THE FUNCTIONAL ANALYSIS METHODOLOGY FOR ENVIRONMENTALLY CONSCIOUS PACKAGING DESIGN

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The roles of packaging design are to preserve the product, protect its damage throughout transportation, and fulfil stakeholder's complicated needs. Moreover, the customers become more environmental conscious to consider in eco packaging before buying. The varieties of tools assist design teams to develop the eco packaging design concepts by integrating environmental aspects into design and development phase. However, the eco packaging design methodology is an inconceivable support for functional analysis into life cycle packaging. The objective of this research is to develop a functional analysis methodology for supporting environmentally consciousness design of packaging. The methodology is obtained in three tools: Eco Packaging Design Checklist (EPDC), Function Analysis System Technique (FAST), and Functional Benchmarking (FB). The proposed methodology is tested through application to the secondary packaging for containment of electronic components. The proposed methodology is crucial to consider not only environmental aspects but also functional aspects. This can assist effectively for design teams to identify the functional packaging in conceptual design phases. The advantages of this methodology are to define the environmental impact in the early design phase by using EPDC tool. This step can be assessed the environmental problems with its easiness and fastness and pointed to the critical requirements and notified for environmental impact situation of current packaging. The FAST tool can be helped to define the function of current packaging and organized the logical relationships between functions. The design team can be clarified to the primary and secondary functions of current packaging and determined the mission statement. The FB is applied to clarify in functional requirements based upon customer's need and compare the functional improvement level with competitors in the current market. This step can help the design team to prioritize the functional requirements to design improvement. The methodology has a majoring benefit than is obtained from applying those three tools independently. The recommendations, limitations and further researches are also presented in this research.

**Keywords:** Eco packaging design; Functional analysis; Eco packaging design checklist (EPDC); Function analysis system technique (FAST)Functional benchmarking (FB).

Paper ID = 43, Session TA1, Room 1101

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## EASY OPENING OR A LOST 16 PER CENT SALE

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The consumers expect the packaging to be functional and to fulfil their specific needs in every way. A national Danish project has documented that 40 per cent experience difficulties, when handling and opening packaging at least once a month, and as a consequence, 16 per cent of the consumers refuse to buy the product next time they go shopping. The issues are worsening due to the expansion of the elderly population in the upcoming decades all over the world. In Denmark the amount of people above the age of 65 years old will rise to index 170 in 2050 compared to 2010. It is also noticeable that 700,000 people in Denmark have a rheumatic associated condition, which account for 13 per cent of the population. Therefore, the chance of excluding a part of an enterprise's target group is every likely, making easy-to-open packaging more relevant than ever. From our experience, the enterprises' most common attitude towards changing the packaging design is associated with economic frustration. Most enterprises have very expensive and effective packaging lines and often the enterprises do not recognize the economic potential of a new packaging design. The trade-off of consumers is simply not common knowledge of many small and medium sized enterprises. The culture among the consumers in Denmark means, that the consumers do not communicate problems directly to the enterprises. They tell their neighbours and friends if they experience difficulties with a product. This attitude makes it almost impossible to rely on complaints as an indicator of the consumer satisfaction with a product. The enterprise needs to collect the information directly from the consumer in order to evaluate the performance of their products. The project "User friendly packaging – Guideline for the industry" seeks to address these issues. The main deliverable is a web-based guideline. The guideline contain collected knowledge regarding the attitudes of the consumers and issues to address about packaging design, also the guideline contain a step by step process to develop easy-to-open packaging. The guideline is constructed in a way that allows the enterprise to pick and choose in respect to the enterprise's needs and competences. The main focus in the development of the guidelines has been to produce a tool that function in a practical manner instead of communicating the absolute scientific truth.

**Keywords:** Easy opening; lost sale; guideline; usability; packaging performance; consumer.

Paper ID = 49, Session TA1, Room 1101

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## PACKAGING FOR PERSONALIZED FOOD FOR NUTRITION OF ELDERLY CONSUMERS MADE USING RAPID MANUFACTURING

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Development of packaging concept allowing manufacture, distribution, graduated microwave heating and consumption of multicomponent personalized meals is one of the most complex tasks in the project "Development of PERsonalized FOod using Rapid MANufacturing for the Nutrition of elderly ConsumErs" (project acronym PERFORMANCE) funded by the FP7 European R&D Programme. In the project, a personalized holistic food supply chain for elderly people suffering from dysphagia, decreased organoleptic perception, mastication and swallowing problems will be developed and validated. Thus the project deals with the delicate gelled rapidly manufactured (3D printed) personalized food that must be cautiously heated in domestic microwave appliances up to temperatures required for safe consumption. At the same time it is of prime importance to ensure that the achieved temperature does not exceed the melting point of the gel, and all components of the personalized meal are heated homogeneously. Other imprescriptible requirements are convenience, aesthetical acceptability, and durability. In response to these challenges, a purposeful packaging concept and physical design allowing graduated simultaneous heating of the food varieties has been suggested. The physical design is based on utilization of packaging elements with variable microwave transmission capabilities. The transmission is controlled by perforated electro conductive patterns that cover the packaging elements. Geometry and dimensions of perforations have been optimized by means of finite-element method computer simulations. The computer models have been set up to calculate electromagnetic wave intensity distributions inside the packaging when placed in a domestic microwave oven cavity. The validation experiments have revealed that graduated homogeneous heating of gelled personalized food can be implemented using developed packaging elements for controlled microwave transmission. The work is currently underway to optimize and finalize the packaging concept and to achieve precision of temperature control meeting requirements set by both personalized food properties and the EU food regulations. Our paper will therefore give a feature-based description and an element-wise analysis of the packaging concept though with a strong bias to the ability of securing homogeneous microwave heating.

**Keywords:** elderly consumers; personalized food packaging; microwave heating.

Paper ID = 69, Session TA1, Room 1101

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## OPENING STATUS COMPARISON WITH MODEL PTPS BETWEEN ORDINARY PEOPLE AND PATIENTS WITH RHEUMATOID ARTHRITIS

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It is usually recognized that people with some handicapped in hand have difficulty of using packaging including drug packaging. Press through Package (PTP) is one of the most commonly used packaging for medicine. So it is particularly important the usability for every user regardless generation and some handicap. We reported that opening status of PTP is correlated with several factor such as material, shape, structure (including fractional void) and pocket and pill size. We also reported that opening status is correlated with pinch power of users. To see the reality of opening packages, we compare the real usability between healthy young adult (group1) and patients with Rheumatoid Arthritis (RA) (group2) using model PTPs. We measured pinch power of each collaborator and ask them to open several model PTPs. We studied the opening status with various type model PTPs using Numeric Rating Scale (NRS). There is a significant difference of opening status of PTPs between two groups. PTP with thick film and hard aluminum, which is relatively worse score in NRS even young adult, these PTPs has been hardly opened by people in group2. One reason is that people in group2 have low pinch power and some has difficulty of curving fingers. The status of cannot open cases are that patients with RA are not push out pills from packages, and some are opened from back side (aluminum side) with nails. It is important to assume human ergonomics of hands and real situation of usage including handicapped or the elderly, and have to design universal drug packaging for every user.

**Keywords:** PTP; Rheumatoid Arthritis; ordinary people; Usability; Comparison.

Paper ID = 75, Poster session

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## ATTENTION GRABBING POWER OF BRANDED VS. UNBRANDED PACKAGING

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Does brand name on the packaging of garden plants capture consumer attention? Is branded packing perceived as more attractive than unbranded packaging? Our study, guided by Elaboration Likelihood Model (ELM) and the Selectivity Model (SM), examined the effect of brand, involvement, expertise and demographic characteristics (e.g., age, gender) on visual attention to product and its packaging. We also investigated whether visual attention influenced perceived product attractiveness. Using a Tobii X1 light eye-tracking device, we collected data from 50 subjects who viewed five images randomly displayed showing flowering shrubs with brand/no brand package condition. Visual attention was measured by total visit duration (TVD) to the product. MANOVA revealed that visual attention to branded packaging was significantly higher than the unbranded plant ( $M_{\text{(branded product)}} = 3.99$ ,  $SD = 3.04$ ,  $M_{\text{(unbranded product)}} = 3.29$ ,  $SD = 2.06$ ),  $F(1, 430) = 32.68$ ,  $p < .001$ ). There was an interaction effect between involvement and expertise on visual attention. This implies that consumers' knowledge is activated from memory when consumers are motivated to process information. Gender, but not age, influenced information search patterns. Females showed longer TVD both on the branded pot and product than men ( $M_{\text{(female (pot))}} = 1.03$ ,  $SD = 1.19$ ,  $M_{\text{(male (pot))}} = .75$ ,  $SD = .49$ ,  $F(1, 430) = 6.37$ ,  $p < .05$ ;  $M_{\text{(female (product))}} = 5.72$ ,  $SD = 3.80$ ,  $M_{\text{(male (product))}} = 4.49$ ,  $SD = 1.62$ ,  $F(1, 430) = 12.15$ ,  $p < .01$ ). This finding indicates that females engage in comprehensive information processing, whereas males employ heuristics processing. Brand significantly influenced perceived product attractiveness; highly involved consumers perceived the product as less attractive compared to less involved consumers. Perceived product attractiveness was higher for women. Our findings imply that branded packaging has greater attention grabbing power than non-branded packaging and that consumers perceived branded products as more attractive.

**Keywords:** Branded Packaging; Eye-Tracking Device; Visual Attention; Perceived Attractiveness.

Paper ID = 94, Session TA1, Room 1101

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## THE DESIGN DEVELOPMENT OF PERFORATION RULE FOR RETAIL READY PACKAGING

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The implementation of Retail Ready Packaging (RRP) is dramatically increasing in the last decade by the cooperation between retailers, brand owners, suppliers, and packaging companies. There are many studies from retailers, packaging suppliers, and consumer organizations on RRP concepts, implementation, and design that have been published and being used as RRP guidelines. Corrugated box with perforation rule is commonly used for RRP because of its compressive strength and display ability, especially smaller flute such as B flute. In addition, the perforation rule on RRP plays an important role to create not only sufficient box strength during transport but also ease of opening with the clean edge on shelf. Three sets of perforation rule were designed and studied in this research. Each set of perforation has two different rules at the front panel and the flap edge of box. The perforation rules are Set-A Front 8x3(cut x non-cut length) and Flap edge 5x4, Set-B Front 10x4 and Flap edge 6x4, and Set-C Front 10x3 and Flap edge 6x5. The corrugated boards B flute made from white top liner(30% virgin pulp) and brown top liner(100% recycled pulp) were used to manufactured RRP with set of perforation rules for bar soap product. Then, the RRP were measured and evaluated on box compression test, drop resistance, ease of opening, and appearance after opened. The results showed that different perforation rules on the same position had no significantly effect on compressive strength of box. The shorter cut length of perforation, Set-A, performed better drop resistance than others longer cut length. The easy-to-open and display appearance were resulted in the same direction. The Set-B was scored "easy" and "satisfied" in easy-to-open and display appearance criteria, respectively. Paper board combined with virgin fibers performed better drop resistance. In contrast, it performed "difficult" on easy-to-use and scored "not satisfied" on display appearance aspects. Base on the results of this study, recommendation guidelines for perforation rule have been developed.

**Keywords:** Retail Ready Packaging; Shelf Ready Packaging; Perforation rule; Packaging Design.

Paper ID = 124, Poster session

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## IS YOUR PACKAGE PRO-LOHAS? – FINDINGS OF THE FINNISH LOHASPAC STUDY 2011-2014

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In recent years, LOHAS (Lifestyles of Health And Sustainability) has emerged as a constantly rising global phenomenon. The LOHAS trend provides major drivers for the package sector, such as a growing interest in personal health and well-being, as well as in ecological, socially responsible and ethical products. Hence, the environmentally-conscious and creative LOHAS consumers can produce valuable insights for packaging research and development. In Finland, one-third of the population are considered as LOHAS consumers. This paper presents some of the key findings of the Finnish LOHASPAC research project conducted in 2011-2014. The aims of the three-year research project were to (1) increase and spread LOHAS knowledge and understanding in package value networks, (2) study means to resolve how to communicate health, well-being, ecology, as well as ethical and social responsibility through packaging, and (3) develop and test consumer research methods for studying multisensory package concepts. This paper will focus on the results of the survey and ethnographic research conducted in 2014. The aim of the survey (N=1000) was to identify the major sources of value in packaging for LOHAS consumers, followed by an ethnography (N=10) aimed at validating the main findings of the survey and identifying the role of packaging in LOHAS consumers' everyday decision making processes. The results indicate that LOHAS consumers set high requirements for packaging. 67% of the LOHAS heavy consumers state that packages have a strong influence on decision making. A majority of the LOHAS consumers experience high value from the environmental, informational, and functional benefits of packaging. Higher value will emerge, if packaging succeeds to contribute to their lifestyle, resulting in delight and commitment. Packaging materials that are safe, more ecological and promote social well-being at a global level, are considered as pro-LOHAS.

**Keywords:** package; value; LOHAS; consumers; survey; ethnography.

Paper ID = 130, Session TC2, Room 1105

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## MATERIAL IDENTITY IN A PACKAGING CONTEXT

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Package design includes a number of considerations ranging from protecting the content to conveying the brand image. The aim of this study was to gain a deeper understanding on how Swedish consumers perceive product packaging attributes, with a special emphasis on in which way packaging material (carton, paper plastic), and structural design (folding carton, paper bag, standing pouch and plastic bag), have an emotional impact on consumers' evaluation of the product and packaging. Assessing the appearance and effectiveness of a packaging system is often confounded by branding, why it is important to separate the brand influence from the attributes of the packaging system. Thus, in the experimental part, packaging prototypes of different structural design and materials were manufactured in order to present commercial cereal brands in different types of packaging. The research involved a combination of qualitative and quantitative methods, comprising (i) focus groups on perfume packaging and cereal packaging; (ii) a mock-up study of four cereal packaging types: transparent plastic bag, carton box, paper bag, and a resalable stand-up plastic pouch; and (iii) a questionnaire on environmental attitudes to packaging materials. Thirty-one respondents participated in focus groups and 20 in the mock-up study. Results show that the paper bag and the carton box were perceived to be the most environmentally friendly packaging material. Heavy ink usage on paper bags and carton boxes can however raise concern regarding the environmental impact. Introducing functionality and good print quality can cause preferences to divert to an alternative packaging material. In the mock-up study the standing pouch was the most liked package type regardless of brands. Functional reasons (protect, re-closable etc.) and appearance reasons (nice print, nice colours) were claimed for giving this package high ratings.

**Keywords:** Perception; Material identity; Packaging design; Eco friendliness; Functionality.

Paper ID = 140, Session TC2, Room 1105

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## CRUMPLING OF PAPER SHEET AND PACKAGING

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Crumpling is now a method derived of the origami techniques that transforms a single paper sheet into a three-dimensional structure by a systematic generation of random folds. The resulting crumpled object is an innovative answer to packaging industries that need attractive and dynamic products in a sustainable context. In order to understand the performances of crumpled structures and their applications in the field of packaging. The specific crumpling techniques developed by CRIMP create organized crease patterns very similar to those observed in nature, allowing attractive dynamic objects for packaging applications. In a sustainable context, the expected environmental performances depends on the elasticity property that provides a simplified transportation in a minimum of space, it also depends on the crumpling process that needs no gluing or cutting activities, and also from the agro-resources that constitute the raw material of the paper sheet for a simplified recycling. New investigations based on empirical experiences performed by CRIMP show that crumpled folds networks fall into three main categories: random, parallel, radial. We have shown using cushion curves that both the thickness and the bending mode provided different damping powers. Comparing them to corrugated single flute cardboard b and c, we could note a broader spectrum for less matter. These results are consistent with the values obtained with polyurethane. It is thus possible to associate lightness, environment and protection.

**Keywords:** crumpling; eco-design; cushioning material.

Paper ID = 141, Session TC2, Room 1105

## **PACKAGING FOR FOOD & AGRICULTURE**

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## MIGRATION OF PLASTICIZERS FROM PAPER AND BOARD INTO FOOD SIMULANT TENAX AND OLIVE OIL DURING MICROWAVE COOKING

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Nan Wang - Jinan University, China  
Jianwen Wu - Jinan University, China  
Zhi-Wei Wang - Jinan University, China

Paper and board are one of the most important food packaging materials. Microwave heating is a widely used food heating method. The migration of the phthalates (PAEs) from paper packaging into food simulants during microwave heating was investigated. 13 kinds of local paper samples were treated using accelerated solvent extraction (ASE) and the concentration and type of PAEs in them were determined by GC-MS. The kinetic migration of PAEs from microwave paper to Tenax and olive oil was studied at different microwave power, respectively. At the initial stage, the migration to both simulants followed the same trend. When the migration reached a certain degree, the migration percentage decreased for Tenax, while remained almost the same for olive oil.

**Keywords:** migration; paper and board; microwave heating; accelerated solvent extraction; phthalates; GC/MS; olive oil; Tenax.

Paper ID = 16, Session TA3, Room 1107

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## THE EFFECT OF PACKAGING ON CONSUMER FOOD QUALITY PERCEPTION IN QUICK-SERVICE RESTAURANTS

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The majority of menu items available in quick-service restaurants (QSR) are consumed directly from a container or package. The main reasons consumers choose to eat fast food are because it is convenient, prepared quickly, a good value, and inexpensive. Therefore, the packaging becomes an integral part of the food product and from a consumer perspective must be consistent with their expectations and motives for choosing to eat fast food. Prior research has directly linked characteristics of consumer food packaging experience to their perception of its contents. The purpose of this research is to determine if consumer quality perception of food products in quick-service restaurants varies depending on the material properties of the packaging in which the food product is presented. The commonly used foodservice packaging styles and materials selected for testing included: a 14-pt paperboard clamshell, an expanded polystyrene clamshell, an F-flute (micro-flute) corrugated clamshell, and a paper wrap. All materials were tested in a realistic QSR environment. Sensory, functionality, and credence attributes were evaluated by participants. Preference and ranking response data was also collected. A questionnaire was used to measure participant response. Findings from the research indicate that while the sensory attribute ratings did not differ significantly, respondents had significant preference for certain package materials based on functionality and credence attributes, and perceived certain materials as more suitable for certain food products.

**Keywords:** packaging; food quality perception; quick-service restaurants; fast food.

Paper ID = 25, Session TA3, Room 1107

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**DETERMINATION OF TI IN NANO/SUBMICRO-TiO<sub>2</sub>-PLASTIC COMPOSITE FOOD PACKAGING BY  
MICROWAVE DIGESTION AND INDUCTIVELY COUPLED PLASMA ATOMIC EMISSION  
SPECTROMETRY OR INDUCTIVELY COUPLED PLASMA MASS SPECTROMETRY**

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Zhi-Wei Wang - Jinan University, China

The determination of Ti in nano/submicro-TiO<sub>2</sub>-plastic food packaging by microwave digestion with inductively coupled plasma atomic emission spectrometry (ICP-AES) and inductively coupled plasma mass spectrometry (ICP-MS) has been studied. Microwave digestion was optimized by trialling different acid mixtures. Both ICP techniques showed good reproducibility, repeatability and recovery. For ICP-AES analysis, the limit of detection (LOD) was 5.0 mg kg<sup>-1</sup>, the analytical range was 100–5000 g L<sup>-1</sup>, the average recoveries for blank samples spiked with Ti were in the range of 94.7–100.1%, and the relative standard deviations (RSDs) were from 2.1% to 7.1%. For ICP-MS analysis, the LOD was 0.3 mg kg<sup>-1</sup>, the analytical range was 0.5–200 g L<sup>-1</sup>, the recoveries were 88.4–96.3% and the RSDs were 6.3–7.4%. These results indicated that proposed methodologies were effective for the determination of Ti in nano/submicro-plastic food packaging.

**Keywords:** microwave digestion; food composite packaging; nano/submicro TiO<sub>2</sub>; inductively coupled plasma atomic emission spectrometry (ICP-AES); inductively coupled plasma mass spectrometry; (ICP-MS).

Paper ID = 26, Session TC1, Room 1101

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## DETERMINATION OF FOUR TYPES OF HAZARDOUS CHEMICALS IN FOOD CONTACT MATERIALS BY UHPLC-MS/MS

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A simple ultrahigh-performance liquid chromatography-tandem mass spectrometric (UHPLC-MS/MS) method for the identification and quantification of two photoinitiators: 4-methylbenzophenone and 2-ethylhexyl-4-dimethylamino benzoate; nine plasticizers including di(2-ethylhexyl) adipate and diisobutyl adipate; three primary aromatic amines: 4-aminobiphenyl, 4-amino-2',3-dimethylazobenzene and bis-(4-aminophenyl) methane; and six bisphenols: bisphenol F diglycidyl ether, bisphenol A diglycidyl ether, bisphenol A (BPA), bisphenol B (BPB), bisphenol E (BPE) and bisphenol F (BPF) in food contact materials has been developed. The chromatographic conditions, pretreatment methods and matrix effects were studied and optimised. For determination of the four bisphenols, BPA, BPB, BPE and BPF, the UHPLC method employed a mobile phase of aqueous ammonia and methanol in binary gradient mode and measurement was based on a triple quadrupole mass spectrometer equipped with an electrospray ionisation (ESI) source operating in negative ion mode. The remaining chemicals were determined using the ESI source in positive ion mode and using the  $[M+NH_4]^+$  or  $[M+H]^+$  adducts as precursor ions for tandem mass spectrometry. The calibration graphs were linear with correlation coefficients of 0.995. Detection limits for the method were in the range of 1–16 g kg<sup>-1</sup>. Analyte recoveries were in the range of 70–114% and relative standard deviations (RSDs) were 1–14%. Under optimised conditions, the chromatographic separation was performed in 12 min. The validation data indicated that the method was effective for the determination of the four classes of hazardous chemicals in plastic packaging materials or in can lacquers. The optimised method was successfully applied to trace analysis of commercially available food contact materials.

**Keywords:** LC/MS; food contact materials; food stimulants; BADGE; packaging; DEHP.

Paper ID = 27, Poster session

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## MODELLING OF MIGRATION FROM PRINTING INKS ON PAPER PACKAGING AND ITS VERIFICATION

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The migration model of the contaminants from the inks on the paper packaging to the food was developed based on the penetration of the ink in the paper and Fick's diffusion. The printed paper was divided as ink layer and paper layer. At the beginning the distribution of the contaminant in the paper layer was gradient. Mass transfer coefficient  $h_m$  and partition coefficient  $K_{F,P}$  in the interface between food and paper were considered. The model was dissolved by the method of separation of variables. Mass transfer coefficient of dibutyl phthalate (DBP) at 50 was obtained by the model based on the partition coefficient obtained by the experimental data and diffusion coefficient obtained by Brandsch model. It was assumed that mass transfer coefficient was independent of the temperature.  $h_m$  at 50 was used in the model to predict the migration behavior at 70 and 100. Because bis(2-ethylhexyl) phthalate (DEHP) and di-n-octyl phthalate (DOP) are isomer, the diffusion coefficients  $D_P$  obtained from Brandsch model are the same, therefore the difference in their migration behavior can't be expressed. Proper  $h_m$  can be chosen to improve the predictive ability of DEHP and DOP. The prediction of the model was investigated at different paper grammage and initial concentration of the contaminant. There was good agreement between the predicted and experimental values, indicating the reliability of this model.

**Keywords:** printing inks; plasticizers; paper packaging; migration; migration modelling.

Paper ID = 32, Session WA1, Room 1101

**GLUCOAMYLASE TIME-TEMPERATURE INDICATORS BASED ON FAT OXIDATION OF CHILLED PORK**

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Guanglin Zheng - Jiangnan University, China  
Qing Feng - Jiangnan University, China

The dynamics property of three glucoamylase type TTIs was studied and the activation energies of three kinds of TTIs were achieved. The research on the fat oxidation of chilled pork gives its activation energy and shelf life. According to the activation energy and ending point matching principle between TTI and the perishable, the matching experiments were set up both in constant and variable temperature. One of the glucoamylase TTI was selected to predict the shelf life of chilled pork accurately based on experiments and following calculation.

**Keywords:** time-temperature indicator; glucoamylase; activation energy; chilled pork; fat oxidation.

Paper ID = 47, Session TA3, Room 1107

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## THE FLEXIBLE PACKAGING LINE – PICKNPACK

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Alexander Bardenstein - Danish Technological Institute, Denmark

In the 12 mill. € European Union financed project under FP7 the PickNPack concept offers the food industry the benefits of automation – cost reduction, greater hygiene and more efficient use of resources – combined with the unique ability to adapt to the product and batch size at hand. PickNPack will give the food industry a vital competitive advantage in the rapidly changing marketplace of the future, where customers demand more quality, more choices and more safety at lower prices. The project will develop three types of modules that can cope with the typical variability of food products and the requirements of the sector regarding hygiene, economics and adaptability, which will be working closely together:

1. A sensing module that assesses quality of the individual or small batch products before or after packaging.
2. A vision controlled robotic handling module that picks up and separates the product from a harvest bin or transport system and places it in the right position in a package.
3. An adaptive packaging module that can accommodate various types of packaging with flexibility in terms of package shape, size, product environment, sealing and printing.

These modules connect to a multi-point framework for flexible integration into a production line that optimally makes use of the capabilities of the modules. The communication is based on a shared, vendor-independent vocabulary. The combination of modules will be with a user-friendly interface and all modules are equipped with automated cleaning systems to ensure hygiene. All available information in the production chain and the information produced by the sensors in the system is combined, stored and made available to the different modules and both upstream and downstream in the chain. With added intelligence, this will lead to maximum performance in quality, reducing change over time, reducing time for reprogramming, adaption to operators, reducing waste of food and packaging material and stock. Human intervention will be reduced to a minimum. The presentation will focus on the adaptive packaging module that can accommodate various types of packaging with flexibility in terms of package shape, size, and product environment, sealing and printing. The scope is to develop an ultimate flexible system able to produce product batches down to 1-100 packs on a batch with almost no need of time to change and reduce lead time from design to production to 5-10 minutes. The system includes an active heating system for heating food in microwave ovens.

**Keywords:** Flexible packaging line; short lead time; small batches; food packaging; flexible decoration; active packaging for heating; microwave oven.

Paper ID = 50, Session WA1, Room 1101

## SULFIDE BLACK IN CANNED MEAT

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Sulfide black and sulfide staining are generic terms used to define the bleaching occurring inside the cans during food packaging. It occurs due to the reaction between sulfur products and some components of the package, such as tin or iron, forming sulfides with brown, black or purplish color. Although it is not dangerous to human health, not changing flavor, odor or the nutritional value of the product, and does not lead to package failures, sulfide staining changes the appearance of the product and its packaging, causing strong negative impact on packaged products, among which stands out the canned meat. This study aimed to evaluate sulfide black formation upon different process parameters variations (tin layer, cure of lacquer applied inside, presence or absence of superficial scratches in the lacquer, sterilizing time and temperature and filling temperature) by analyzing the composition of the black spots using the techniques of infrared spectroscopy, scanning electron microscopy (SEM) and X-ray microanalysis by energy dispersive (EDX). The characteristics of the steel can exposure through the porosity of the lacquer and the tin layer are also evaluated. The results of SEM and EDX showed that there was exposure of metallic material and the region of the cans with a higher incidence of black spots was the curvature or radius of the lid in the countersink region and spectral microanalysis showed the presence of P and Cl in the stains, indicating a probable relationship of these elements with the sulfide black reaction. Attenuated total reflectance Fourier transform infrared spectrometry (ATR-FTIR) affords a lot of structural information in order to evaluate the organic part of the different products. It shows that there are differences between regions with and without the presence of sulfide black associated to the carbonyl group bonds characterized by C = O and the center N. In additional, it was possible to conclude that the techniques are suitable tools in the sulfide black evaluation.

**Keywords:** sulfide black; corned beef; canned meat; metallic packaging; SEM/EDX; ATR – FTIR.

Paper ID = 56, Poster session

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## PACKAGING FOR CONTROLLING TEXTURE OF FROZEN MICROWAVEABLE SANDWICHES

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A generic packaging concept for re-heating of frozen microwaveable sandwiches allowing the retaining of the bread original dual texture (crispy exterior–soft interior) is proposed and tested. The packaging comprises two main functional components: First, an internal packaging, which is a perforated cardboard microwave susceptor box with built-in metal film coil that is thick enough to displace the microwave field. Second, an external packaging, which is a sealed heat-insulating box or bag (e.g. a corrugated carton or a laminated paper wrapping). Each of these inherent components carries a whole number of functions determined by thermal and dielectric properties of a microwaved sandwich. As a packaging unit, they prevent ‘water pumping’ and staling phenomena in the re-heated bread achieving at the same time homogeneous heating of all components of a sandwich. This concept has been particularly embodied in tailor-made packaging solutions for several kinds of frozen sandwiches that include top and bottom bread, cheese, bacon, sausage patty or burger, and egg patty. This kind of sandwiches is a nutritious yet convenient breakfast and lunching option that is popular in many countries, especially in the United States. Fully cooked and assembled frozen sandwiches are as a rule meant for both conventional- and especially microwave-oven reheating. Microwaving gives consumers the highest convenience though and becomes increasingly demanded in our pressed-for-time world. In the microwave oven, these sandwiches, however, often fall short of providing proper bread texture and with it even temperature distribution in the sandwich. In particular, it is the frozen egg patty that presents a challenge in the microwave oven. Monitoring of temperature in components of a ‘bare’ microwaved frozen sandwich reveals that the core temperature of the egg patty hardly reaches 30°C (86°F) at the moment when the bread temperature has already reached 100°C (212°F). Obviously, a desperate attempt to reach the temperature of 75°C (or ~165°F) required for safe consumption, simply by extending heating, results in deterioration of bread texture because of evaporation of moisture. The developed packaging solutions tackle this difficulty by local increase of the microwave field strength in the egg patty and formation of the hot air environment (around 150°C or ~ 300°F) in the sealed packaging thereby giving microwaved sandwiches similar quality as freshly baked.

**Keywords:** frozen sandwiches; egg patty; microwave packaging.

Paper ID = 70, Session MB2, Room 1105

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**EFFECT OF PROPOLIS EXTRACT ON PHYSICAL AND ANTIOXIDANT PROPERTIES OF CHITOSAN FILM**

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This research aimed to study the effect of Thai propolis on physical and antioxidant properties of chitosan based film. Thai propolis extract was prepared by using 60:40 water to ethanol solution. Different concentrations of the propolis extract including 0, 2.5, 5 and 10% (w/v) were added into the chitosan film-forming solution. Chitosan film without propolis extract was used as control. Physical properties including surface color ( $L^*$ ,  $a^*$ ,  $b^*$ ), water vapor permeability (WVP), tensile strength (TS), and elongation at break (%E) were measured. Antioxidant properties including total phenolic content (mg gallic acid equivalent/g) and radical scavenging activity were determined using Folin-Ciocalteu method and 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity, respectively. The results showed that E, TS, %E of the film increased, while %T and WVP decreased with concentration of the propolis. Total phenolic content and DPPH increased with concentration of the propolis.

**Keywords:** propolis; chitosan film; antioxidant.

Paper ID = 88, Session TC1, Room 1101

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## EFFECTS OF IN-PACKAGE ATMOSPHERE ON TEMPORAL CHANGES IN THE FRACTIONATION OF OXYGEN ISOTOPES DURING RESPIRATION IN TOMATOES

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Oxygen molecules that diffuse into biological cells are utilized by mitochondrial enzymes such as cytochrome c oxidase (COX). This reaction is required to oxidize the protons produced during oxidative phosphorylation, resulting in the generation of adenosine 5-triphosphate (ATP), an energy-rich compound. Plant cells utilize an alternative pathway to oxidize protons without generating ATP through the action of alternative oxidase (AOX). This enzyme preferentially acts on  $^{32}\text{O}_2$  over  $^{34}\text{O}_2$ , and this tendency is stronger than that observed in case of COX. Moreover, AOX activity has been reported to increase with an increase in the respiratory rate. Modified atmosphere packaging (MAP) is a popular method of storing horticultural products by depressing respiratory rate. These findings suggest that AOX activity of products that have been sealed in a pouch is influenced by their respiratory rate. However, there have been no reports describing  $\text{O}_2$  consumption by AOX during storage under MAP. Therefore, in the present study, the effects of in-package atmosphere on AOX activity of tomatoes that were packaged in pouches were evaluated on the basis of temporal changes in the fractionation of  $\text{O}_2$  isotopes. Two types of micro-perforated film pouches were prepared to create two levels of in-package  $\text{O}_2$  concentrations. Two tomatoes were sealed in a micro-perforated film pouch and stored at 15°C or 25°C. Changes in in-package  $\text{O}_2$  and  $\text{CO}_2$  concentrations were monitored using a gas chromatograph equipped with a thermal conductivity detector. Changes in the fractionation of  $\text{O}_2$  isotopes were measured using a mass spectrometer. The fractionation of  $^{34}\text{O}_2$  increased with increasing in-package  $\text{O}_2$  concentrations, suggesting that AOX activity increases with increasing  $\text{O}_2$  concentrations or  $\text{O}_2$  uptake rate. Thus, AOX activity may affect the respiratory rate and shelf life of tomatoes stored under MAP.

**Keywords:** alternative oxidase; modified atmosphere packaging; stable isotope.

Paper ID = 89, Session TC1, Room 1101

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## **AN INNOVATIVE CORRUGATED SHIPPER TO IMPROVE PALLETIZED LOAD AIRFLOW FOR FRESH PRODUCE**

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Jay Singh - Cal Poly State University, United States

The best possible quality of any fresh produce exists at the moment of harvest. Beyond this point quality cannot be improved, only maintained. Deterioration of fresh commodities can result from physiological breakdown due to natural ripening processes, water loss, temperature injury, physical damage, or invasion by microorganisms. All of these factors can interact, and all are influenced by temperature. This research studied the effectiveness of an innovative corrugated fiberboard shipper design towards air flow, and hence temperature maintenance, for palletized loads of baby carrots and bananas. Test palletized loads constructed using the new shipper design were compared for temperature performance against control loads constructed of commonly deployed existing shipper styles. All palletized loads were instrumented with temperature monitors and were subjected to field trials in distribution channels from packinghouse to storage to destination markets. Both fresh produce types were able to maintain better air flow and lower product temperature for the test loads as compared to the control loads.

**Keywords:** fresh produce; post harvest; cooling; airflow; corrugated fiberboard.

Paper ID = 95, Session TA3, Room 1107

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## DEVELOPMENT OF A FRESHNESS INDICATOR FOR MONITORING CHICKEN MEAT FRESHNESS

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Food waste has acquired dimensions that must be considered as a worldwide problem that affects all the food supply chain from farm to fork. In Europe, total food waste is estimated in 89 million tonnes per year. The Waste and Resources Action Programme (WRAP) found that over a quarter of avoidable food waste was thrown away whole or still in its packaging [1]. One reason is because current product expiry dates are conservative. That means that to prevent food-borne illness and assure food quality, products show a shorter shelf life than the shelf life that they really have so, hundreds and hundreds of tonnes of safe food are wasted each year. The development of intelligent packaging solutions could be a tool for reducing it. To be precise, the development of a freshness indicators that will inform about the real shelf life of each individual product according to their microbial loads and degree of freshness, will allow to print longer shelf lifes on the products. A freshness indicator for monitoring chicken meat freshness has been developed in SENSOPACK project. This technology will inform in an easy way about the real shelf life of packed fresh chicken meat products. This indicator uses a solvent based flexographic ink. This ink is formulated using a reactive indicating compound, instead of common dyes or pigments. The indication compound is a metallic salt, which is allowed to be used in food contact applications. The initial colour of the metallic salt is blue. When sulphur volatile compounds are generated during the chicken breast spoilage, the metallic salt reacts with them and metal sulphide is generated, which colour is black. As the more spoiled the meat product is, the darker the indicator colour is, so the indicator colour is related with the degree of freshness of the meat product.

### Acknowledgements

Authors would like to thank the SENSOPACK consortium and the financial support by Spanish Ministry of Economy and Competitiveness (MINECO) and European Commission for the Project SENSOPACK - IPT-020000-2010-014.

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**Keywords:** Intelligent packaging; Freshness indicator; Monitoring fresh chicken meat quality; Smart packaging; Colorimetric indicator; Visual change; Visual indicator; Smart inks; Reactive compounds; Freshness ink.

Paper ID = 101, Session MB2, Room 1105

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## **IF AT FIRST YOU DON'T SUCCEED: OLDER CONSUMERS AND HOSPITAL FOOD & BEVERAGE PACKAGING – A MATTER OF TRY, TRY AND TRY AGAIN!**

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'Openability' of food and beverage packaging has been shown to be problematic for older consumers. Pressure on resources has seen the use of packaged food and beverages increase in Hospitals within the NSW region of Australia. Studies at the University of Wollongong have shown that not only is Hospital food & beverage packaging problematic, difficulty opening it was identified as a barrier to nutritional intake. Given the serious nature of the problem, a series of studies have been undertaken by the University of Wollongong and Sheffield Hallam University, to evaluate the issues surrounding the 'openability' of this packaging in an attempt to understand in detail the issues leading to difficulty in use. Amongst the poor performing packs were seen to be water bottles, drink cartons and cheese portions. Whilst issues surrounding strength were seen to be linked to accessed to bottled water, all other pack types were significantly affected by dexterity and in particular the fine control needed to pinch and peel tabs or remove drinking straws. Sound ergonomics indicates that products should be designed for the user population, yet the experience of our consumers indicates that this is not necessarily the case. Work is ongoing to understand in more detail the effects of ageing such a reduced dexterity on packaging 'openability' as well as the effects of age and posture. The eventual aim of this work is to collaborate with packaging designers, manufacturers and brand owners to develop and produce effective and reliable packaging for both the healthcare and retail environments.

**Keywords:** older consumer; food & beverage packaging; ergonomics.

Paper ID = 108, Session MB2, Room 1105

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## EQUILIBRIUM MODIFIED ATMOSPHERE PACKAGING FOR PRESERVING QUALITY AND EXTENDING SHELF-LIFE OF LONGAN

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Longan is non-climacteric which deteriorates rapidly unless proper handling techniques are employed. The major factors reducing the storage-life of longan are microbial decay and pericarp browning. Equilibrium modified atmosphere (EMA) packaging with different oxygen transmission rate (OTR) was developed to create optimum atmosphere inside the package for extending storage-life of longan. Sulfur dioxide (SO<sub>2</sub>) fumigation was applied to pre-packaged longan for preventing fruit rot. A package size of 18 cm x 25 cm was used for 450 g packed fruit. The type of packages under this study are plastic net bag (Control), polyethylene film with OTR of  $2,551 \pm 123 \text{ cm}^3 \cdot \text{m}^{-2} \cdot \text{d}^{-1}$  (B2500) and polyethylene film with OTR of  $6,056 \pm 244 \text{ cm}^3 \cdot \text{m}^{-2} \cdot \text{d}^{-1}$  (B6000). Packaged longan was then stored at 2°C. Different quality attributes such as weight loss, total soluble solids and SO<sub>2</sub> residue in both longan pericarp and flesh were determined at regular intervals. Fruit stored at 2°C retained quality up to 15, 20 and 40 d in control bag, B6000 package and B2500 package, respectively. Both EMA packaging of SO<sub>2</sub>-treated fruits resulted in a reduction of weight loss ( $0.42 \pm 0.05\%$ , as compared with  $16.43 \pm 1.86\%$  when stored in plastic net (control)) for the same period of time. Prevention of browning and retention of good color were obtained in the EMA packaging. It was also found that the reduction rate of the SO<sub>2</sub> in the longan flesh packaged in B2500 packaging was slower than that of the fruit packaged in B6000 bag and control bag (plastic net) resulting in delaying fruit decay and eventually extending the shelf-life of the longan. The humidity level inside the package was shown to differently affect the SO<sub>2</sub> residue on the longan flesh.

**Keywords:** longan; modified atmosphere packaging; storage-life.

Paper ID = 115, Session TC1, Room 1101

## DEVELOPMENT OF TIME-TEMPERATURE INDICATOR BASED ON POLYDIACETYLENE/SILICA NANOCOMPOSITE FOR MONITORING FRESH SKINLESS CHICKEN BREAST QUALITY

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A novel new colorimetric time-temperature indicator (TTI) based on polydiacetylene (PDA) and silica nanoparticles were investigated and developed for monitoring spoilage of fresh skinless chicken breast. An irreversible color change of a PDA/SiO<sub>2</sub> nanocomposite as a colorimetric indicator occurs due to temperature change. Temperature which is one of the most critical factors can affect the quality of food products, especially chilled and frozen foods, during transportation, distribution and storage. PDA is widely known for excellent color transition from blue to red upon temperature and other external stimuli. For an incorporation of silica nanoparticles, a functional group of silica nanoparticles can form a strong ionic interaction with a carboxylic groups head groups of PDA vesicles and can occur the stability of PDA structures. To formulate PDA/SiO<sub>2</sub> nanocomposite-based TTI label, a suspension consists of a blue-colored PDA/SiO<sub>2</sub> nanocomposite solution, poly(vinyl alcohol) (PVOH) as matrix polymers, and plasticizer. A mixture of Pluronic F127 and poly(ethylene glycol-400) (PEG-400) was used as plasticizer. The PEG-400-added PDA/SiO<sub>2</sub> embedded PVOH film showed initially purple color due to a plasticizer impact upon the stability of PDA structures. The PEG-400-added PDA/SiO<sub>2</sub> film was attached on a fresh skinless chicken breast's package and kept at 4 and 10 °C. Carbon dioxide (CO<sub>2</sub>) was used as spoilage metabolite because the amount of CO<sub>2</sub> increased during storage time. Its color changes, in terms of total color difference (TCD or E) indirectly correlated with CO<sub>2</sub> levels of skinless chicken breast. At 10 °C, the CO<sub>2</sub> levels rapidly increased in the package, in turn, a purple-to-red color change was faster in comparison with the treatment storing at 4 °C. Therefore, this polymer-based TTI prototype could be used as an effective tool for monitoring the quality of fresh skinless chicken breast.

**Keywords:** Time-temperature indicator; Polydiacetylene; Silica nanoparticle; Chicken; CO<sub>2</sub>.

Paper ID = 122, Session MB2, Room 1105

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## RESPONSE MODELLING OF TIME-TEMPERATURE INDICATOR BASED ON POLYDIACETYLENE/SILICA NANOCOMPOSITE

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The development of time-temperature indicator (TTI) based on polydiacetylene (PDA) and silica nanoparticles as an effective tool was investigated. With a time-temperature change, a PDA/SiO<sub>2</sub> nanocomposite could irreversibly change from blue to red color under a color transition temperature of PDA vesicles (>60 °C). However, the addition of plasticizer into PDA/SiO<sub>2</sub> nanocomposite embedded in poly(vinyl alcohol) (PVOH) film did not exclusively increase flexibility during film formation, but it reduced the color transition temperature of PDA/SiO<sub>2</sub> films as well. Hence, it could be suitably applied with the chilled food products. The plasticizer could be possibly inserted into a PDA vesicle structure and its mobility occurred, thus the initial color of plasticized PDA/SiO<sub>2</sub> film was shifted from blue to purple. In this research, the different TTIs prepared from three types of plasticizer were poly(ethylene glycol-400), glycerol and sorbitol-added PDA/SiO<sub>2</sub> films. Both constant temperature profile and dynamic temperature profile were designed in this study. The mathematical model of TTI revealed the relationships between the changes of time and temperature and the TTI's color changed in terms of total color difference (TCD or E). Higher temperature at isothermal condition was presented in a faster color change from blue to purple, reddish purple and finally red. Moreover, it could be determined Arrhenius kinetics parameters of the TTI system as a function of temperature. For dynamic thermal condition, the recorded data was TTI-response modelled and calculated the effective temperature (T<sub>eff</sub>) and the remaining shelf life (t<sub>r</sub>) of TTIs. Finally, it showed potentially the applicability and usefulness of TTI for chilled food distribution, and this new polymer-based TTI used as a reliable device could exhibit time-temperature history.

**Keywords:** Time-temperature indicator; Polydiacetylene; Silica nanoparticle; Activation energy; Shelf life kinetics.

Paper ID = 123, Session WA1, Room 1101

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## DEVELOPMENT OF A BIODEGRADABLE COATING BASED ON SEAWEED EXTRACTS AND STARCH FOR FOOD PACKAGING APPLICATIONS.

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Paper and cardboard are sustainable food packaging alternatives since they are highly recyclable materials. In order to achieve better barrier properties, there is a high interest in the improvement of their water and oil resistance by the application of coatings based on petrochemical derived waxes and polymers. However, due to the increasing petroleum costs, the packaging sector is looking for alternatives of reliable and sustainable coating products [1] reducing the economic cost of recycling or improving the paper compostability. In this sense, starch and seaweed extracts are friendly biopolymers capable to improve the functional properties of the cellulosic packaging material at the same time they can extend shelf life of the packaging material [2]. However, their poor barrier properties limit its application as food packaging, particularly in the presence of water and grease. In order to improve the grease properties of paper and paperboard, PLANTPACK project has developed a biodegradable coating based on seaweed extracts combined with starch. The application of these formulations on the substrates resulted in coatings that gave excellent grease resistance. The mechanical behaviour of the paper and cardboard samples and its biodegradability and compostability is not affected by the application of the coating dissolution. From the results obtained, it is important to highlight that this new package will reach conventional synthetic multilayer materials in specific products applications opening a new market opportunity for all the SMEs and RTDs involved in the consortium.

### Acknowledgements

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**Keywords:** BIODEGRADABLE COATING; PAPER AND PAPERBOARD; SEAWEED EXTRACT/STARCH COATING; FOOD PACKAGING.

Paper ID = 129, Poster session

## **PACKAGING MATERIALS**

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## EVALUATION OF STATIC AND DYNAMIC CUSHIONING PROPERTIES OF POLYETHYLENE FOAM FOR DETERMINING ITS CUSHION CURVES

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Vincent Rouillard - Victoria University, Australia

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A comparison of static and dynamic cushioning properties is discussed in this paper. A variable dynamic stress and dynamic factor functions are defined and obtained from the analysis on the experimental data from compression and cushion tests. Then the total instantaneous stress during impacts can be approximated by the static compression data multiplied by the dynamic factor function. This research can assist in determining the accuracy of cushion curves from the dynamic factor function of special cushioning material and compression test data. This new procedure will greatly simplify the experimental process for determining cushion curves.

**Keywords:** Cushion curve; Dynamic effect; Compression; Impact; Polyethylene Foam.

Paper ID = 5, Session MC2, Room 1105

## OUTDOOR WEATHERING OF HDPE CONTAINERS FILLED WITH NITRIC ACID

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Uncoloured high-density polyethylene (HDPE) jerrycans were exposed outdoors, for one Berlin summer season. They were filled with nitric acid (HNO<sub>3</sub>), water or air, and half of them were protected from sunlight by an UV absorbing canvas. Thus the separate effects of UV radiation and nitric acid could be compared to the combined impact. Combined impact was mainly affected by decomposition of nitric acid, resulting in presence of reactive nitrogen oxides, increased oxygen partial pressure, and UV radiation energy, simultaneously in vapour phase. To investigate the degradation effects, jerrycans were exposed to a so called hydraulic internal pressure test, after the outdoor exposure. After combined impact of UV radiation and nitric acid, internal pressure tests show very fast failures, whereas after separate impacts no remarkable deteriorations are observed, compared to unaged jerrycans. Samples of the degraded containers were investigated by colour measurements and UV-VIS spectroscopy. Relating to whole components, colour change in the form of lightness increase L correlates very well with these failures. In contrast, yellowing only indicates nitric acid exposure. Thus, it is essential to focus on milkiness due to microcracks, in mandatory regular visual inspections which are particularly sensitive to yellowing.

Considering local effects, after combined exposure, visually most damage was noticeable in amorphous regions of the jerrycans, whereas mechanical failure occurred in strongly drawn edges.

The combined exposure was found to be much harder than the sum of the separate UV and nitric acid exposures, revealing synergistic effects.

**Keywords:** high-density polyethylene HDPE; nitric acid HNO<sub>3</sub>; UV radiation; outdoor exposure; weathering.

Paper ID = 9, Session MB1, Room 1101

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## THE EFFECT OF A VIBRATION FORCE FIELD ON THE CRYSTALLIZATION AND BARRIER PROPERTIES OF POLYMER NANOCOMPOSITES

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High-density polyethylene (HDPE)/nano-SiO<sub>2</sub> and polypropylene (PP)/nano-SiO<sub>2</sub> films have been prepared by two different processing conditions; i.e., under traditional steady state (TSS) and with a vibration force field (VFF). In this paper, we mainly studied the crystallization and barrier properties of films manufactured under different processing conditions. The results showed that the barrier, crystallization and mechanical properties of the nanocomposites processed under the VFF condition were superior to those processed under the TSS condition. Differential scanning calorimetry (DSC) and scanning electron microscopy (SEM) were used to characterize the crystalline structure and morphology of the films which provided evidence for the explaining the distinct barrier and mechanical properties under the two processing conditions. DSC and SEM results clearly showed that an increase in the degree of crystallinity and orientation of the lamella were found in the nanocomposites prepared under the VFF condition.

**Keywords:** vibration force field; crystallization; barrier properties; lamella; orientation.

Paper ID = 13, Session WA2, Room 1105

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## THE EFFECT OF HEATING SPEED ON THE EXPRESSION OF HEAT SEAL STRENGTH IN PLASTICS PACKAGING MATERIALS.

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Heat sealing is an indispensable technique for the use of plastic packaging materials. Heat seal bonding can be easily completed by heating and cooling. It has been believed for the past half century that "heat sealing strength" can be adjusted in two dimensions by adjusting "heating temperature". Based on this "conventional wisdom, the author also believed that proper heating is indispensable to effective heat sealing for the past two decades. The "MTMS" method that measures the temperature on the bonding layer directly was developed. [1] Although development of accurate heat sealing was attempted, the lack of agreement for data on expression of heat sealing strength was not resolved. The results of application of high precision temperature measurements to precise control of heating temperature has shown that "heating speed" greatly influences heat sealing strength. It was shown that this phenomenon is common to polyolefin materials. A detailed analysis of the measurement method, details of the phenomenon and heating speed is presented in this paper. It has been shown by these analyses that heat sealing is a three dimensional phenomenon of melting surface temperature, heating time and heat sealing strength. And, the phenomenon was distinctly expressed within the range of regularly used speeds. It has been shown that the measurement of the melting surface temperature response including speed information will be indispensable in the evaluation of the heat seal phenomenon in the future. This phenomenon was named the "Hishinuma Effect". The mechanistic analysis of the expression phenomenon has not been completed. However, it has been inferred that distribution of molecular weights in the material is involved from experimental data.

This discovery provides information that will contribute to improvement in the field of packaging machinery technology and material technology that depend on heat sealing technology.

**Keywords:** heat sealing; heat sealing strength; Openability; Closability; peel sealing; Heating Speed; MTMS; CUT; "Hishinuma Effect"; ASTM; minute sensor.

Paper ID = 28, Session MC2, Room 1105

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## MAXIMUM GAUGE PRESSURE IN DANGEROUS GOODS PACKAGINGS UNDER NORMAL CONDITIONS OF CARRIAGE - COMPARISON OF DIRECT MEASUREMENT AND CALCULATIONS

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The aim of this experimental work was the measuring of the maximum gauge pressure in the vapour phase above the liquid in different design types of dangerous goods packagings under normal conditions of carriage. The scenario of intercontinental transport of dangerous goods packagings in freight containers was assumed as normal conditions of carriage. The design types investigated were steel and plastics packagings with a volume of approximately 6 l. Dichloromethane was used as a filling substance because it belongs to the most important transported substances relating to their quantitative amount and has a relatively high vapour pressure. The pressure inside the packaging filled with dichloromethane was directly measured using data loggers in the vapour phase. The test was performed under simulated conditions of carriage (degree of filling: 90 %; filling temperature: 15 °C; temperature during storage: 31 °C). The maximum measured gauge pressures inside the packagings were between 89 mbar for a light plastic jerrican and 336 mbar for a steel drum. The calculated value for a rigid receptacle is 553.5 mbar for the same scenario. The results show that the gauge pressures which can occur during normal conditions of carriage can be above the level for the leakproofness test of dangerous goods packagings prescribed by the international UN Model Regulations article 6.1.5.4 (200 mbar for packaging group II and III; 300 mbar for packaging group I). They are covered by the level prescribed for the internal pressure (hydraulic) test according to UN Model Regulations article 6.1.5.5.4 b) which requires a test pressure of 150.000 kPa (1500 mbar) for dichloromethane.

**Keywords:** dangerous goods packagings; gauge pressure; overpressure; dichloromethane; data loggers; normal conditions of carriage.

Paper ID = 29, Session WA2, Room 1105

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## PREPARATION AND CHARACTERIZATION OF LOW METHOXYL PECTIN/CARBOXYMETHYL CELLULOSE-BASED MMT COMPOSITE FILMS

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Recently, there is an increasing interest of using biodegradable, renewable and edible materials to prepare food packaging films. Pectin and Carboxymethyl Cellulose (CMC) have been used to prepare edible/biodegradable films and coating. However, their using is limited due to the poor mechanical properties of pectin and lower water barrier property of CMC. The aim of this study to improve the mechanical properties of pectin and water barrier property of CMC and by preparing the Low Methoxyl Pectin/CMC-based nano-montmorillonite (LMP/CMC-MMT) composite films with different proportion of LMP and CMC and different content MMT (0-8%). The mechanical properties (e.g. tensile strength (TS) and elongation at break (EAB)), color, transparency and water vapor permeability (WVP) of LMP/CMC-MMT composite films were investigated. The maximum of TS of the composite films was 252% of that of the pure LMP film due to the formation of hydrogen bonds proved by fourier transform infrared spectroscopy (FTIR). With the addition of CMC and nano-MMT to the pure LMP film, the EAB decreased slightly. The maximum reduction of WVP of the composite films was 333% of that of the pure CMC film because of the tortuosity effect of the nanoclay platelets. Fourier transform infrared spectroscopy (FTIR) and morphological characteristics of x-ray diffraction (XRD) and scanning electron microscopy (SEM) were also studied.

**Keywords:** food packaging; composite lms; pectin carbomethoxy cellulose; nano-montmorillonite.

Paper ID = 33, Session MB1, Room 1101

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**NEW BIO-BASED PLASTICS, FROM A NON-EDIBLE PLANT OIL SIDE-STREAM, FOR FILM EXTRUSION**

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Renewable sourced PET, PA, PE, starch blends, etc, has are fastly growing due to the processability and final performance, that is similar to their petroleum derived options. A bit in the shadow of the development of these plastics, development is ongoing on another group of plastics, made directly of the side-streams of agricultural products: oil plant residues and proteins. They can be used in edible applications but not all of them are suitable for food or forage. Industrial oilseed meal from *crambe abyssinica* contains relatively high levels of protein that is not suitable for human or animal consumption due to the presence of anti-nutritional compounds. This paper presents research on *crambe* meal as a base for new plastics, developed to extrude continuous, flexible plastic films based on *crambe* meal, blended with vital wheat gluten as an elastic component and urea as a protein denaturant. The effect of process parameters, such as screw speed, die temperature and pressure, and the effect of components were studied with regards to the final performance of the film extrudates. E.g. mechanical properties, oxygen permeability and moisture content were determined and surface and cross-section morphologies were examined with electron microscopy. The results showed that *crambe*-based blends can be extruded as continuous, flexible plastic films, which exhibit barrier properties towards oxygen. Recipes and methods for pelletizing of master batches for post-converting (e.g. extrusion or compression molding) were successfully developed. Addition of a renewable plasticizer, at about 20 wt%, improved the extrusion performance and resulted in less hygroscopic films, which further showed the overall highest tensile strength while the extensibility was nearly unaffected.

The results provide a first basis to further develop the process and the blend towards potential industrial applications, for example as packaging materials to trays, pots and similar type of packages.

**Keywords:** Bio-based; barrier plastic; plant; side stream.

Paper ID = 45, Session MB1, Room 1101

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## DEGRADATION OF STEEL PACKAGES IN TROPICAL ENVIRONMENTS – RESULTS AFTER 10 YEARS OF DISCARDING

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The performance of steel cans and other packages in the environment is mentioned in several publications, including infantile education books. In spite of this, just a few scientific data are available. A study considering Brazilian environmental conditions was carried out aiming to the development of data on the metal packaging performance when discarded in different natural conditions instead of an adequate disposal. The behavior of steel packages in four local tropical environments during the time of 10 years was studied: on the ground at an industrial site, on the seashore, buried in the ground and immersed in a river bed. Four different kinds of steel cans were used (plain milk powder and soybean oil three piece tins, lacquered soft drink DWI tinplate can and tomato sauce tinplate three piece cans). Alternative packages containing the same products - PET bottles for soybean oil, aluminum cans for soft drinks, laminated plastic bags for milk powder and carton based multilayer packaging for tomato sauce - were used as control. Annually, samples of all packages were removed from the studied sites and visually analyzed. Milk powder and soybean oil cans were completely degraded in the industrial and marine environments between 6 and 7 years. Tomato sauce can sample was totally degraded between 7 and 8 years in the industrial environment. However, although some important surface damage was observed, none of the studied types of steel cans was completely degraded in both conditions: buried in the ground and immersed in a river bed during the 10 years of study. Alternative packaging showed smaller alteration than steel cans in the studied period and conditions.

**Keywords:** Steel packaging; Degradation of packaging; Tropical environments.

Paper ID = 54, Poster session

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## CHARACTERISTICS OF POLY(LACTIC ACID) COMPOSITES REINFORCED WITH NATURAL FIBRES

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The use of biopolymers as alternatives to synthetic polymers has increased extensively in recent years for a wide range of applications. Food packaging, in particular, has seen a growth in the use of materials derived from natural and renewable resources such as poly(lactic acid) (PLA). In many cases, however, the initial costs associated with new technologies to produce biopolymers that rival synthetically derived materials are typically high so new techniques must be employed to reduce costs without compromising material properties. Naturally sourced fibres such as kenaf are often used as cost-reducing fillers for PLA. In some cases the fibres can be treated by alkalization to improve the compatibility with the polymer matrix. This work explores the thermal and mechanical properties of PLA composites incorporated with treated or untreated kenaf fibres together with the addition of thymol, a natural antimicrobial substance. Composites of PLA incorporated with 30% (w/w) kenaf fibre and 10% (w/w) thymol were prepared and compared with control systems containing either no kenaf or no thymol. The composites containing treated kenaf had significantly higher tensile strength than composites prepared with untreated fibres. Micrograph images of the fracture surface revealed better adhesion between the treated fibres and the matrix was achieved resulting in improved reinforcement of the composite. In addition, composites containing thymol demonstrated lower tensile strength than those without thymol suggesting a possible plasticizing effect in the presence of the additive. Thermal analysis by differential scanning calorimetry showed similar trends for composites with treated and untreated fibres with decreases in the glass transition temperature, cold crystalline temperature, melting temperature and melting enthalpy with the addition of thymol. The results suggest that composites containing treated kenaf fiber in particular have the potential for the development of food packaging materials.

**Keywords:** poly(lactic acid); kenaf fibre; antimicrobial; composites; tensile properties.

Paper ID = 61, Session MB1, Room 1101

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## PROPERTIES OF CORRUGATED LINER MADE FROM MUSA SAPIENTUM LINN BANANA PULP AND RECYCLED KRAFT PULP

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This research was aimed to examine and compare physical and mechanical properties of corrugated liner made of banana pulp mixed with recycled kraft pulp and virgin kraft pulp mixed with recycled kraft pulp as well as to estimate the production cost of banana pulp, and to compare with the cost of imported virgin kraft pulp. Initially, banana pulp was cooked in a closed system with the use of Sodium Hydroxide, then handsheets of 125 grams were produced by mixing recycled kraft pulp with banana fiber at 10, 20, 30, 40 and 50 percent (on oven dry weight). Later, their physical and mechanical properties were measured. The results showed that the optimal condition for cooking banana pulp was with the use of 20 percent Sodium Hydroxide, and its yield was 29.2 percent. It was found that the samples made of banana pulp mixed with recycled kraft pulp at 50:50 had the optimal physical and mechanical properties. The results also indicated that the virgin kraft pulp mixed with recycled kraft pulp samples yielded higher tearing strength, tensile strength and bending resistance than the banana pulp mixed with recycled kraft pulp samples. However, banana pulp mixed with recycled kraft pulp samples performed better with respect to ring crush resistance and bursting strength. Lastly, the production cost of banana pulp was 23,058 Baht/ton and the import cost of virgin kraft pulp was 24,000 baht /ton.

**Keywords:** Banana Pulp; Recycle kraft Pulp; Corrugated Liner.

Paper ID = 81, Poster session

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## EFFECT OF COMPATIBILIZER ON PHYSICAL AND RHEOLOGICAL PROPERTIES OF PLLA/PPC BINARY BLENDS

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Poly(L-lactic acid) (PLLA)/Poly(propylene carbonate)(PPC) binary blend was prepared with/without the maleic anhydride (MA) as compatibilizer in an internal mixer under the presence of radical initiator in reactive compatibilization process. The properties - structure relationship of PLLA/PPC binary blends was observed, and the effect of compatibilization on physical, mechanical, and morphological properties of PLLA/PPC blends was also assessed. The T<sub>g</sub> of PLLA decreased indicating that the addition of PPC resulted in increasing the molecular chain mobility of PLLA in the binary blend. It was also found that the addition of PPC had a significant effect on reducing the onset decomposition temperature of PLLA indicating the thermal stability of the PLLA greatly decreased while the reactive compatibilization of PLLA/PPC 80/20 (weight percent) blend showed little effect on the thermal stability of the blends. The tensile strength revealed the decrease tendency with addition of ductile PPC, and the cavities and clear edges from morphological observation showed the poor interfacial adhesion between PLLA and PPC. The PPC effect on the oxygen barrier property was observed, and the compatibilized PLLA/PPC blend showed the better oxygen barrier than neat PLLA/PPC binary blend.

**Keywords:** Poly(L-lactic acid); Polypropylene Carbonate; Blend; Compatibilization.

Paper ID = 100, Poster session

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## INFLUENCE OF REPROCESSING ON MECHANICAL PROPERTIES OF SAN COPOLYMERS IN INJECTION MOLDING

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As plastic wastes increase, packaging companies should now develop a strategy of sustainable development with a good management efficiency. As the price of raw plastic materials is directly linked to petroleum costs, reducing the volume of their waste remains their major cause of concern. Thus they have to better consider the recycling of their sprues and of their undelivered packages. Among plastic packaging, one could find the styrene-acrylonitrile copolymer (SAN). Because of its good balance of properties, toughness/strength coupled with high quality surface finish, SAN has a very wide range of applications including cosmetic packaging. As SAN is sensitive to thermo-oxidation, it could be degraded during repeated processing cycles. This study was focused on the influence of reprocessing on mechanical properties of virgin SAN copolymer in injection molding in order to understand the structure-property relations. In fact, this would help manufacturers to control and limit the degradation of SAN during processing. Therefore it would make the recycling of SAN packaging possible without significantly reducing its properties. SAN copolymer was reprocessed up to fifteen times. The effect of temperature and reprocessing cycles were evaluated by mechanical tests (tensile and impact tests). Yellowness indexes were measured for all samples. It was found that the yellowing index increased according to an exponential law and saturation was reached twice faster at higher temperature. Rheological properties showed the influence of repeated cycles and temperature on viscosity. Average molecular weights determined by Gel Permeation Chromatography (GPC) were found to decrease with injection cycle number. However, the effect of temperature on properties was not significant up to fifteen recycling steps even if Young moduli were slightly modified. Stress and elongation at break were unchanged.

**Keywords:** Reprocessing; mechanical; properties.

Paper ID = 104, Poster session

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**DEVELOPMENT OF BIODEGRADABLE STARCH-BASED CUSHIONS WITH HIGH SHOCK ABSORPTION**

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Plastic foam materials exhibit a massive environmental problem because petroleum-based foams are hard and expensive to recycle. This induces huge opportunities for biodegradable or renewable polymers and a lot of efforts has been made to improve the development of biodegradable foams. The purpose of this study was to optimize the development of biodegradable cushion foams previously presented at the 26th IAPRI Symposium. Biopolymers, natural fibers and other additives were added to wheat starch formulation, to provide more strength and stability to the extruded starch-based foam materials. An experimental study was developed to identify the effect of natural fibers and additives on the cellular structure, the mechanical properties, the water sensibility and the biodegradability of the starch based foams. Several characterizations were performed on the foams: dynamic cushion curve, compressive creep, compressive strength, bulk density, expansion ratio, foam microstructures and biodegradability tests. Also, a dropping test was performed on several products protected by the starch-based foam material. The impact absorption of the foams was registered and the level of protection provided for the products was identified. The results showed that foam mechanical properties have been improved by adding biopolymers into the formulation. The extruded materials demonstrated their suitability for cushioning use, by having good shock absorption performances in comparison to the commercial petroleum plastic foams such as the ones made of polyethylene, polystyrene, polyester... The products were considerably better protected by the starch-based foams after a series of dropping tests. Current efforts are about optimizing the shape, the aspect and the aging stability of the foams which would expand their use in the packaging market.

**Keywords:** Starch; Biopolymers; Foams; Cushions; Packaging; Reactive extrusion; Biodegradable; Shock absorption.

Paper ID = 106, Session MC2, Room 1105

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## EVALUATING THE DYNAMIC CHARACTERISTICS OF STARCH BASED LOOSE-FILL

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In line with a global trend to minimise packaging waste, concerns related to the environmental impact of many traditional protective packaging materials have been raised. Consequently, the use of environmentally friendly alternatives is increasing. However, the performance of many of these materials is not well established. This paper focuses on the evaluation of the dynamic characteristics of a biodegradable, starch based loose-fill cushioning material, Envirofill™. The mechanical characteristics pertinent to cushion design were investigated experimentally under a broad range of environmental conditions including extremes in temperature and relative humidity. Compression, shock and vibration tests were performed. Results reveal measurable differences in performance of the material over the range of environmental conditions. Compression tests show that prolonged exposure at high temperature and low humidity results in a slight increase in compressive stiffness. However, the material has the ability to re-absorb moisture over time and fully recover its original compression characteristics. In terms of cushion curves, results show that the environmental conditions do not have a significant influence on the shock absorbing characteristics of the material for the first drop. However, when the material is subjected to extreme heat and dry conditions, its cushioning performance was reduced for sequent drops; a result of the brittle nature of the dry beads creating increased susceptibility to damage. Furthermore, an increase in moisture content appears to have some improvement on the long term cushioning performance (repeated shocks) of the material. Vibration tests show that the material's dynamic characteristics remain consistent across the environmental conditions used as well as a reasonably broad range of nominal stress. The results of this study provide a valuable reference for the use of biodegradable, starch based loose-fill as a protective packaging material. They can also be used to assist in optimising the design of cushioning systems using loose-fill material.

**Keywords:** climatic conditioning; Enviro-fill; bio-degradable packaging; cushion curves; frequency response function.

Paper ID = 109, Session MC2, Room 1105

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## DESIGNING POLYPROPYLENE LIDDING FILM WITH COMBINED PEELABLE AND ANTIFOGGING PROPERTIES FOR FOOD PACKAGING

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In general, fresh produce and ready-meal products packaged and stored at cold temperature would require film with effective easy peel and antifog performance for convenience and display reason. Structuring plastic film having a minor phase dispersed in the polymer matrix is one route in tailoring bond strength when sealed with a substrate and to produce desirable peelable property. Based on this principle and polymer blending, metallocene catalyzed linear low density polyethylene (mPE) was selected and incorporated into PP in this study. Some early investigations revealed improved processability of this blend, however, published data on the peel-seal property of this particular blend have not been found. In addition to the desired peelable performance, selecting a suitable antifogging additive (AF) was also considered. Three-layer films with thickness of 40  $\mu\text{m}$  were produced by co-extrusion. Sealant and antifogging function were designed in the skin layer with a thickness of 7.5  $\mu\text{m}$  where the core layer of 25  $\mu\text{m}$  was neat PP. The mPE and AF were blended with PP in various compositions (10 to 40 wt% of mPE and 3 to 9 wt% of AF). The fabricated film was then sealed with a PP sheet having a thickness 300  $\mu\text{m}$ , at 150°C and 1 bar. Peel force was measured by I-peel method. Low measured peel force was achieved within a commonly known easy peel range of 2.70 - 7.95 N. 15cm<sup>-1</sup>. Findings revealed that the peelable films were obtainable through an incorporation of at least 20 wt% of mPE (peel force 5.90±0.71 N. 15cm<sup>-1</sup>). Antifog performance of lidding films was analyzed by cold fog test. Using 3 wt% of AF could result in clear film with no discrete water droplets. Results of easy peel, failure mechanism, antifog and mechanical properties of the PP blend films will be presented at the conference.

**Keywords:** easy peel; antifog properties; multilayer PP film.

Paper ID = 117, Session WA2, Room 1105

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## MICROPERFORATION OF THREE COMMON PLASTIC FILMS BY LASER AND THEIR ENHANCED OXYGEN TRANSMISSION FOR FRESH PRODUCE PACKAGING

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Teerapon Yamwong - National Metal and Materials Technology Center, Thailand

This paper described the use of Nd-YAG laser to perforate three plastic films including biaxially-oriented polypropylene (BOPP), biaxially-oriented polyethylene terephthalate (BOPET) and low density polyethylene (LDPE). The films were perforated under various pulse energies of 50, 150 and 250 mJ and with pulse duration of ~10 ns and pulse repetition of 1 Hz. It was found that perforation diameters of all films increased with increasing pulse energies. Observed perforations were different among the three film types. Explanation was contributed to material inherent property and its interaction with laser. Incorporation of an inorganic filler (i.e. silica based anti-blocking agent used in packaging film) of 0.5 wt% into the LDPE films (0.5Si-LDPE) could improve perforation performance for LDPE. This was attributed to an increased thermal diffusivity of the 0.5Si-LDPE film. Commercial BOPET and BOPP films containing 97 microholes.m<sup>-2</sup> (hole diameter of 100 microns) showed an improvement in oxygen transmission rate (OTR) of 18 and 5 times that of the regular films. In the case of perforated film of 0.5Si-LDPE having similar perforation quantity of 97 microholes.m<sup>-2</sup> and perforation diameter of 100 microns, a two-fold increase of OTR was obtained. Gas transmission rates of the microperforated films were measured based on the static method. Measured OTR and CO<sub>2</sub>TR values of the three films with varying perforation diameters in a range of 40 - 300 microns were compared and discussed. Overall results clearly indicate that perforation by laser is an effective process in developing breathable films with tailored oxygen transmission property for fresh produce packaging.

**Keywords:** Microperforation; Oxygen transmission rate; Modified atmosphere packaging.

Paper ID = 119, Session WA2, Room 1105

## THE STUDY ON PACKAGING CUSHIONING PERFORMANCE AND PHYSICAL PROPERTY OF POLY (VINYL ALCOHOL) SPONGE

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Poly (vinyl alcohol) Sponge is a porous body of continuous pore made by PVA resin and foaming agent. The dry sponge has no elasticity when compressed but has great hydrophilic property, water- absorption capacity, water- absorption rate, water holding capacity and good solvent resistance. The waste can be fully biological degraded in the environment. The volume of the material expands rapidly after absorbing water and has soft elasticity. There is no rough harm to the contacted surface. Using such properties of PVA sponge, packaging cushioning material can be compressed in dry condition to protect water soluble liquid containers. If the container leaks liquid when suffer a great shock, the sponge can expand suddenly, absorb and lock the liquid in case of the further leakage. Commercial PVA sponge is discussed in this paper. First the microstructure was analyzed by IR method. It appeared that the material has the similar characteristic peak as PVA resin. It also has stretching vibration peak of methylo C-O in  $1006\text{ cm}^{-1}$ , of ether bond C-O in  $1065\text{ cm}^{-1}$  and of carbonyl C=O in  $1650\text{ cm}^{-1}$ . It meant the PVA resin maybe partly acetal processed which give the PVA resin better water resistance and improved mechanical properties. Separating the peak of IR spectrogram of the sponge, the characteristic peak of phenol formaldehyde (PF) resin was also appeared which means that PVA blended with PF can modify the heat, water and grease resistance of the material. The density, hardness, water absorption capacity, water absorption rate were tested. The materials' static compression performance of different water-absorption capacity was also discussed. Dry PVA sponge has great compression strength and permanent set. According to the wet PVA sponge, as the water weight increased, the compression stress and water holding capacity reduced significantly, permanent set decreased and elastic resilience turned better. Making a comprehensive survey of the physical properties, the PVA sponge of density of  $0.143\text{ g/cm}^3$  can be used as packaging cushioning material to prevent liquid containers from leaking.

**Keywords:** Poly (vinyl alcohol) sponge; Packaging Cushioning Performance; Physical property.

Paper ID = 133, Poster session

## **PACKAGING PRINTING & GRAPHICS**

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## QUALITATIVE ANALYSIS OF COVERAGE VALUE TRANSFER IN MODERN PACKAGING PRINTING WORKFLOW

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Modern packaging printing workflow has been nowadays directed to the flexography printing technique. It requires a usage of a number standardised processing procedures in order to create an attractive and consumer appealing packaging. With constantly increasing number of brands on the market, new qualitative requirements are present for flexography. The aim of this research was to evaluate two different types of modern flexographic workflow systems (LAMS and TIL technology). The hypothesis was that the standardised different workflows should give a product of similar technical and visual appearance quality. Measured parameters were: the formation and structure of the image elements on the printing plates, transfer of the printing ink to the printing substrate, dot gain on the printing substrate and visual evaluation of the imprints. Obtained results revealed the differences in formation of image elements on the printing plates as well as the difference in coverage values transfer from the printing plate to the printing substrate. Differences were detected in specific coverage areas (highlights, shadows), where the surface structures of the printing plates was significantly different. Addition analysis in form of visual evaluation of images, specific colours and tone gradients has been made and gave different results. They indicated that highlights and realistic colour on the imprint have been better reproduced by LAMS printing plate, despite the fact that better transition of tones through the whole tone range was measured on reproductions with TIL printing plate. This research has proved that technically correct printing plate and imprint can give a reproduction of lower visual appearance quality. Results have shown that reproduction of each packaging product should be considered individually in a closed reproduction workflow. Visual impression should be considered as a relevant parameter used in planning and production of packaging in order to satisfy the appealing and creative design requirements in packaging.

**Keywords:** flexography; LAMS; TIL; coverage value; dot gain; visual evaluation.

Paper ID = 15, Session TB1, Room 1101

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## A METHOD FOR GENERAL PRINTING ANTI-COUNTERFEITING BY MOIRÉ PATTERNS

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Moiré security is a type of information hiding technology based on optics. The generation and principle of moiré pattern anti-counterfeiting were analysed. The mobile terminals unlock technologies of moiré pattern security for general printing was discussed in depth. According to the structure of the LCD screen, the feasibility of the mobile terminal screen decoding implementation is analysed. Graphic design software was used to design a special information implied in moiré patterns, and apply it to the security design, proofing and verify the effect of the mobile terminal screen decoding. The results show that the security documents which were applied by moiré anti-counterfeiting technology can reveal hiding information pre-designed using a mobile terminal screen to decoding, and a certain authentication effect can be obtained. Finally, the design elements for mobile terminal screen to decode the moiré pattern application and implementation process are given.

**Keywords:** moiré; information hiding; optical security; printing anti-counterfeiting; mobile terminal decoding.

Paper ID = 79, Poster session

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## THERMOFORMING IN-MOULD LABELLING

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Thermoforming in-mould labelling (TIML) is a pioneering technology for creating rigid plastic packaging. It combines in mould labelling – traditionally only available in injection moulding – to thermoforming process, thus enabling a sophisticated decoration in combination with a high barrier and retortable packaging. TIML containers are economic in terms of material usage, investment cost as well as production efficiency. In November 2013, the innovation was awarded the Oscar d'Emballage. In thermoforming, a plastic sheet is heated to pliable forming temperature, formed into shape in a mould and trimmed to final shape. Traditionally, thermoformed products have been decorated after forming by dry offset printing, shrink sleeves, carton wrapping or adhesive labels. In TIML, labelling is integrated directly with the forming process. The pre-printed label is inserted into the mould right before forming the sheet and adheres to the container due to forming temperature. Different shapes and combinations of labels are possible, and the whole outer surface of the container from bottom to sealing rim can be used to promote the brand. Barrier layers coextruded or laminated to the plastic sheet remain intact in the thermoforming process, which allows for high barrier packaging. Due to the forming process, even relatively thin-walled packaging is sturdy enough for industrial packaging lines and sterilisation processes. TIML production has relatively high output and low waste level. The TIML technology offers a unique combination of attractive decoration, long shelf-life and high production efficiency.

**Keywords:** thermoforming; in-mould labelling; decoration; barrier packaging; retortable packaging; innovation.

Paper ID = 120, Poster session

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## THE STUDY ON SYMBOL CONTRAST OF INKS AND PAPER LINERS FOR BARCODE PRINTING ON CORRUGATED BOX

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Barcode's primary function is to carry data from the point at which it is originated to the point that the data has to be captured. So barcode is a vital link in data communication chain of any applications. If it fails, the chain will break. A barcode which cannot be scanned causes more problems to trading partners than no symbol at all. As a result, barcode readability becomes one of the top serious concerns in packaging industry, especially for corrugated packaging. Although most of the times barcode defects found are related to the print quality, there are other factors that make barcode unreadable. One among those factors is color combination of inks (the printed bars) and substrates (the spaces). It is widely known that the best color combination for barcode is black bars on a white background. Though other combinations can be used, not all are functional; especially in flexographic printing where the cooperation of ink pigments, printing methods, and substrates critically results in color limitations. This research addresses the limitation of barcode color combinations on corrugated packaging by conducting an experiment, based on GS1 General Specifications, to identify scope of materials to be practically used. In this experiment, the Symbol Contrast between ink colors (using 3 color-groups: cold, medium, and warm) and corrugated liners (using 4 different colored-liners: white (KS), light brown (KI), golden yellow (KA), and dark brown (KT)) were graded using Axicon 6015 barcode verifier. The results showed that the group of cold colors (dark blue, light blue, green, and black) on white liner (KS) had the highest Symbol Contrast (B grade), followed by those colors on KI and KA (C grade), and on KT (D grade). The group of medium colors (purple, pink, dark brown, and grey) received C grade on KS and D grade on the rest liners. For the group of warm colors (white, yellow, red, and orange), the Symbol Contrast was D grade for all liners. The collected data were then analysed and developed to be a guideline for barcode readability improvement in the real production.

**Keywords:** barcode readability; barcode verification; symbol contrast; flexographic printing.

Paper ID = 128, Session MC3, Room 1107

## **PACKAGING SUSTAINABILITY**

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## IMPLEMENTING PACKAGING SUSTAINABILITY METRICS IN A DEVELOPING ECONOMY

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The objective of this paper is to study the feasibility and challenges associated with implementing various sustainability metrics and guidelines prescribed by International Standard for Sustainable Packaging (ISO TC122/SC4), (SPC) Sustainable Packaging Coalition (SP Metrics Framework) and Australian Packaging Covenant (APC) in a developing economy where the mind set of stakeholders and consumers at various levels differs in their interpretation and expectation of the definition of what may be classified as truly sustainable from the rest of the world. The focus of the paper is on the Indian Economic model. The paper highlights through real life examples from the industry the scope for processes and designs to become more sustainable via source reduction, technological advancement and managing the requirements of packaging without compromising on quality. There exists a gap between what may be considered a truly sustainable organization in a developing economy and a developed economy. Even though global organizations such as Walmart expect the same standards world over, this gap cannot be ignored. By setting different benchmarks while implementing metrics and guidelines, this gap can be bridged without having to negotiate on the primary functions of packaging. Sustainability in a developing economy can be achieved alongside economic development and economic development need not be a precursor to it. In this lies a tremendous opportunity for economic progress to reflect not only in terms of GDP (gross domestic product) but also in terms of sustainability. By implementing metrics and setting realistic targets, this could turn into a reality.

**Keywords:** sustainability; sustainable packaging; metrics; green packaging; developing economy; life cycle assessment; sustainable development product; sustainable profit ratio.

Paper ID = 42, Session TB1, Room 1101

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## ULAB© CLOUD TESTING SYSTEM FOR FLEXIBLE PLASTIC PACKAGES

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There are over 20 conventional testing items for flexible package and even more if we need a comprehensive test. It is costly and not efficient to purchase instruments and perform tests in one laboratory. The test results are isolated and not sharable. Statistical analysis based on mega data is unavailable. To comply with the trend “Green Package and Resource Sharing”, ULab© Cloud Testing System is proposed by Labthink, supported by the company’s advanced testing instruments and leading technologies. ULab© Cloud Testing System for flexible plastic packages is a powerful and convenient testing platform, which is developed on the basis of Internet of Things, cloud computation technology and multiple testing instruments with automatic data uploading function. It will be widely used to provide flexible plastic manufacturers and customers with reliable, highly efficient and cost effective automatic testing services. The customers do not need to establish their own laboratories, thus saving numerous investments and social resources. ULab© Cloud Testing System is composed of a remote laboratory data management system and a site testing data management system, which could collect and analyze online test data and then generate testing report and analysis report automatically. Customers only need to register an account and log in the system to get reports for the materials tested. Testing items in ULab© cover the overall properties of flexible plastic packages. The site testing instruments could test the product packages in production line so that unqualified packages could be identified. ULab© could also be used to provide various industries with quality diagnosis and precautionary of packaging material in different links. With optimization of resource allocation and information system, ULab© provides its customers with the tons of test data tracing, management and statistical analysis services throughout the quality control process. This article introduces basic concept, structure and applications of ULab©.

**Keywords:** ULab© Cloud Testing System; Flexible Plastic Packages; Green Package; Resource Sharing.

Paper ID = 44, Poster session

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## GREEN FIBRE BOTTLES

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In the Danish project: Green Fibre Bottles, EcoXpac and Danish Technological Institute has an on-going development project with the purpose of creating an environment friendly bottle that is biodegradable and can replace glass and plastic bottles and also cans for both carbonised and non-carbonised liquids. The bottle has several environmental and commercial advantages.

- Bottles can be designed with either screw cap or single-use seal.
- Packing can be produced in order to fit in with any existing filling plants.
- Raw material can be all kinds of paper pulp – a sustainable material.
- New patented production technology guarantees high level of energy saving - up until 80% compared with conventional moulded pulp production.
- After use the bottle can enter into recycling systems on equal terms with cardboard and paper, or decompose directly in nature.
- The production unit is small and compact, thus it can be transported and set up wherever in the world the bottles are to be filled.
- The bottle quality is very convincing with a surface as writing paper.
- The surface coating is based on a natural sustainable applied very thin.
- The total barrier performance will be almost as perfect as glass bottles and metal cans.
- Production costs are lower than similar packaging.

The development project is carried out in collaboration between a number of experts including the Danish Technological Institute. The project budget is funded by the Business Innovation Fund in Denmark. The presentation will include a presentation of the background of this on-going project and a description of the innovative production method. Also samples of fibre based bottles will be presented to the audience. The coating strategy for the fibre bottle will be presented by Dr. S. Vikram Singh in another presentation.

**Keywords:** Sustainable packaging; bottle; paper; liquid packaging; molded paper packaging.

Paper ID = 48, Session TB1, Room 1101

## PLASMA ENHANCED SURFACES FOR SUSTAINABLE FIBER BASED PACKAGING

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The recent trends of packaging materials and technology have been highly oriented towards sustainability along with search for novel applicability areas. In this connection, sustainable biodegradable fibrous material such as tree based new fibers, recycled fibers, etc., are excellent raw materials. Packaging made by utilizing such materials has already appeared in the market in one form or the other. However, packaging produced from such materials often suffers from poor gas and liquid diffusion barrier; hence external additive materials are introduced to improve such barrier properties. To keep the sustainability of the packaging, the external additives/intrusions/treatments/fillings have been tried to keep minimal, and limited to the surfaces of the packaging. Moreover, these introduced materials often dictate the nature of the packaging in terms of its sustainability. Plasma based surface processing have emerged as a potential candidate to enhance gas and liquid barrier properties, printability, hydrophobicity, etc., of a surface. Note that few microns thick plasma coating (even <2% of the original material) can be enough to achieve desired material properties. Here an atmospheric pressure plasma enhanced chemical vapor deposition was utilized to deposit SiO<sub>x</sub>-like (where x = 1-2) thin film coatings on highly porous paper substrates to enhance gas and liquid barrier properties. The thin films were deposited by controlling hexamethyldisiloxane (HMDSO) and O<sub>2</sub> plasma chemistry in the ambience of He, Ar or N<sub>2</sub> discharge. The coated paper samples have excellent barrier properties against water; moreover, the coated surfaces are also investigated for their barrier properties against other liquid along with gases like O<sub>2</sub>, CO<sub>2</sub>, etc. We also studied influence of distinct discharges on packaging surfaces to obtain improved hydrophobicity, adhesion and printability. All these plasma induced surface processing were performed using radiofrequency capacitively coupled plasma, where the substrate temperature was kept at room temperature.

**Keywords:** Sustainable fiber based packaging; SiO<sub>x</sub>-like plasma coating; Surface modification of packaging material.

Paper ID = 52, Session MC3, Room 1107

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## **THE GREENHOUSE GAS PROFILE OF A “HUNGRY PLANET”; QUANTIFYING THE IMPACTS OF THE WEEKLY FOOD PURCHASES INCLUDING ASSOCIATED PACKAGING AND FOOD WASTE OF THREE FAMILIES**

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Enda Crossin - RMIT University, Australia  
Stephen Clune - Lancaster University, United Kingdom  
Simon Lockrey - RMIT University, Australia  
Maud Rio - RMIT University, Australia  
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Helen Williams - Karlstad University, Sweden

The United Nations Food and Agricultural Organisation have estimated that 1.3 billion tonnes of food is waste across the supply chain, while food security emerges as one of the leading challenges facing a growing global population. Life cycle assessment (LCA) can illustrate the environmental implications of food production, consumption and waste. In 2005, Peter Menzel and Faith D’Aluisio presented a photographic study in “Hungry Planet – What the World Eats” documenting what thirty families across twenty-four countries ate during the course of one week. The weekly food purchasing inventories of three of these families have been combined with LCA data to report the greenhouse gas intensity of these food purchases. The greenhouse gas emission profile including those of 128 varieties of fresh food , along with data on packaging material production and household food waste , have been used in the calculations. The paper will present the findings illustrating the contribution each component has: food, packaging and food waste; and will also discuss the implications for food packaging design.

**Keywords:** life cycle assessment; LCA; food; food waste; packaging; greenhouse gas emissions.

Paper ID = 112, Session TB1, Room 1101

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## FILM PERFORMANCE OF POLY(LACTIC ACID) BLENDS FOR PACKAGING APPLICATIONS

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Poly(lactic acid) (PLA), a biodegradable thermoplastic derived from renewable resources, stands out as a substitute to petroleum-based plastics. PLA based films for food packaging has been an area of both industrial and research interest within the context of sustainability. In spite of its excellent properties, packaging applications have been limited because PLA is more brittle than traditional oil-based plastics. Because of this, films display low tear and impact resistance and produce a loud crackling sound when manipulated. Although many studies address the toughening of PLA in the bulk, little attention has been placed on the film performance. The present study is aimed at providing a survey of binary PLA based blends with other biodegradable and non-biodegradable plastics. Acrylic impact modifier (AIM, 5 wt. %), ethylene vinyl acetate (EVA, 20 wt.%), Polyhydroxybutyrate (PHB, 10 wt.%) and polycaprolactone (PCL, 20 wt.%) were each blended with PLA through single-screw extrusion and converted into films via the blown-film process. Tear resistance, impact resistance, heat seal strength, and noise level were measured. AIM improved the heat seal strength and impact strength, but reduced the tear strength. When blended with another resin, the tear resistance improved regardless of the resin used, with EVA and PCL having the highest effect. This may be due to the dispersed phase in the blends which provide resistance to the crack propagation. PHB showed a marked effect in increasing the heat seal strength followed by AIM. Conversely, EVA did not show a significant effect in increasing heat seal strength. All blends showed a modest increase in impact resistance with AIM having the highest effect. Significant noise reduction was achieved in films containing EVA. These results will be used to select blend systems for the further study of specific properties.

**Keywords:** Polylactic acid; Films; Blends; Melt blending; Noise; Tear strength; Impact strength.

Paper ID = 118, Session MC3, Room 1107

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**TRENDS AND DRIVERS INFLUENCING PAPERMAKING AND ITS PRODUCTS TOWARDS THE FUTURE**

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“Papermaking towards the future” is a project investigating the current state and future of global paper manufacture. The project is a critical investigation into the most important questions for the industry today and into the future. What changes can be observed and are currently taking place? What are the challenges at present, and how will they manifest themselves going forward? In which areas is the outlook most promising for the paper industry and how are we going to get there? Through a combination of expert interviews, workshops, a Dephi survey with respondents in 21 different countries, a student survey, and months of our own research, we have identified what we believe are the most important drivers for global change and the most important growing trends in the paper and packaging industry going forward 20 years. Projecting the information collected throughout this project forward in time, we see a high likelihood that the paper and packaging industry will shift into one centred around bio-refining, where a broad range of forest based products will be produced to support a bio-based world. The future products creating the greatest return on investment will include bio-plastics, bio-chemicals, bio-energy, cellulose textiles, and paper-based packaging materials, where everything produced will be sustainably sourced and everything recycled. However, it is critical that the paper and packaging industry strategize today for this promising future of tomorrow, through investments in marketing, organization, and new product innovation. Moreover, it is important that the industry capitalize on their strong position within this potential bio-based world, by exploiting their fibre processing infrastructure, knowledge, and experience with producing sustainable and recycling products from the forest.

**Keywords:** paper; papermaking; trends; drivers; packaging materials.

Paper ID = 139, Session MC3, Room 1107

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