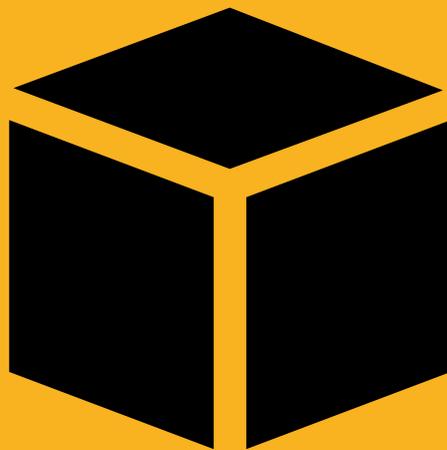


WELCOME TO THE
29TH iapri 
Symposium on
 **Packaging**



**SERVING
SOCIETY
INNOVATIVE
PERSPECTIVES
ON PACKAGING**



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Symposium on
Packaging

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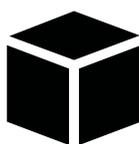


TOPICS ORAL PRESENTATIONS

- Active & intelligent packaging
- Distribution packaging
- Logistics & supply chain
- Medical, cosmetic & pharmaceutical packaging
- Novel packaging
- Packaging design, ergonomics & human factors
- Packaging for food & agriculture
- Packaging machinery & systems
- Packaging materials
- Packaging printing & graphics
- Packaging standards & legislation
- Packaging sustainability
- Hazardous and dangerous goods

Active & intelligent packaging

- Active edible packaging: solution for lipid oxidation
- Consumer value for time-temperature indicators in sushi packaging
- Advanced Food Packaging Applications of Modified Commercial PET-based Microwave Susceptors
- Characterization of biopolymer blends based on poly(lactide) entrapped with natural volatile compound for antifungal packaging applications in bakery products
- Methodology for Medical packaging design with a social approach
- Synthesis of bio-based Cyclodextrin Metal-Organic Framework for encapsulation of Ethanol
- Ink-ased printed susceptor for food packaging applications within the snack sector
- Vanillin-Based Active Paper Packaging Influence on Shelf Life of Bakery Products



• An Intelligent Colorimetric Indicator based Curcum-in-Methylcellulose for Detecting Status of Sea Bass Fillets during Chilled Storage Condition

• Market Implementation of Active and Intelligent Packaging – Opportunities from a Socio-economic Perspective

Distribution packaging

• A Numerical Model for Predicting the Vibratory Behaviour Road Transport Vehicles.

• A Method for Predicting the Compression Strength of any Type of Corrugated Box

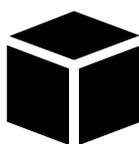
• Relation between conditions of cushioning design and resonant frequencies of cushion – product system

• Kurtosis Response Spectrum Analysis for Anti-Vibration Package Design

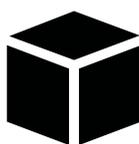
• Accumulated fatigue spectra for random vibration testing

• Emergency braking and Stability testing, Response Analysis

• Response performance of semi-rigid stacked plastic drum units along shock impulses



- Analysis of the axial crushing of thin-walled rectangular paper tubes with different strength in tension and compression
- Equivalent condition between acceleration RMS-life and stress-life curves for accelerated random vibration testing of packaged product
- Methodology for Medical packaging design with a social approach
- Angular accelerations, the key to transport simulation.
- Analysis of a forklift handling course and multiple propositions with evaluation of laboratory simulations
- ISTA distribution environment data collection program
- The Effect of Coplanar Sensor Spacing on Determining the Angular Acceleration of Vehicles
- Investigation of the Effect of Column Stacked Corrugated Boxes on Load Bridging using Partial Four-Way Stringer Class Wooden Pallets.



Logistics & supply chain

• Analysis of the axial crushing of thin-walled rectangular paper tubes with different strength in tension and compression

• Equivalent condition between acceleration RMS-life and stress-life curves for accelerated random vibration testing of packaged product

• Methodology for Medical packaging design with a social approach

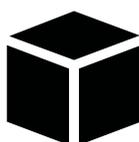
• Pharmaceutical Packaging and Logistics for the Elderly

• Four-dimensional concurrent engineering - an extended theoretical framework integrating packaging

Medical, cosmetic & pharmaceutical packaging

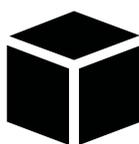
• Methodology for Medical packaging design with a social approach

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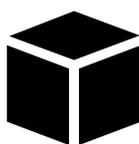
Novel packaging

- Active edible packaging: solution for lipid oxidation
- Student sense of belonging in a large classroom introductory packaging course
- Methodology for Medical packaging design with a social approach
- Synthesis of bio-based Cyclodextrin Metal-Organic Framework for encapsulation of Ethanol
- Nanocellulose as material reinforcement and its potential for packaging applications



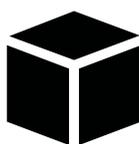
Packaging design, ergonomics & human factors

- Current Issues and Advances in Consumer Research and Testing for Sustainable Packaging
- Consumer value for time-temperature indicators in sushi packaging
- Frustrated and malnourished: unwrapping older peoples' food and beverage pack experiences in hospital
- Using mobile eye tracking and K-coefficients for analyzing usability trials
- Design thinking in packaging education
- Methodology for Medical packaging design with a social approach



Packaging for food & agriculture

- Reducing plastic by using recyclable materials without compromising quality and shelf life of salmon fillets
- Active edible packaging: solution for lipid oxidation
- Replacing conventional laminate material (PA/PE) with recyclable monomaterials (PP, HDPE): A case study on hot dogs
- Modeling American Household Fluid Milk Consumption and their Resulting Environmental Footprint
- Migration from Food Packaging materials - Concerns and Opportunity
- Light transmittance in packaging materials and effect of light barrier on greening of Folva cultivar potatoes (*Solanum tuberosum* L.) stored at 20 °C under LED light
- Changes in properties of shrinkable plastic packaging due to the effect of storage conditions



• Study of the possibilities for developing recyclable plastic films for packaging

• Advanced Food Packaging Applications of Modified Commercial PET-based Microwave Susceptors

• Development of Packaging System and Transport Packaging Technology for Philippine Broccoli

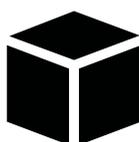
• Development of antifungal film to delay postharvest decay in mango fruit

• Study of the oxygen barrier properties of PET via ultrasonic spray coating of ZnO nanoparticles

• Synthesis of bio-based Cyclodextrin Metal-Organic Framework for encapsulation of Ethanol

• Aroma Compounds Characterization of Dried “Tom Yum” Soup Herbs in Different Packaging Materials by Gas Chromatography-Mass Spectrometry Combined with Sensory Evaluation Techniques

• Ink-based printed susceptor for food packaging applications within the snack sector.

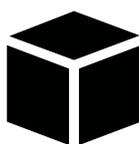


- Improving recycled PET polymeric blends through the incorporation of commercial nanoreinforcements

Packaging machinery & systems

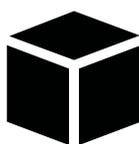
- Study of the possibilities for developing recyclable plastic films for packaging

- Flexible Low-Batch Size Manufacturing of Molded Paper Packaging with Barriers
-



Packaging materials

- A Method for Predicting the Compression Strength of Any Type of Corrugated Box
- Next level of corrugated board research
- Perforations on Boxes – Some Fundamental Facts
- Hygroexpansion, Lacquer Coating and Surface Roughness Affect the Electrical Resistivity and Gas Barrier of Physical Vapor Deposited Aluminum Coatings on Paper
- Active edible packaging: solution for lipid oxidation
- Sorting as a key factor for high quality of recycled polypropylene
- Box compression strength of packages in different climates
- In-situ changes of thermo-mechanical properties of poly(lactic acid) film immersed in aqueous-alcoholic solution
- Fluorescent Bioplastic Film from Konjac Glucomannan Mixed with Chitosan and Turmeric for Security Food Packaging



• Study of the possibilities for developing recyclable plastic films for packaging

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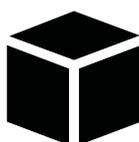
• Diffusion of organic molecules in poly lactic acid (PLA) films

• Study of the oxygen barrier properties of PET via ultrasonic spray coating of ZnO nanoparticles

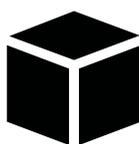
• Synthesis of bio-based Cyclodextrin Metal-Organic Framework for encapsulation of Ethanol

• Effect of zeolite 5A incorporation on poly(butylene adipate-co-terephthalate)/ thermoplastic starch blend

• Surface Modification of Coconut Fiber for Reinforced Thermoplastic Starch Foam



- Biaxial orientation of biodegradable PLA/PBAT/TPS blend for packaging application
- Improving recycled PET polymeric blends through the incorporation of commercial nanoreinforcements
- Development of a biodegradable thermoformed tray for food waste handling
- Nanocellulose as material reinforcement and its potential for packaging applications
- PLA/NR/TPS ternary blend: A promising bio-based material for secondary packaging
- Improving mechanical and barrier properties of thermoplastic starch-based blown films for flexible packaging
- Simulation and experimental verification of a drop test and compression test of a Gable top package
- Evaluation and Optimization of seal behavior through solid contamination of heat sealed films
- Determination of the nitrogen gas transmission rate of ethylene vinyl alcohol copolymer, using a newly developed permeation measurement system



Packaging printing & graphics

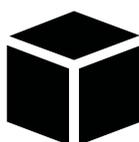
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Packaging standards & legislation

- Accumulated fatigue spectra for random vibration testing

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Packaging sustainability

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- Methodology for Medical packaging design with a social approach



• How Changes in Consumer Package Design Impact Environmental Sustainability

• Improving the collection of Packaging waste through smart containers and pay as you throw systems

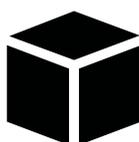
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• Nanocellulose as material reinforcement and its potential for packaging applications

Hazardous and dangerous goods

• Leakproofness of dangerous goods packagings - comparison of worst-case limit leakage rates and sensitivity of the bubble test



Active edible packaging: solution for lipid oxidation

Authors

Frederico Castro (Fac. of Sciences, Univ. of Lisbon) and Fernanda Vilarinho (INSA).

Abstract

Introduction: In the last few years, and to respond to consumers necessity of better ways to protect food, active packaging came to light.

Objective: The main objective of this study was to verify the effectiveness of an edible whey protein concentrate (WPC) film with aromatic plant extract on delaying lipid oxidation of a high fat content food.

Methods: The antioxidant capacity was evaluated by two methods: free radical DPPH inhibition system and β -carotene bleaching test. Moreover, total phenolics content (TPC) and total flavonoids content (TFC) was determined. Four methods were applied to assess lipid oxidation state of fresh salmon: peroxide value, p-anisidine value, TBARS (Thiobarbituric Acid Reactive Substances) assay and monitoring of hexanal.

Results: Initially, the antioxidant capacity of two aromatic plants extracts, rosemary and green tea was compared. Then, the existence of the synergic effect between extracts was verified through comparison of the antioxidant capacity of three mixtures of rosemary and green tea extract (in different percentages) against individual extract samples. Based on the results, green tea extract (GTE) was chosen to incorporate the active film. Fresh salmon was packaged with the active film (WPC incorporated with GTE) and with the control film (WPC film without GTE). The oxidation level of non-packaged samples was tested during at different storage times (0, 3, 5, 7, 10 and 12 days), while packaged samples were evaluated at (5, 7, 10, 14 and 17 days).

The results obtained in this study indicate that the whey protein active film was successfully produced and it was effective in delaying lipid oxidation of fresh salmon samples until the 10th day of storage, for example, the results of TBARS to 10th days with salmon packaged with control film was 0.3255 ± 0.03 and with active film was 0.4808 ± 0.03 .

Keywords: Active packaging, Whey protein, Aromatic plants, Green tea, Fresh salmon, Lipid oxidation

Topics: Active & intelligent packaging Novel packaging Packaging for food & agriculture Packaging materials Packaging sustainability



Consumer value for time-temperature indicators in sushi packaging

Authors

Virpi Korhonen (Package Testing & Research Ltd).

Abstract:

At the time of the current public discussion of food and packaging waste, a growing market is emerging for optimised packaging solutions seeking to remedy these problems. Intelligent packaging, such as time-temperature indicators (TTIs), can help cut down food waste and achieve higher food safety and trust in the food chain. The main targets of use have been fish, meat and poultry, which are sensitive to temperature changes.

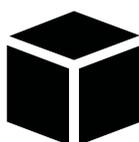
This paper presents a study on consumer value perceptions and willingness-to-pay for Tempix® time-temperature indicators in retail packaged sushi. Data was collected through two focus group discussions with 12 consumers. All participants consumed sushi and had purchased take-out sushi during the past six months. Both a carton and a plastic tray with 12 pieces (450g) of sushi were evaluated, first without and later with the indicator.

The packages with the TTI were perceived as safer and more hygienic, as well as delivering expertise and innovation. The majority of the participants stated that the TTI increased both the perceived safety and trust in the sushi product. It was also perceived to decrease product mistreatment. The TTI created a significant increase in the perceived value of the carton tray both in terms of perceived benefits and willingness-to-pay. For the plastic tray, the value increase was lower, as the overall safety of the tray was not perceived very high because of its fragile lid.

The consumers also expressed doubts about the technology, i.e. whether the indicators generate needless food waste or who should pay for them. These challenges in communication must be solved to gain the most value from the technology. From a retailer perspective, TTIs offer considerable potential for gaining higher levels of customer trust and loyalty.

Keywords: intelligent packaging, time-temperature indicator, consumer, value

Topics: Active & intelligent packaging Packaging design, ergonomics & human factors



Advanced Food Packaging Applications of Modified Commercial PET-based Microwave Susceptors

Authors

Alexander Bardenstein (Danish Technological Institute), Stanislav Landa (Danish Technological Institute) and Karina Kjeldgaard-Nielsen (Danish Technological Institute).

Abstract:

Convenience food products with crispy surface and high water activity interior fail to achieve a proper texture and heating homogeneity when prepared in a microwave oven using conventional PET-based susceptor constructions. Several modified susceptor constructions have been proposed in the literature to overcome this problem. One of these modifications being a laminate of two commercial aluminised susceptor films has been optimised, and a pilot batch has been produced. The laminate comprises two 12µm susceptor films separated by a 12µm PET-film, laminated on 30µm thermostable 60gsm paper, totalling approx. 70µm. In contrast to a habitual susceptor, the manufactured laminate converts up to 70% of incident microwave energy into heat resulting in only 3-5% to be transmitted. This increases the temperature at the interface between susceptor and product surface and prevents overheating of the product interior. This created similar cooking conditions to a conventional oven resulting in a dry and crispy surface, leaving a soft and moist interior. Packaging based on this susceptor construction has been produced and implemented for vegetarian spring rolls, fish in puff pastry, and French fries. The microwaved meals were subjected to the assessment of a tasting panel, which compared the results of microwave preparation to the reference obtained by conventional oven baking according to consumer instructions. The assessment revealed 25-35% and 30-45% improvement of crispiness and browning parameters, respectively. The results form a firm basis for commercial implementation of the improved susceptor construction not only of the chosen test products, but any product with similar properties, like nuggets, fish and chips, schnitzels, samosas.

Keywords: microwave packaging, microwave susceptor, convenience food packaging, browning

Topics: Active & intelligent packaging Packaging for food & agriculture Packaging materials



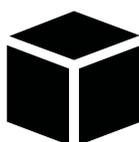
Characterization of biopolymer blends based on poly(lactide) entrapped with natural volatile compound for antifungal packaging applications in bakery products

Authors

Panitee Suwanamornlert (Department of Packaging and Materials Technology, Faculty of Agro-Industry, Kasetsart University), Vanee Chonhenchob (Department of Packaging and Materials Technology, Faculty of Agro-Industry, Kasetsart University), Nopadon Kerddonfag (National Metal and Materials Technology Center, National Science and Technology Development Agency), Wannee Chinsirikul (National Nanotechnology Center, National Science and Technology Development Agency) and Weibiao Zhou (Food Science and Technology Programme, Faculty of Chemistry, National University of Singapore).

Abstract:

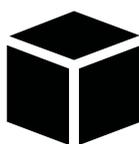
Fungi are responsible for significant spoilage and economic losses in the food chain, especially in bakery products. Another concern about the presence of fungi is the potential risk of off-flavor formation and mycotoxins production. Consumers have increased awareness of the potential risk of the consumption of synthetic antimicrobial agents and the direct exposure to the agents. Hence, there has been a growing interest in the development of antifungal packaging containing natural antifungal agent. Poly(lactide) (PLA) has received considerable attention as alternatives to synthetic polymers due to its biodegradability and existing commercial process. This study determined the antifungal efficacy, in vitro using the vapor diffusion assay of poly(lactide)/poly(butylene succinate-co-adipate) (PLA/PBSA) blends film entrapped with thymol. The remaining contents of thymol were evaluated by thermogravimetric analysis (TGA). The thermal properties of films were characterized by differential scanning calorimetry (DSC). Static headspace and solid phase microextraction (SPME) coupled with gas chromatograph-flame ionization detector (GC-FID) were used to determine the release kinetic of thymol during storage time at 25 °C. The results showed that the percentage loss of thymol after the converting process of the films was approximately 20 – 21 %, of which 2.1 % thymol was lost during the masterbatch preparation. The antifungal films demonstrated high antifungal activities against major foodborne (e.g. *Aspergillus* spp., *Penicillium* spp.) pathogens in bakery products. The addition of PBSA and thymol in the polymer matrices resulted in decreased glass transition temperature (T_g), melting temperature (T_m) and percent crystallinity (c). The second-order kinetic model provides the best fit for thymol release from the film.



The antifungal packaging developed delayed microbial growth and had potential for commercialization and applications in bakery products.

Keywords: biopolymer, volatile compound, antifungal efficacy, thermal properties, release kinetic

Topics: Active & intelligent packaging



Methodology for Medical packaging design with a social approach

Authors

Cristina Guzman-Siller (Universidad de Monterrey), Ana Catalina Ana Catalina Garza-Perez (Universidad de Monterrey), Ana Luisa Arroyo-Villa (Universidad de Monterrey), Ivonne Rodriguez-Jacobo (Universidad de Monterrey), Paulina Rayas-Cabello (Universidad de Monterrey) and David Dombrowski (Pfizer Consumer-Healthcare).

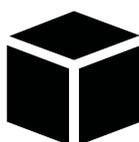
Abstract:

According to the World Health Organization (WHO), about one third of the world's population does not have access to medicines, especially in underdeveloped countries. Due to this, the same organization considers that urgent measures are required to end this problem. (Oscanoa, 2012).

The objective of this project is to commercialize high quality products at affordable prices, making them available to the population of low socio-economic level.

This methodology was designed to match the objectives of a cost reduction project in packaging with the objectives of a social project. This methodology consists in 10 stages:

1. Immersion: the aim is to introduce the designers in the context of the project.
2. Discover: second-hand information (interviews) and previous studies will be researched and analyzed.
3. Empathize: obtain first-hand information on the field with tools such as dialogue and observation.
4. Interpret: analyzing the information collected on the subject, insights and conclusions are obtained that will support the solution of the project.
5. Ideate: begins the creative stage in which the brainstorm and sketches are obtained and evaluated until the final idea is developed.
6. Mock up: the ideas previously designed are built to get a better analysis about them.
7. Evaluate: prototypes are valued by the user to ensure its effectiveness, its compliance with the premises, and obtain feedback to make improvements.



8. Evolve: the improvements obtained in the evaluation are made to regenerate the proposal and obtain the most suitable final product.

9. Conceptualize: the design language is defined based on the concept and environment in which the final product will be used.

10. Prototyping: the first copy of the final product is generated (3D).

The result was a methodology designed to develop a packaging product with a social approach for the pharmaceutical Pfizer, which is on testing phase.

Keywords: pharmaceutical, sustainable, distribution, logistic, individual doses, sale system, novel packaging

Topics: Active & intelligent packaging Distribution packaging Logistics & supply chain Medical, cosmetic & pharmaceutical packaging Novel packaging Packaging design, ergonomics & human factors Packaging sustainability



Synthesis of bio-based Cyclodextrin Metal-Organic Framework for encapsulation of Ethanol

Authors

An-Katrien Pauwels (California Polytechnic State University), Mieke Buntinx (University of Hasselt, Belgium), Trevor Harding (California Polytechnic State university), Joongmin Shin (California Polytechnic State university) and Ajay Kathuria (California Polytechnic State university).

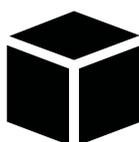
Abstract:

In the last two decades, various porous materials have been researched by the scientific community for diverse applications. Metal-organic frameworks (MOFs) belongs to the class of microporous, high surface area crystalline materials synthesized by coordinating metal ions with organic linkers. MOFs can host various molecules in their pores, depending on their interaction. This host-guest chemistry can be utilized to sorb established active organic compounds such as ethanol, acetaldehyde, formaldehyde, cinnamaldehyde, thymol, etc. Extended release of such active species can be used to optimize the shelf life of food products. In addition, MOFs have the potential to be used for sensing applications in Smart Packaging.

In this study, benign bio-based cyclodextrin metal-organic framework (CDMOF) was synthesized using edible, bio-based compounds. Ethanol, an antifungal, antimicrobial and antiseptic compound, was encapsulated in the CDMOF crystals using a vapor diffusion process. The synthesized CDMOF crystals before and after encapsulation were characterized using X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM), Fourier Transform Infrared Spectroscopy (FTIR), Differential Scanning Calorimetry (DSC) and Thermo-Gravimetric Analysis (TGA). Microporous high surface area body centered cubic crystal were obtained as observed by XRD and SEM. It was observed that CDMOF can encapsulate ~17% w/w of ethanol into the crystals.

Keywords: Active Packaging, Metal-Organic Framework, Ethanol, Gamma-cyclodextrin, Encapsulation

Topics: Active & intelligent packaging Novel packaging Packaging for food & agriculture Packaging materials



Simulation and experimental verification of a drop test and compression test of a Gable top package

Authors

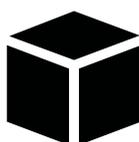
Mikael Nygårds*, Stefan Sjökvist, Gustav Marin, Jonas Sundström
RISE, Box 5604, SE-114 86 Stockholm, SWEDEN

Abstract:

Abstract: A finite element framework has been proposed that can be used to simulate both empty paperboard packages and package filled with plastic granulates. A Gable top package was made of a commercial paperboard, and material properties needed in the material model was determined. Two simulations were performed, a drop test and a compression test. By comparison between experimental and numerical results, the deformation mechanisms at impact could be identified and correlated to material properties. When the package was filled with granulates different mechanisms was activated compared to an empty package. The granulates contribute to bulging of the panels, such that the edges became more load bearing compared to the panels. When the edges carried the loads the importance of the out-of-plane properties also increased, and local failure initiation related to delamination was observed. Comparison between experimental and numerical impact forces show that there are still important things to consider in the model generation, e.g. variation of properties within the package, which originate both from material property variations and the loading history, e.g. during manufacturing and handling.

Topics: Packaging materials

Paper from the peer review stream, will be published in Packaging Technology & Science



Evaluation and Optimization of seal behavior through solid contamination of heat sealed films

Authors

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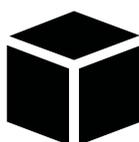
3 Fraunhofer Institute for Process Engineering and Packaging, Division Processing Technology, Heidelberger Str. 20, 01189 Dresden, Germany

Abstract:

Abstract: A method is presented to apply solid powder/granulate contamination (ground coffee, blood powder) in between the heat conductive seals of flexible packaging materials. A response surface method is tested and validated to optimize seal strength of heat conductive sealing with and without solid contamination. In this study, a maximal seal strength is defined as optimal. Using these methods, three typical packaging films with varying seal layer composition (metallocene LLDPE, plastomer and sodium ionomer) are maximized towards contaminated seal strength. Contamination caused a decrease in seal strength and narrowed down the process window (seal temperature and time combinations) in which at least 90% of the maximal strength is obtained. The influence of seal layer composition on the clean and solid (ground coffee, blood powder) contaminated seal performance (seal strength, process window and leak tightness) was evaluated. The film with the plastomer based seal layer outperformed the other films with respect to the width of the process window. It also reached a higher seal strength and a higher amount of leak tight seals (evaluated with the dye penetration test) after optimization. The hot tack test was evaluated as predictive test for the contaminated seal strength. The results of this study do not support an indicative relationship.

Topics: Packaging materials

Paper from the peer review stream, will be published in Packaging Technology & Science



Determination of the nitrogen gas transmission rate of ethylene vinyl alcohol copolymer, using a newly developed permeation measurement system

Authors

Caroline Maes^{1,2}, Wout Luyten¹, Geert Herremans¹, Roos Peeters², Robert Carleer³, Mieke Buntinx²

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3 Hasselt University, IMO-IMOMEC, Applied and Analytical Chemistry, Agoralaan Building D, 3590 Diepenbeek, Belgium

Abstract:

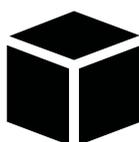
Ethylene vinyl alcohol copolymer (EVOH) is widely used in different applications such as food packaging, fuel tanks in the automotive sector, pipes for floor heating in the building industry amongst other uses due to its high gas barrier properties.

The oxygen (O₂) barrier properties of EVOH have been widely investigated, but for other gases the available data are usually limited to dry conditions, due to the limitations in measurement equipment. New permeation measurement equipment with low detection limits is required to determine the permeation of other gases, such as nitrogen (N₂), which is known to have a lower gas transmission rate (GTR) than O₂. Because EVOH is susceptible to moisture, the equipment should be able to operate at different temperature and relative humidity (RH) settings. In this study a versatile permeation measurement system is designed and used to determine the N₂ GTR of EVOH at varying temperature and RH. The system consists of two subsystems: a permeation system and a detection system. The first is equipped with four permeation cells with temperature, flow and humidification control. The detection system is based on the principles of gas chromatography. With this new system the N₂ GTR of 20 µm EVOH film containing 32 mol% ethylene was determined at 30, 35, 40 and 45°C in dry conditions. The R² value of 0.9944, resulting from the Arrhenius curve, indicates the system's integrity. The N₂ GTR curve plotted at 35°C, with the RH ranging from dry conditions to approximately 65%, reaches a minimum of approximately 0.12 cm³/(m²·day·atm) around 30-35% RH, and increases to 0.70 cm³/(m²·day·atm) at 65% RH. This curve shows a similar trend to that of the O₂ GTR for the same grade of EVOH. This study shows that the developed permeation measurement system is suitable to measure the N₂ GTR of EVOH in varying conditions.

Keywords: EVOH, nitrogen gas transmission rate, permeability, barrier properties

Topics: Packaging materials.

Paper from the peer review stream, will be published in Packaging Technology & Science



Ink-based printed susceptor for food packaging applications within the snack sector

Authors

Nuria Herranz Solana (ITENE), Jose Luis Vázquez (ITENE), Alicia Pinazo (ITENE), Raul Díaz (ITENE), Leticia Requena (ITENE), Teresa Calvo (ITENE) and Lluís Pascual (ITENE).

Abstract:

The snacks industry demands a recyclable solution to change from the traditional susceptors (aluminized PET foil) to a more affordable and environmentally -friendly solution because of the legislation developments which aims all packaging solutions must be recyclable, re-used or compostable in 2030. In that sense, ITENE has developed an ink based printed susceptor applied over kraft paper substrates.

Likewise, to evaluate the effectiveness of the development, ITENE has developed an evaluation protocol too. These test protocols were aimed at the evaluation of the ink behaviour, including: cooking tests, deposition and adhesion measures, viscosity parameters, biodegradability and migration tests, among others.

In comparison with current commercial susceptor, the ink-based printed susceptor shows similar cooking index, being in the range of 80-90% of cooked popcorn. Besides that, the ITENE's ink-based printed susceptor is able to reduce costs of the susceptor up to 30% during manufacturing. Therefore, the ITENE's ink-based printed solution is able to meet market requirements. Migration and compostability tests showed also positives results making this solution even more attractive to the food industry sector. Furthermore, ITENE has scaled-up and validated the development with the printing industry, specifically, flexography and gravure printers to verify the appropriate deposition and adhesion of the ink with common printing techniques while reaching good cooking percentages as well. It is worth to note that during the scale-up of the process it was not necessary the change of the current parameters of industrial processes of packaging printing.

Moreover, it will be presented the latest developments aimed at work in the adaptation of the ink in polymeric matrices to develop a new generation of printed susceptors. This new approach will enable print susceptor inks in processed foods to achieve roasted or gratin effects. The new approach will generate a novel generation of packaging with a new market niche.

Keywords: printed susceptor, microwave, food packaging

Topics: Active & intelligent packaging Packaging for food & agriculture Packaging printing & graphics



Vanillin-Based Active Paper Packaging Influence on Shelf Life of Bakery Products

Authors

Napatsorn Leabwan (KASETSART UNIVERSITY), Tunyarut Jinkarn (KASETSART UNIVERSITY) and Pattarin Leelaphiwat (KASETSART UNIVERSITY).

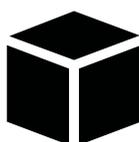
Abstract:

The effectiveness of most antimicrobial packaging are based on migration of active agent from packaging materials through food or through headspace surrounding the food to inhibit the target microorganisms. There are many kinds of active compounds such as antimicrobials and antioxidants. Vanillin is the natural active compound presenting the antimicrobial activity and it has been used to incorporating to the petroleum-based plastic film.

This study developed active paper coated with vanillin as antimicrobial agent. The agar diffusion and agar dilution methods used to determine minimal inhibitory concentrations (MICs) of vanillin for bacteria (*Escherichia coli*, *Bacillus cereus* and *Staphylococcus aureus*) and fungal (*Aspergillus niger* and *Penicillium sp.*). The active paper was developed based on the MIC of vanillin and placed in the package of banana cupcake comparing to the commercial packaging. Then aerobic plate counts and yeast and mold were determined during storage at 25 °C for 18 days. The results suggested that 0.24 g of vanillin completely inhibited the growth all bacterial and fungal in this study. The active paper coated with vanillin showed the inhibition of microbial growth for the banana cupcake. Bacterial, yeasts and molds counts were smaller for the packaging with vanillin coated paper than the commercial packaging for banana cupcake.

Keywords: vanillin, active packaging, paper packaging, shelf life, bakery product

Topics: Active & intelligent packaging



An Intelligent Colorimetric Indicator based Curcumin-Methylcellulose for Detecting Status of Sea Bass Fillets during Chilled Storage Condition

Authors

Nawaporn Wannawisan (Kasetsart University), Kanokporn Pathanasriwong (Kasetsart University), Pongtep Wilaipun (Kasetsart University), Jiraporn Runglerdkriangkrai (Kasetsart University), Amporn Sane (Kasetsart University) and Panuwat Suppakul (Kasetsart University).

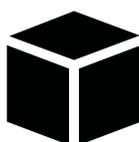
Abstract:

Fish spoilage indicator (FSI) based on curcumin as a pH sensitive dye was developed by employing metabolites related to total volatile basic nitrogen (TVB-N) in packaged head space to monitor a deterioration of the status of sea bass fillets during chilled storage. An influence of storage conditions (4°C and 10°C) on microbiological (total viable count (TVC) and Pseudomonas count) and chemical (TVB-N) changes were investigated.

A color transition of curcumin solution was evaluated using a UV-Vis spectrophotometer whereas a color transition of curcumin-incorporated methylcellulose based indicator film on pH buffer and ammonia vapor were assessed using a CIE L*, a*, b* chroma meter. In this work, TVC and Pseudomonas count of sea bass fillets stored at 4°C gradually increased while at 10°C substantially rose and reached a minimum spoilage level (6 log cfu.g⁻¹) after 6 and 2.3 days, respectively. In addition, TVB-N at minimum spoilage level was approximately 22 mg/100g sample. This indicator film was turned from yellow to orange in a pH buffer range of 7.0-9.0 and from orange to red brown in a pH buffer range of 9.0-13.0. After exposure to ammonia vapor (0.01-0.10 M ammonia solution), this indicator film was highly sensitive to ammonia concentration in which turned from yellow to orange and orange-brown within a few minutes. Consequently, this fish spoilage curcumin-incorporated methylcellulose based indicator film can be possibly applied as an intelligent device for monitoring a status of packaged fresh fish fillets in chilled conditions.

Keywords: Curcumin, Fish spoilage indicator, Intelligent packaging, Methylcellulose, Sea bass, Total volatile basic nitrogen

Topics: Active & intelligent packaging



Market Implementation of Active and Intelligent Packaging – Opportunities from a Socio-economic Perspective

Authors

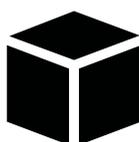
Johanna Lahti (Tampere University), Sanne Tiekstra (Bumaga BV) and Mieke Buntinx (Packaging Technology Center imo-imomec, University of Hasselt).

Abstract:

Bioeconomy is based on the shift from fossil to renewable raw materials to respond to the challenges of climate change, ecological scarcity and depletion of natural resources. Packaging plays an important role in the bioeconomy. The demand for high quality active and intelligent packaging (AIP) concepts is constantly increasing. Most of the current active or intelligent packaging solutions are plastic-based, so there is a clear demand for renewable and sustainable solutions to create new packaging materials and concepts. The use of bio-based materials in packaging decreases the dependence on fossil fuels. Wood based biomass that is available in a large scale offers attractive “green” polymers. Also biopolymers that are based on agricultural or other waste streams offer interesting alternatives for traditional oil-based polymers. Developments of new fibre-based packaging materials with active and intelligent features offer huge potential, as AIP can help to optimise the supply chain, increase food shelf life and consumer consciousness of food utilisation. However, very few of the potential and existing solutions currently have been able to reach the market. To identify the key social, technical and technological, economic, ecologic, and legislative factors that hinder this market introduction, COST Action FP1405 Active and intelligent fibre-based packaging - innovation and market introduction (ActInPak) was established in 2015. Within this multidisciplinary platform, both science and industry gathered to gain insights in the barriers towards market introduction of active and intelligent solutions in packaging industry. This paper presents these insights especially from the socio-economic perspective.

Keywords: Active packaging, Intelligent packaging, Socio-economic perspective, Market

Topics: Active & intelligent packaging



A Numerical Model for Predicting the Vibratory Behaviour Road Transport Vehicles

Authors

Matthew Lamb (Victoria University), Michael Long (Ororra Research and Technology) and Vincent Rouillard (Victoria University).

Abstract:

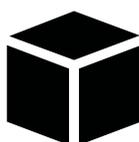
With increasing demand for reducing packaging waste, there is an impetus to use light weight systems, such as stretch and shrink wrap for containing unitised loads. As well as their ability to withstand vertical vibrations during road transport, such containments systems are expected to overcome their susceptibility to the dynamic lateral forces generated by transport vehicles. In addition to the (transient) lateral forces created by vehicle manoeuvres, sustained lateral forces arise from the pitch and roll vibratory motion of the vehicle caused by road surface unevenness. These need to be taken into account if laboratory simulation is to be realistic and accurate.

Recent efforts by the authors have exposed the many challenges associated with experimentally establishing the influence of various parameters (such as vehicle geometry, dynamic characteristics and vehicle/payload inertial properties) and recommend the creation of a vehicle numerical model to allow independent variations of each parameter; hence enabling the establishment of the influence of these parameters on the multi-axial vibratory behaviour of ground transport vehicles.

This study focuses on establishing the relationship between the heave, pitch and roll response of transport vehicles and their sensitivity to variations in the vehicle's parameters as well as the mass and position of the payload. The analysis was achieved using a specially-developed numerical tool which simulates the multi-axial vehicle vibrations resulting from road profile excitation. Results from the analysis of the envelope distributions as well as heave versus pitch and roll bivariate histograms reveal that this relationship can be modelled by a linear function, the slope and spread of which are related to the geometric and inertial characteristics of the vehicle and payload system. Importantly, the numerical model enables prediction of Power Density Spectra and rms distribution that are essential for accurate simulation of multi-axis vibration for the optimisation of containment systems.

Keywords: Vibration, road vehicles, heave, pitch, roll

Topics: Distribution packaging



A Method for Predicting the Compression Strength of Any Type of Corrugated Box

Authors

Takashi Takayama (Ph. D. Student, Graduate School of Maritime Sciences, Kobe University) and Katsuhiko Saito (Transport Packaging Laboratory, Kobe University).

Abstract:

Several formulae for calculating the compression strengths of corrugated boxes have been proposed based on both the Kellicutt and McKee formulae. These formulae can be applied only to regular slotted containers, meaning that they cannot be applied to other varieties of boxes or boxes with partitions. Thus, it is necessary to perform multiple tests in order to obtain sufficient and reliable data related to compression strength.

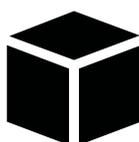
In this study, we propose a practical prediction method based on modified versions of the Kellicutt or McKee formulae, which are capable of estimating the compression strengths of panels with differing geometrical constraint conditions. Regarding the calculation method, first, the boxes are disassembled into panels. Second, the compression strength of each panel is calculated using the modified formulae according to the panel's geometrical constraint condition. Finally, the box's compression strength is obtained by adding the compression strengths of each individual panel.

To confirm the validity of our proposed method and formula, the obtained compression-strength values are compared with the actual measured values. The results of this validation suggest that our method and formulae are accurate within 20% deviation and 7.5% average error; this accuracy can be considered sufficient for practical use.

In conclusion, our proposed method and formulae can effectively contribute to the improvement of R&D related to the box-design field.

Keywords: Corrugated Box, Compression Strength, Distribution of Load-Carrying Capacity, Kellicutt Formula, McKee Formula

Topics: Distribution packaging Packaging materials



Relation between conditions of cushioning design and resonant frequencies of cushion – product system

Authors

Kazuki Tsuda (Osaka research institute of industrial science and technology), Akira Hosoyama (Osaka research institute of industrial science and technology) and Shogo Horiguchi (Osaka research institute of industrial science and technology).

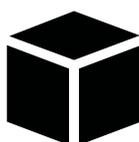
Abstract:

Vibration tests have been conducted to packaged freights in various industries in order to prevent troubles due to transportation vibration. The authors have also conducted the tests to various packaged freights, have often experienced that packaged products resonate in a low frequency range (about 10Hz to 30Hz) during the tests. Because cushioning design for shock is mainstream in current design of cushioning materials, damping design for vibration is often insufficient. As a resonance causes troubles due to vibration, if it is possible to grasp and adjust a resonant frequency at a cushioning design stage, both cushioning design and damping design become possible. In this paper, as a basic study to understand the relation between both designs, the relations between conditions of cushioning design and resonant frequencies of a cushion – product system is examined. In this case, an expanded polyethylene (EPE) cushioning material was used. It was focused on the rigidity of cushioning material which changes in each cushioning design. The rigidity range of cushioning material designed by using the cushion curve was calculated. The resonant frequency range of the cushion – product system (the resonant frequency range) was calculated. Therefore, changing conditions such as mass of packaged products, critical acceleration, thickness of cushioning material and expansion ratio, the relations between them and the resonant frequency ranges were examined. As a result, it was found that these relations had following tendencies.

- (1) Even if the mass of packaged products increases, the resonant frequency range does not tend to change.
- (2) If the critical acceleration of packaged products increases, the resonant frequency range tends to expand.
- (3) Even if the expansion ratio of cushioning materials increases, the constant tendency to the resonant frequency range is not observed.
- (4) If the thickness of cushioning material increases, the resonant frequency range tends to change low frequency range.

Keywords: Cushioning material, Cushioning design, Damping design, Resonant frequency, Packaged freight, Vibration test

Topics: Distribution packaging



Kurtosis Response Spectrum Analysis for Anti-Vibration Package Design

Authors

Akira Hosoyama (Osaka research institute of industrial science and technology), Kazuki Tsuda (Osaka research institute of industrial science and technology) and Syogo Horiguchi (Osaka research institute of industrial science and technology).

Abstract:

Anti-vibration package design is performed to protect products from vehicle vibration. Generally, in anti-vibration package design, cushioning material dimension is determined so that acceleration root-mean-square (RMS) of products becomes lower, assuming that the real-world vibration is Gaussian. However, in many cases the field data represents a non-Gaussian distribution, so we need to consider non-Gaussianity as well as acceleration RMS. This paper develops a kurtosis response spectrum as a measure for anti-vibration package design considering non-Gaussianity of vehicle vibration. A kurtosis response spectrum is a plot of the kurtosis of an acceleration response of a series of a single-degree-of-freedom (SDOF) system to base acceleration input. In addition, this paper calculates the kurtosis response spectrum of measured vehicle vibration and clarifies that the kurtosis response changes depending on the natural frequency of a SDOF system. A kurtosis response spectrum provides useful information to understand the effect of the natural frequency on kurtosis response, so packaging engineer can obtain necessary information for anti-vibration package design considering non-Gaussianity from a kurtosis response spectrum.

Keywords: anti-vibration package design, non-Gaussian distribution, kurtosis, cushioning material, response spectrum

Topics: Distribution packaging



Accumulated fatigue spectra for random vibration testing

Authors

David Shires (Wiley Journal of Packaging Technology & Science), Changfeng Ge (Rochester Institute of Technology) and Kyle Dunno (Rochester Institute of Technology).

Abstract:

This paper shows that, for most collated products, random vibration testing could effectively be conducted over a narrower frequency range. In turn this indicates the potential for the simplification of test systems, in particular multi-axis systems.

Objective

To explore the potential for simplifying vibration test systems by demonstrating that most fatigue is accumulated in collated products over a much narrower frequency range than typically used in current tests.

Methods

Transmissivity data were determined (single vertical axis) for palletised collations of five different products. The data were interpreted to show the accumulation of fatigue as a function of frequency and presented as accumulated fatigue spectra. Results were determined for standard power density spectra for leaf spring and air-ride journeys.

Results and Conclusions

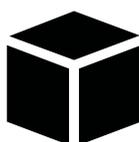
Results show that:

- 1: the first major resonances of the collated products studied fall between 8 and 25 Hz;
- 2: 95% of fatigue is accumulated in a bandwidth of 5 to 80 Hz for products with a complex secondary (higher frequency) response (for both leaf spring and air-ride test spectra);
- 3: 95% of fatigue is accumulated over a frequency range of 5 – 30Hz for products with a “classic “ (single peak) response.

It is concluded that random vibration tests for typical collated products could be conducted over a narrower frequency band, with corresponding simplification of test systems. In particular this indicates the potential for simpler “add-on” pitch and roll systems to extend the test potential of current single axis machines.

Keywords: vibration, random vibration, fatigue, bandwidth, multi-axis testing

Topics: Distribution packaging Packaging standards & legislation



Emergency braking and Stability testing, Response Analysis

Authors

Manuel García-Romeu Martínez PhD*1, Enrique de la Cruz Navarro MSc1
1 Safe Load Testing Technologies, Paterna 46980, Spain.

Abstract:

Abstract: This paper shows how to undertake in the lab accurate stability tests for unit loads. The number of standard stability tests, procedures and regulations including stability requirements for load units are growing in order to increase safety on road and optimize packaging costs. Tests and regulations for unit load stability due to braking and lateral forces usually defines only the "steady acceleration", some other tests define the "dwell" test duration and a small group define the "jerk" time to reach the steady acceleration. The horizontal natural frequency of the unit load it is determinant for the response level of this unit load subjected to that pulses. According to the literature the horizontal natural frequency responses of palletized loads are typically bigger than 1,5 Hz. This document shows the frequency relationship between the real transport braking and stability testing methods by using the response spectrum (RS) tool analysis. The analyzed tests are the horizontal impact test, the dynamic dwell test and the dynamic dwell with jerk control test. The target is to define the requirements for an acceleration pulse able to produce the real braking intensity for all the range of horizontal natural frequency of common loads. In the paper has been demonstrated that a maximum of 200 ms time jerk duration to get the steady acceleration following by a minimum of 300ms time dwell duration of a trapezoidal pulse it is required to get exactly the same response as produced in a real emergency braking for unit loads of horizontal natural frequency greater than 1,2 Hz. About inclined or horizontal impact tests, as they are habitual half-sine pulses of around 10ms or 15 ms duration between 0,9 and 2,6 m/s of total velocity change, it has been demonstrated that the difference of horizontal response of a unit load subjected to that shocks with respect a real emergency braking response with equivalent total change velocity, starts to increase from 0,6 Hz horizontal natural frequency of the unit load, reaching a 398% difference for unit loads of 2,8 Hz and 1786% difference for unit loads of 9 Hz, not being these short duration impacts able to simulate the response of an emergency braking. Only horizontal impact tests with half-sine pulses of at least 680 ms duration and same steady acceleration of a real emergency braking can reduce the difference of response. For example, for a natural frequency of the unit load of 2,8 Hz the difference in response drops to less than 12%.

Keywords: Jerk, Shock response spectra, SRS, ARS, DRS, real testing, truck braking, load stability test, horizontal acceleration, impact test, emergency braking

Topics: Distribution packaging



Response performance of semi-rigid stacked plastic drum units along shock impulses

Authors

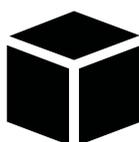
Bence Molnár (Széchenyi István University), Antal Bakonyi (Széchenyi István University), Sher Paul Singh (Packaging Forensic Associates, Inc.) and Péter Böröcz (Széchenyi István University).

Abstract:

Stacked packaging unit is one of the main forms of distribution packaging of products, but its dynamic performance is not perfectly understood. This study focuses on the response acceleration level and attenuation phase of semi-rigid plastic drums in three-layer stacked unit occur input shock impulse on vibration table. The dynamic behavior of unit is investigated along the variables such as filling height, input citation level (in G's), and with constraint of ratchet strap, and without ratchet strap. The research conducted shock impulses at the measurements to observe the force amplification by different layers and to present a possible relationship with parameter estimation of changes along the peak accelerations and in attenuation phase. The magnitude of half-sine shock impulses were 0.5G, 1.0G, 1.5G, 2.0G and 2.5G with a duration of 6 ms. The damping factor was in general between 0,2 and 0,7 depending on magnitude of impulse and existence of ratchet strap. The acceleration levels naturally became more severe with the increase of input acceleration level, but in each case lower peak acceleration was detected from the bottom layer to the top layer. The attenuation phase of drums was well evaluable when the semi-rigid drum was half filled, and could not be clearly examined when it was total filled due to the high frequency components of response in the out of phase motion. In total, the acceleration levels of layers are significantly influenced by both input magnitude level and filling level, furthermore the semi-rigid material played damping role in the aspect of stacked unit.

Keywords: dynamic performance, stacked packaging units, semi-rigid packaging, shock

Topics: Distribution packaging



Analysis of the axial crushing of thin-walled rectangular paper tubes with different strength in tension and compression

Authors

Xiaogen Lian (Jiangnan University), Liao Pan (Jiangnan University), Lixin Lu (Jiangnan University) and Jun Wang (Jiangnan University).

Abstract:

There are a number of models available to predict the energy absorption characteristics of metal tubes with the same tensile and compressive properties. However, most of these models are unsuitable to the emerging, sustainable packaging and energy absorption structure, such as composite and paper tubes with complex material properties. In this paper, an approximate energy absorption prediction model for the crumpling process of rectangular paper tubes is derived based on the kinematic analysis of a basic folding mechanism. The proposed model can be used to predict the mean crushing load and energy absorption characteristics of rectangular tubes with different strength in tension and compression. Besides, the relationship between solidity ratio and effective stroke ratio (ESR) was presented to improve the applicability of the proposed model. Then the model results were compared with experimental data which considered various geometric parameters of paper tubes. The results indicate that the mean crushing load increases substantially with an increase in the ratio of compressive yield strength to tensile strength, and ESR is linearly increasing with the decrease of solidity ratio. Furthermore, model solutions considering ESR show a good agreement with the experimental results while the previous models deviate from the test data. Therefore, the model can be applied to the paper tube design for energy absorber and protective packaging solutions, contributing to the sustainable packaging.

Keywords: energy absorption, axial crushing, tensile and compressive yield strength, rectangular paper tube

Topics: Distribution packaging Logistics & supply chain



Equivalent condition between acceleration RMS-life and stress-life curves for accelerated random vibration testing of packaged product

Authors

Zhi-Wei Wang (Packaging Engineering Institute, Jinan University).

Abstract:

Transport packaging of products is a complex structural system, having a variety of modes for vibration damage failure in logistics. The accelerated random vibration testing is an important tool to evaluate effectively the vibration performance of transport packaging.

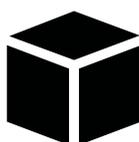
The existing accelerated vibration testing is based on Basquin fatigue model of power function. However, this model does not cover all forms of vibration damage and fatigue of materials and components. The vibration damage mechanism in different materials, components and packaging containers is different.

The author has developed a more general method for accelerated random vibration testing of product and transport packaging, which is based on the acceleration RMS-life curve (Grms-N) of component, and is suitable for the different fatigue models more than Basquin fatigue model.

This paper is a continuation of previous researches. It aims to search for the equivalence or equivalent condition between the acceleration RMS-life curve (Grms-N) and stress-life curve (σ -N). Two cases are taken into consideration: Basquin's type (power function type) and exponential function type materials. The result of this paper, together with the previous author's studies, constitutes the complete methodology of accelerated random vibration testing of transport packaging.

Keywords: transport packaging, accelerated random vibration testing, acceleration RMS-life curve, stress-life curve

Topics: Distribution packaging Logistics & supply chain



Angular accelerations, the key to transport simulation.

Authors

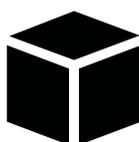
Ariana Gómez Tabanera (ITENE) and Patricia Navarro Javierre (ITENE). Angular accelerations, the key to transport simulation.

Abstract:

Traditionally, the modeling of distribution routes has been done with devices that only recorded accelerations in linear directions, obviating angular directions. These are key, due to the great influence they have on the damage identified in the goods. As a consequence, this study aims to demonstrate the influence of pitch and roll movement (angular accelerations) on the behaviour of loads throughout the distribution cycle. For this purpose, critical product distribution routes will be monitored by using the data recorder developed by ITENE, which is able to record in linear (vertical) and angular (pitch and roll) directions. The data obtained from the data recorder, will be used to perform comparative tests in the simulation laboratory, vertical vibration and vertical vibration with pitch and roll. All this in order to demonstrate the importance of recording angular accelerations for the validation of loads in the simulation laboratory using pitch and roll equipment.

Keywords: pitch and roll, transport accelerations, transport simulation, packaging damage, angular accelerations, distribution cycle

Topics: Distribution packaging



Analysis of a forklift handling course and multiple propositions with evaluation of laboratory simulations

Authors

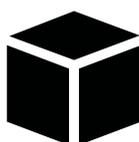
Anne-Sophie Bonnin (METROPACK), Jean-Baptiste Nolot (ESIREims - ESIEC - Université de Reims Champagne Ardenne), Victor Huart (METROPACK), Nicolas Krajka (METROPACK), Jérôme Pellot (METROPACK), Serge Odof (ESIREims - ESIEC - Université de Reims Champagne Ardenne / GRESPI) and Damien Erre (ESIREims - ESIEC - Université de Reims Champagne Ardenne / GRESPI).

Abstract:

From production to detail, packaging systems undergo mechanical, physical and climatic constraints. There is therefore a need in testing packaging systems before any launch to ensure their protective performance. Warehouses, loading docks and unloading docks are critical to packaging systems. On the one hand, surface defects such as potholes, bumps and gutters on the ground of the warehouse generate phenomena to the packaging system when carried by a forklift. On the other hand, loading or unloading goods to or from trucks can lead forklift operators to quickly operate, causing phenomena to the packaging system. That is why protocols, such as International Safe Transit Association (ISTA) or American Society for Testing and Materials (ASTM), for packaging systems shipping integrate forklift handling course. For the purpose of this study, a forklift has been equipped with an on-board data logger which aim is to record accelerations, in any direction, that occur when an operator proceeds to the 3B ISTA handling course. As the aim of this study is to determine the entirety of a packaging system after test, an academic system has been placed on the pallet carried by the forklift. This academic system constitutes a severity measurement. The vibratory phenomena and the transient events are analysed in both directions: horizontal and vertical. This analysis can permit to recreate test protocols which use vibration (Power Spectral Density (PSD)), or shocks (acceleration, duration velocity change and number), or transient events (Shock Response Spectrum (SRS)), or real-time replication. This research mainly focuses on shocks and transient events by sorting them according to their nature, level, duration and SRS. The study proposes a few test protocols based on SRS computing. These protocols are laboratory verified in both directions. An evaluation of each protocol using the academic sample is carried out.

Keywords: packaging system, forklift handling course, transient events, shock response spectrum

Topics: Distribution packaging



ISTA distribution environment data collection program

Authors

Brian O'Banion (International Safe Transit Association).

Abstract:

ISTA's mission to empower the people and organizations affecting packaging to minimize product damage throughout distribution and optimize resource usage through effective package design continues to be greatly influenced by packaged-product performance testing. As part of our strategic plan to deliver on this mission, ISTA developed a new "Distribution Environment Data Collection Program" with the primary goal of expanding our distribution environment data resources.

Objective

ISTA will use the "Distribution Environment Data Collection Program" to expand our distribution environment data resources. This data will then be leveraged to improve current testing protocols, add new testing protocols, and create a world-class data repository that can be leveraged by ISTA, and its members, to better model distribution locally, nationally, and internationally.

Methods

Through both directly-funded research and industry collaboration, we have begun obtaining atmospheric, vibration, storage and handling data that meets our established data collection standards for five prioritized global distribution routes.

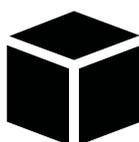
Results

This data will then be developed and implemented into ISTA test procedures as deemed appropriate by the ISTA Testing Council and Technical Division Board.

This approach will yield data that can then be segmented to model global distribution routes. It is also intended to serve as a starting point and not an end goal. We are also interested in working with members of the community who own data for routes outside of these identified target areas and have interest in sharing and building the ISTA data repository. This will ultimately serve to improve testing and package design globally.

Keywords: ISTA, Distribution, Environment, Data, Collection

Topics: Distribution packaging



The Effect of Coplanar Sensor Spacing on Determining the Angular Acceleration of Vehicles

Authors

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¹ Department of Food, Nutrition, and Packaging Sciences, Clemson University, SC, USA

² School of Mechanical Engineering, Purdue University, IN, USA

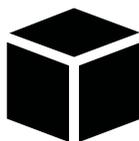
Abstract:

Vehicle vibration presents challenges to a packaged product that is inevitable in any distribution environment. Typically products are tested in only a single, vertical axis, researchers have shown that there is energy in all six axes of motion.

In this work, we study the recording methods of the six degrees of freedom (6DOF) motion of a transport vehicle. Using a co-planar sensor array, three tri-axial linear accelerometers and three angular rate sensors mounted in a L shape, are used to calculate the rotational accelerations that occur in the back of a vehicle. Missing from prior work is a scientific study designed to determine the minimum sensor spacing necessary to accurately capture the yaw, pitch, and roll of transport vehicles. A sensitivity study is conducted to determine the effect of the misplacement and misorientation of sensors on the angular acceleration calculation. A laboratory study is used to determine the distance error begins to accumulate in the angular acceleration calculation in response to a sinusoidal input. A field study is conducted to calculate the rotational motions of a vehicle on a rough road. It is found that a mounting fixture is valuable in assuring the necessary sensor placement accuracy needed to accurately determine angular accelerations of a truck. Additionally, laboratory and field analysis show that as the sensor spacing location approaches the origin sensor, angular acceleration calculation error increases due to a loss in distinctiveness. Sensors can be mounted closer than 76.20 cm but should be mounted greater than 12.70 cm apart.

Topics: Distribution packaging

Paper from the peer review stream, will be published in Packaging Technology & Science



Investigation of the Effect of Column Stacked Corrugated Boxes on Load Bridging using Partial Four-Way Stringer Class Wooden Pallets.

Authors

Laszlo Horvath.

Abstract:

Pallets are the foundation of the global packaging supply chain. They provide a way to store and transport products in an efficient manner. The load capacity of pallets greatly depends on the type of packages carried by the pallet; however, current pallet design methods do not consider the effect of packages on the load carrying capacity of the pallet. This results in excessive use of materials which reduces the sustainability of unit loads, drives costs up, and creates potential safety issues. The objective of this study was to investigate the effect of corrugated box size and headspace on pallet deflection and stress distribution on the top of the pallet as a function of pallet stiffness across multiple pallet support conditions.

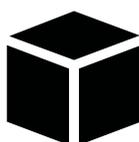
Data analysis identified that box size had a significant effect on the deflection of the pallet. This effect was only significant for warehouse racking across the width and length support conditions. As much as a 53% reduction in pallet deflection was observed for high stiffness pallets supporting corrugated boxes with 25.4 mm headspace when the size was increased from small to large. The redistribution of vertical compression stresses towards the supports as a function of the increasing box size was observed. The increased concentration of compression stresses on top of the supports and the resulting lower pallet deflection could significantly increase the actual load carrying capacity of some pallet designs.

The effect of box headspace was significant in some scenarios but inconsistent thus more investigation with a larger sample size is recommended.

Keywords: Pallets, Unit Loads, Pressure Distribution, Load Bridging, Corrugated Boxes

Topics: Distribution Packaging

Paper from the peer review stream, will be published in Packaging Technology & Science



Pharmaceutical Packaging and Logistics for the Elderly

Authors

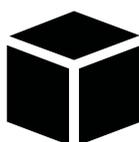
Kevin Smith (Brandman University) and Paul Singh (Packaging Forensic Associates Inc.).

Abstract:

This research will share pharmaceutical challenges within the elderly community in relation to smart packaging safety, e-commerce options, and reducing vulnerabilities in relation to cost, autonomous delivery and disposal expectations. Pharmaceutical packaging safety for elders is an area that must be explored and exploited without violating the integrity of the industry's ability to prevent potentially harmful or dangerous situations from occurring within their community. As the elderly community continues to grow their involvement with e-commerce will continue to expand. Identifying technologies to enhance their experience from cradle-to-cradle without insulting them is critical to a healthy supply chain relationship. The best strategies to reduce vulnerabilities in relation to cost, autonomous delivery, and disposal expectations involve implementing procedures that deal with risk associated with cost-effective solutions. The physical and logistical challenges facing pharmaceutical packaging are complex for the elderly community. We will share why packaging and logistics network flow are critical to developing, designing, and delivering packaging products that meet the logistical supply chain system for the elderly community.

Keywords: Smart, Packaging, Safety, E-Commerce, Vulnerabilities, Cost, Autonomous, Delivery, Disposal

Topics: Logistics & supply chain Medical, cosmetic & pharmaceutical packaging



Four-dimensional concurrent engineering - an extended theoretical framework integrating packaging

Authors

Chris Dominic (University of Gävle) and Carl Olsmats (Dalarna University).

Abstract:

This paper takes on the challenge to integrate packaging in a concept of four-dimensional concurrent engineering (4DCE). The purpose is to explore a conceptual model and empirically evaluate the specific performance of packaging in interrelation with product and processes in the Supply Chain (SC). The objectives are to better understand the concepts of packaging logistics and logistics management in the SC. The conceptual model 4DCE is developed based on the three-dimensional concurrent engineering theories.

The tool Packaging Scorecard is applied to evaluate the concurrent performance of packaging throughout the SC. The packaging system involves many actors that are integrated into the 4DCE framework with focus on interaction of SC and logistics in relation to packaging and product, with the overall aim to operate as effectively and efficiently as possible. In order to explore the potential of the 4DCE framework, empirical verification and testing of the concept has been carried out. The process has been done through multiple in-depth, action-oriented case studies in three different industries on the Swedish market. The case studies covered holistic aspects on the packaging system.

The concept 4DCE contributes to packaging logistics theory by providing a framework for assessment incorporating complex and dynamic interactions between product, packaging, logistics and SC. Furthermore, the holistic packaging development concept is ensured by increasing knowledge of the packaging system and how it interacts with actors and performs to fulfil requirements along the SC. The 4DCE provides valuable data for packaging development processes in the cases, however there is a need for broader studies in different industries.

Keywords: packaging logistics performance, concurrent engineering, 4DCE, redesign

Topics: Logistics & supply chain



Student sense of belonging in a large classroom introductory packaging course

Authors

Alyssa Harben (Michigan State University School of Packaging) and Laura Bix (Michigan State University).

Abstract:

Introduction: Student persistence and success in obtaining a college degree is dependent upon not only cognitive ability, but also interpersonal and intrapersonal competencies. While most work aiming to prepare students to succeed in college focuses on critical thinking, problem solving, and other cognitive skills, research suggests that the student's beliefs about whether or not they belong at a university or a program of study is a strong motivator for educational attainment. This sense of belonging, which is strongly correlated to student success, is especially important for students from underserved groups pursuing degrees in STEM fields, such as packaging science.

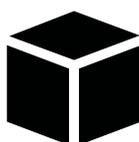
Objective: to compare how differently structured formative assessments influence differing levels of a feeling of belonging in the packaging discipline, as self reported by students in real time.

Methods: This study was conducted in a large classroom introductory packaging course. Over multiple class periods, directly after different types of formative assessments, (in class group activities (GA), individual i-Clicker questions (IQ), and peer discussion i-Clicker questions (DQ)) students responded via i-Clicker to items taken from an adapted version of the Psychological Sense of School Membership, a Likert Scale ranging from "not at all true" to "extremely true" (1-5).

Results: Pilot results calculated using Repeated Measures ANOVA indicate statistically significant differences between the three formative assessments at $\alpha=0.05$. Students ($n=36$) indicated the highest sense of belonging directly after IQ, with a mean score of 4.118 (S.E. .095), followed by questions directly following DQ with a mean of 3.791 (S.E. 0.95), with the lowest sense of belonging reported directly after GA, with a mean of 3.519 (S.E. 0.79). These preliminary results suggest individual interactions with the instructor might influence students' sense of belonging more than interactions with peers. This study is ongoing; data collection is scheduled to be completed in April 2019.

Keywords: Packaging Education, Teaching, Student Response Systems, Clickers, Sense of Belonging, STEM Education

Topics: Novel packaging



Nanocellulose as material reinforcement and its potential for packaging applications

Authors

Rafael Sanchez Serrano (ITENE), Pilar Albaladejo Sanchez (ITENE), Soraya Sanchez Ballester (ITENE), Jose Maria Alonso Soriano (ITENE) and Miriam Gallur Blanca (ITENE).

Abstract:

Nowadays, the increase in the amount of waste produced has become a major concern throughout the world. Therefore, the development of new strategies for reuse and reprocessing of waste materials is necessary, aligned with the circular economy and the bio-economy.

In this sense, ITENE is focused on the exploitation of different alternative sources (cereals, tomato plant, etc.) to obtain added-value additives for packaging like nanocellulose and their practical application in bio-based materials.

With this aim ITENE has been working several projects like AGRIMAX, PULPACKTION and SINSOST in order to explore the possibilities of nanocellulose as reinforcement additive for packaging applications. Two main objectives were addressed: a) the production of "low-cost nanocellulose" through a disintegration process of the cellulose obtained from residues; b) their application as additive to improve polymeric and paper packaging materials.

Regarding first objective, in AGRIMAX project different agroindustrial waste have been tested for obtain low cost nanocellulose. In addition, the evaluation between commercial and low cost nanocellulose properties have been carried out according to the Quality Index, obtaining similar values between both.

For the second objective nanocellulose have been used to improve different packaging materials by using different technologies, specifically, two applications will be presented:

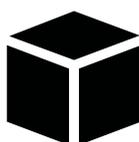
1) Modification of nanocellulose with polymeric solutions for their application as coating for cellulose wet moulded trays. Here it was found improvements of more than 99% in the barrier properties (PULPAKTION project).

2) Application in paper as an additive for reinforcement. Improvements of more than 50% in the mechanical properties and more than 90% in terms of permeability were found in the framework of SINSOST project.

These results can effectively contribute to mitigating the environmental impact of waste, moving towards a biorefinery concept. Furthermore, the use of MFC for improve bio based-materials will impact on the packaging industry providing sustainable alternatives to conventional packaging.

Keywords: Nanocellulose, biopolymers, packaging, sustainability, agroindustrial waste

Topics: Novel packaging Packaging materials Packaging sustainability



Current Issues and Advances in Consumer Research and Testing for Sustainable Packaging

Authors

Ziyne Boz (Packaging Technology and Research LLC.), Virpi Korhonen (Package Testing and Research) and Claire Koelsch Sand (Packaging Technology and Research LLC.).

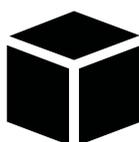
Abstract:

Sustainability in packaging has co-evolved with the incorporation of sustainable development principles in economic, environmental, and social aspects of various industrial and organizational platforms. Today, the packaging industry is confronted by the impact of packaging on the environment which has manifested itself in the form of: visible plastics-related pollution, other packaging waste, declining air, and water quality, and climate change. Value chain complexities of incorporating more sustainable packaging can discourage companies from implementation of what are known as more sustainable solutions. For this reason, many sustainable packages never make their way into the marketplace. However, positive consumer attitude towards more sustainable packaging can ensure the return of the efforts and motivate industry to employ next-generation sustainable solutions. Thus, a better understanding of consumer dynamics towards sustainable packages such as environmental-friendliness, material origins, and recycling is of primary importance. The objective of the present study is to explore and review the advantages and disadvantages of previous and current practices in consumer-related aspects of sustainable packaging. Hence, opportunities, strategies, research gaps were pointed out on how to improve the current approaches toward implementing sustainable packaging.

This study summarizes the available research and data on consumer attitudes and behaviors on sustainable packaging. The gap between the sustainability framework and the consumer perceptions are explained by several behavioral theories and applications; and accordingly, strategies to improve the understanding and attitude on eco-friendly, recyclable, returnable and compostable packaging are presented. Consumer-research approaches to re-align industry strategies and consumer behaviors at the time of purchase and post-consumption disposal were discussed. The critical discussions in this research are expected to provide guidance for the packaging industry for the consumer aspects of sustainable packaging applications.

Keywords: Sustainability, Packaging, Consumer Attitude and Behaviors

Topics: Packaging design, ergonomics & human factors Packaging standards & legislation Packaging sustainability



Frustrated and malnourished: unwrapping older peoples' food and beverage pack experiences in hospital

Authors

Alison Bell (University of Wollongong), Karen Walton (University of Wollongong) and Alaster Yoxall (Lab4Living, Sheffield Hallam University).

Abstract:

The aging population means that over half of all public hospital beds are occupied by older adults, many with complex medical needs. Malnutrition among this group of people is unfortunately a common reality. Food service in hospitals increasingly rely on packaged food, beverage and supplements in order to provide portion controlled and cost efficient nutrition. However, research with well older people has shown that this packaging often provides barriers to the older person and may impede rather than encourage dietary intake.

Objective

The objective of this research was to observe older people in a large teaching hospital interacting with packaging and gain their views on the ease of pack opening.

Method

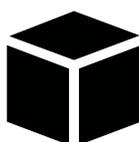
Fifty-nine older adult inpatients were recruited at The Canberra Hospital, ACT, Australia. Measures included nutritional status, video observation data and interviews.

Major Findings

Margarine, cutlery and fruit cup were the top three problematic packaged items requiring the longest times and highest number of attempts to be opened, while questionnaire result showed that cutlery, juice cup and water bottles were the most difficult packs to open. These findings provide useful information to packaging designers and manufacturers – gaining insights from real users in real settings to inform improved design.

Keywords: food and beverage packaging, openability, older adults, hospital food service

Topics: Packaging design, ergonomics & human factors



Using mobile eye tracking and K-coefficients for analyzing usability trials

Authors

Irene Carbonell (California Polytechnic State University) and Javier de la Fuente (California Polytechnic State University).

Abstract:

Mobile eye-tracking technology provides data that can be linked to user attention during visual perception. The relationship between fixation duration and saccadic amplitude immediately following the fixation has been proposed for the analysis of static and dynamic scene viewing. Short durations followed by long saccades are characteristic of ambient processing. Longer fixation durations followed by shorter saccades suggests focal processing.

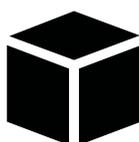
The objective of this study was to apply a novel parametric scale (i.e., K-coefficients) to eye movement data from packaging usability trials of known difficulty to investigate the relationship between fixations, saccades, and cognitive-challenging phases in user-package interactions.

A panel of 40 participants were asked to stand behind a counter of a fixed height wearing an ASL Mobile 5 glasses and complete a task in a lab facility. They were instructed to imagine an emergency scenario where they needed to remove all contents from a package as quickly as possible. Half of the participants were randomly assigned a package with a pull tab on the top of the container (i.e., easy task) while the other half tested a package with a press-in mechanism on the bottom of the folding carton (i.e., difficult task). K-coefficients for each trial were calculated using fixation durations and saccade amplitudes.

One-way analyses of variance were used to explore the relationship between task difficulty, gender, and K-coefficients. Results revealed significant differences between K-coefficients of the difficult and easy tasks ($F(1,38)=6.59$, $p=0.0143$). Moreover, mean K-coefficients of the easy task were negative, signaling ambient processing, while mean K-coefficients of the difficult task were positive, an indication of focal processing. No significant differences were found between genders ($F(1,38)=1.04$, $p=0.3146$). Findings have critical implications for understanding user-package interaction problems and support the use of algorithmic processing of eye-tracking data for automatic usability problems detection.

Keywords: Package design, Eye tracking, Usability, Affordances, Ergonomics

Topics: Packaging design, ergonomics & human factors



Design thinking in packaging education

Authors

Javier de la Fuente (California Polytechnic State University), Irene Carbonell (California Polytechnic State University) and Mary LaPorte (California Polytechnic State University).

Abstract:

Historically, curricula of American universities offering packaging degrees have been largely based on a “technology/science” model in which design thinking struggles to find a place. In a broader context, students in scientific/technical-oriented disciplines find it challenging to achieve good levels of innovation when exposed to design problems. Research indicates the need for implementing alternative pedagogical approaches in technical curricula that enhance students’ creative skills.

The purpose of this study was to evaluate the implementation of a cross-disciplinary pedagogical approach based on the Stanford Design Thinking model with a focus on teaching innovation in the field of packaging engineering at a university in the United States.

A Design Thinking Project-Based Learning (DTPBL) approach was used to improve the levels of innovation in student work. Its outcomes were compared with those of a Traditional Project-Based Learning (TPBL) approach. The implementation of DTPBL across several courses took place between 2015 and 2018. TPBL was the norm in these courses between 2009 and 2014. National and international student design competitions were used to assess the level of innovation of student work externally. Statistically significant differences were found in levels of innovation of student work between approaches. DTPBL projects placed higher in design competitions, and they were recognized more often by independent expert judges than TPBL projects. At a national level, TPBL generated 172 projects in 11 instances, obtaining 12 awards. DTPBL produced 61 projects in seven instances, and student work was recognized with 21 awards. At a global level, student work created with TPBL was never recognized, while student projects generated using DTPBL received five recognitions in two participation instances.

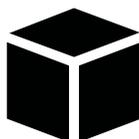
This study provides evidence that a Design Thinking Project-Based Learning (DTPBL) approach can be a successful pedagogical strategy to enhance students’ creative skills and produce innovative packaging design solutions.

Keywords:

Packaging Engineering Pedagogy, Innovation, Design Thinking, Project-Based Learning, Capstone Course

Topics:

Packaging design, ergonomics & human factors



Reducing plastic by using recyclable materials without compromising quality and shelf life of salmon fillets

Authors

Marit Kvalvag Pettersen (Nofima), Magnhild Seim Grovlen (Nofima), Paal Georg Storo (Salmar AS) and Anlaug Aadland Hansen (Nofima).

Abstract:

Food waste is an extensive global problem and causes significant societal challenges. Recently, focus has also been put on packaging in general and plastics in specific and environmental implications have escalated consumers awareness. The emphasis has previously been on packaging solution for shelf life extension. However, optimal packaging concepts should focus on both quality and shelf life, in addition to concepts for reduced environmental impact e, g, material selection and transport efficiency.

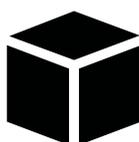
The purpose of the study was to gain knowledge on how packaging solutions can be designed to fulfill both food quality and environmental aspects. More specifically, to investigate how the quality of salmon stored in recyclable monomaterial (Polypropylene trays) was affected by g/p ratio, CO₂-emitter and storage temperature. The experiment included four g/p ratio (1.0 1.32 1.95 and 2.27), three storage temperatures (1°C, 4°C and 6°C) and the use of CO₂-emitter.

The results show that when stored at 4°C the g/p ratio has significant effect on the drip loss and bacterial growth. However, at the end of storage period the differences are relatively small. The differences in drip loss due to g/p ratio and the CO₂-emitter were most apparent at low storage temperature. The bacterial growth was, as expected, affected by storage temperature and the effect of CO₂-emitter was reduced at increasing temperatures. Sensory quality was influenced by the g/p ratio after 8 days of storage for some of the attributes, e.g. cloying odor, but no differences after 12 days of storage.

These results show that recyclable materials can be applied for storage of salmon with required shelf life obtained. This study shows that potential reduced environmental impact can be obtained by using recyclable material and reducing g/p ratio. Whereas the potential to increase transport efficiency while the quality and shelf life of the product is maintained.

Keywords: Recyclable materials, Food quality, Gas/product volume ratio, Active packaging

Topics: Packaging for food & agriculture Packaging sustainability



Replacing conventional laminate material (PA/PE) with recyclable monomaterials (PP, HDPE): A case study on hot dogs

Authors

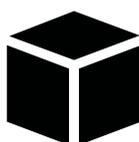
Julie Nilsen-Nygaard (Nofima), Jawad Sarfraz (Nofima), Tanja Radusin (Nofima) and Marit Kvalvåg Pettersen (Nofima).

Abstract:

In light of today's increased focus on circular economy and sustainability, there is a drive towards development of food packaging concepts that allow the use of simple and recyclable plastic materials. In this study the effect of reduced material complexity on food quality and shelf life was investigated for hot dogs. The conventional laminate barrier material (PA/PE, bottom web) was replaced with selected monomaterials; HDPE and PP. The suitability of the monomaterials for maintaining the quality and shelf life of the product were studied for different packaging methods including; modified atmosphere packaging (MAP) (100% N₂, 60% CO₂/40% N₂, 100% CO₂) vacuum and skin pack. Active packaging was also tested by utilizing CO₂ emitter in selected MAP concepts. Gas composition, drip loss and microbial content were analyzed and sensory evaluation was performed at selected sampling days. After 41 days of storage hot dogs in all packaging concepts had good overall quality with total viable count (TVC) below log 3 cfu/g. By odor evaluation all samples were found to be acceptable even after 51 days of storage. However, hot dogs in packaging concepts with CO₂ emitter had comparatively the best microbial quality (TVC log 2 cfu/g) similar to that of the reference. In addition, a reduced drip loss was observed for concepts with CO₂ emitter. The results clearly demonstrate the unfulfilled potential for applying simple and recyclable plastics in food packaging without compromising the product quality and shelf life.

Keywords: Food quality, Increased recyclability, Packaging method, Active packaging

Topics: Packaging for food & agriculture Packaging sustainability



Modeling American Household Fluid Milk Consumption and their Resulting Environmental Footprint

Authors

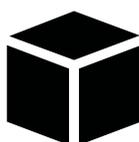
Sebastian Stankiewicz (The School of Packaging, Michigan State University), Rafael Auras (The School of Packaging, Michigan State University) and Susan Selke (The School of Packaging, Michigan State University).

Abstract:

Fluid milk waste accounts for 8% of all US food wasted and lost. This equates to approximately 4.8 billion kg of milk wasted by US consumers each year. For every kg of milk consumed, 2.05 kg CO₂e are emitted, thus US milk production and US consumers' waste accounts for around 50 and 10 billion kg CO₂e released each year, respectively. Few models have been created on food waste generation (FWG) within American households, but they could provide insight on causes of FWG. This study examines how discrete-event simulation (DES) and Monte Carlo (MC) simulation can identify areas for FWG through packaging and behavioral changes. Model parameters included: amount and type of consumption, type and number of containers bought, buying behavior, shelf life of milk, and waste generation. Simulations comparing purchase of quart, half gallon, and gallon milk containers were run for 10,000 days to identify which package type reduced waste for 50 one, two and four-person households. Previous research indicates that increasing packaging can reduce the overall environmental footprint (EF) if food waste decreases. Based on consumption averages from the National Dairy Council, results suggest that if 1 and 4-person households change their purchasing behavior from 1 half-gallon to 1 quart and 2 gallons to 3 half-gallons, then they can reduce their total EF for milk consumption by 36 and 13%, respectively. Thus, households that purchase less smaller containers, can decrease milk spoilage significantly and still meet consumption requirements, whereas purchasing more smaller containers equivalent to a larger size, decreased spoilage, but not enough to reduce a consumer's total EF. Like results from other studies, model results imply that packaging plays a minuscule role in the total EF of food consumption; most of a consumer's impact comes from milk spoilage and consumption. Additional field-testing is necessary to validate the model.

Keywords: Sustainability, Dairy, Shelf-life, Climate-change, Discrete event simulation, Food-waste

Topics: Packaging for food & agriculture Packaging sustainability



Migration from Food Packaging materials - Concerns and Opportunity

Authors

Javiera Rubilar Parra (Research Consultant), Claire Sand (Packaging Technology and Research; Michigan State University, California Polytechnic University) and Ziyet Boz (IFT, PTR).

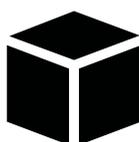
Abstract:

Migration from packaging into food is a topic of much research. There is a growing need to enhance migration research to ensure that Intentionally Added Substances (IAS) and Non-Intentionally Added Substances (NIAS) migrants into food are controlled. This rationale is multifaceted and encompasses value chain dynamics, recycling, the use of Food Simulating Liquids (FSLs), and new technology to pinpoint compounds. While processing aids to reduce energy costs or yield improved mechanical or chemical properties are known, the cumulative effect is not transferred in the value chain and via recyclates and pre-consumer rework. As a result, NIAS and IAS enter into food packaging at higher than allowable levels. Accurate knowledge on the control of migrants into food packaging may increase the viability of recyclates and reuse as well as gain more consumer confidence in packaging.

Government entities, major food companies, and industry groups have created regulations and guides of what is allowable in food packaging. This has resulted in: a non-level playing field between companies who effectively monitor migrants, an unstable supply chain, and higher operational costs. There is a need to guard against growing migration risk due to fluid Chain of Custody within the industry. The objective of this study is to provide a guide to migrants of concern and direction on how to mitigate risk for food and beverage companies as well as intermediaries in the packaging converting process. Known migrants and allowable levels in regulations and in industry guides are compared to actual levels found in packaging. Direction includes: reducing risk, uniform compliance, elimination of chemicals by their class, and the connection between food and package fraud. Advocacy and rationale for research are shared on: toxicological analyses of viable low-doses, refined FSLs to more effectively mimic migration from packaging used into food and value chain process controls.

Keywords: Migration, Food Packaging, Research

Topics: Packaging for food & agriculture Packaging standards & legislation



Light transmittance in packaging materials and effect of light barrier on greening of Folva cultivar potatoes (*Solanum tuberosum* L.) stored at 20 °C under LED light

Authors

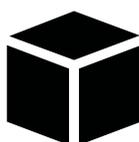
Hanne Larsen (NOFIMA), Karen Wahlstrom Sanden (NOFIMA) and Eldrid Molteberg (NIBIO).

Abstract:

Light exposure induces formation of chlorophyll (greening) and glycoalkaloids (α -solanine and α -chakonine) in potato tubers. High intake of glycoalkaloids can cause serious illness with possibly fatal consequence for humans. At retail, potatoes are usually illuminated when displayed at chill and room temperature. Development of green discoloration lead to rejection by the consumers giving food waste and economic loss. The aim of this study was to: 1) measure irradiance and record type of illumination used for potatoes in grocery stores, 2) measure spectral light transmittance for packaging materials commonly used for potatoes and 3) illuminate potatoes packaged in selected materials to evaluate the protective effect of different light barrier in the materials. Approximately 2/3 of the illumination equipment was fluorescent light (FL) tubes and 1/3 was light emitting diodes (LED) with irradiance ranging from 0.7 to 11.3 W/m² and 3.2 to 16.6 W/m², respectively. Mean values were 5.5 W/m² for FL tubes and 7.8 W/m² for LED. Spectral light transmittance through the packaging materials was measured using a portable spektroradiometer placed between the packaging material and FL tubes or LED illumination. Fiber materials did generally have lower light transmittance than plastic materials regardless of ink colour, whereas dark inks (black, brown, dark blue, dark green) protected against light transmittance also for the plastic materials. Potatoes of the cultivar Folva were packaged in materials with different light barrier properties followed by LED illumination at 20°C. Colour of the potatoes was daily measured using a Minolta Chroma meter. The packaging material should have a total light transmittance lower than 0.02 W/m² to avoid development of green colour during light exposure in the grocery stores.

Keywords: Irradiation light sources, Fiber and plastic packaging materials, Critical light tolerance limit

Topics: Packaging for food & agriculture



Changes in properties of shrinkable plastic packaging due to the effect of storage conditions

Authors

Lea Oliveira (INSTITUTO DE TECNOLOGIA DE ALIMENTOS), Claire Sarantopoulos (INSTITUTO DE TECNOLOGIA DE ALIMENTOS) and Daisy Moitinho (INSTITUTO DE TECNOLOGIA DE ALIMENTOS).

Abstract:

High barrier plastic shrinkable bags are widely used for vacuum packaging of fresh meat and cheese. However, they are susceptible to changes in properties due to exposure to high temperatures during distribution and storage. These changes could compromise package properties resulting in food losses. The objective of this study was evaluate the effect of storage time and temperature on the properties of shrinkable high gas barrier plastic packaging. Two samples (S1 and S2) with PVDC (polyvinylidene chloride) as a gas barrier layer and EVA (ethylene vinyl acetate) or LDPE (low density polyethylene) as a sealant layer were evaluated during storage at 23°C (18 months), 35°C (8 months), 40°C (5.5 months) and 45°C (4 months). The temperature from 35°C had a significant effect on the dimensions of the shrinkable bags, especially in the manufacturing direction, at the beginning of storage. From 35°C the unrestrained linear thermal shrinkage decreased at machine direction and increased at transverse direction during storage. The reduction in heat seal strength along storage was statistically significant at all storage temperatures for sample S2. Regarding sample S1 similar effect was verified at 23°C and 45°C. However, at 23°C the final value (3.48 kgf / 25.4 mm) was only 0.6% lower than that observed at 35°C indicating that the same effect would be verified at that temperature in the subsequent storage. The heat sealing integrity and the oxygen transmission rate were not affected by storage time and temperature under the studied conditions. The stability of this type of shrinkable bag could be assured during 18 months at 23°C. Storage time affects the degree of unrestrained linear thermal shrinkage and the strength of the heat seal. The storage temperature affects the dimensions of the package and the degree of shrinkage.

Keywords: plastic package, storage life, shrinkable package, temperature stability, mechanical properties, barrier properties

Topics: Packaging for food & agriculture



Study of the possibilities for developing recyclable plastic films for packaging

Authors

Søren Rahbek Østergaard (Danish Technological Institute) and Peter Sommer-Larsen (Danish Technological Institute).

Abstract:

The study has investigated and tested if it is possible to replace flexible laminated plastic films made of several plastic types with coated plastic film made of only one type of plastic. The new flexible plastic film shall be able to work in a circular economy and fulfil all packaging requirements as:

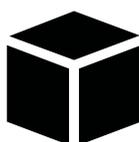
- Efficient barrier to various liquids and gases
- Flexible and retain its properties during use
- Weldable in existing packing machines
- Suitable for printing
- Transparent
- Suitable for recycling after use
- Suitable for food contact

The Danish study indicate that coating technology today is well developed to be used in flexible packaging. However, the coating technology demand inelastic plastic materials as PET. A recycling system for PET is already working on the market. The challenge is welding on existing packaging machines. The study proposes several strategies to overcome this practical and technical challenge.

The Danish Environmental Protection Agency under The Danish Ministry of Environment and Food has financed the study performed in 2018 to be published in the beginning of 2019.

Keywords: Sustainable packaging, Circular packaging, Packaging material, Food packaging, Flexible packaging

Topics: Packaging for food & agriculture Packaging machinery & systems Packaging materials Packaging sustainability



Development of Packaging System and Transport Packaging Technology for Philippine Broccoli

Authors

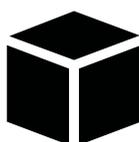
Daisy Tanafranca (Packaging Technology Div., Industrial Technology Development Institute, Department of Science and Technology) and Ericson Nolasco (Packaging Technology Div., Industrial Technology Development Institute, Department of Science and Technology).

Abstract:

Agriculture remains a main industry in the Philippines. However, productivity in the agriculture sector remains low due to issues on high postharvest loss and inappropriate use of packaging from farm to market. The study was implemented with the objective of reducing the damage on broccoli by 20% through the development of packaging system and packaging technology. By simulating the actual handling practices, packaging currently being used by the farmers and transporting by using a closed type unrefrigerated truck as mode of transport, the actual damage gathered on fresh broccoli was 69%. The use of plastic crates has reduced the damage to 32.5% which is about 53% reduction based on 69% as baseline. By using a reefer van as a mode of transport, from 69% the damage was reduced to 46% for broccoli packed in current polyethylene (PE) bag used by the farmers. Result indicated that by trimming the broccoli and removing the leaves, the transport efficiency increased and the damage reduced significantly. The use of corrugated box instead of the current PE bag and recycled corrugated box also reduced the damage by more than 20%. Double-layered placement of broccoli inside the corrugated box reduced the damage to 37% compared to the 46% damage on random placement of broccoli. Individual wrapping of broccoli with plastic film has significantly decreased the damage to 8.33%. Based on the result of storage study, the freshness and shelf life of broccoli could be extended up to 22 days if wrapped in plastic film and stored at 1-3oC compared to the 5 days if stored at room temperature (30+2oC).

Keywords: broccoli, corrugated, polyethylene

Topics: Packaging for food & agriculture



Development of antifungal film to delay postharvest decay in mango fruit

Authors

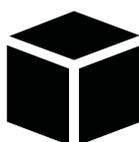
Witchuda Daud (National Metal and Materials Technology Center), Kanchana Boonruang (Kasetsart University), Noppadon Kerddonfag (National Metal and Materials Technology Center) and Vanee Chonhenchob (Kasetsart University).

Abstract:

Antifungal films of thymol compound were developed for controlling anthracnose pathogen found in mango fruit. The masterbatch with 20 wt% thymol compound was prepared via melt blending process using an internal mixer at 120°C. Then, the masterbatch was converted via film blowing method with temperature from hopper to die ranging from 110°C to 140°C and the screw speed of 40 rpm. The concentration of thymol in the film with average thickness of 80-85 µm was adjusted to 5 and 10 wt%. It was found that approximately 85-100% of thymol was retained in the films after processing. The results indicated that direct incorporation of thymol into a polymer matrix under low processing temperatures had a small effect on the loss of thymol in the end products. The antifungal activity against anthracnose pathogen isolated from mango was studied at 12°C by vapor diffusion assays. The thymol contents in the antifungal films were related to the vapor concentration of thymol in the Petri dish headspace and length of the mycelial growth. Complete inhibition of mycelial growth was found in the Petri dish containing antifungal films with 10 wt% thymol which had the highest concentration of thymol on day 0 at 1,445 µg/L. In this study, fungistatic activity was observed as the fungal mycelia regrows after transferring the mold plugs from the Petri dish with antifungal film to the new Petri dish containing PDA for 7 days. The antifungal film containing 10 wt% thymol was selected for further study as the releasing pad to control anthracnose in an individual package for retail stored at 12°C. The results showed that the addition of antifungal film significantly reduced fungal development, disease severity and lesion area. Antifungal film could be used to control postharvest decay, maintain quality and prolong the shelf-life of mango and possibly other fruits.

Keywords: Antifungal film, Thymol, Anthracnose, Mango

Topics: Packaging for food & agriculture Packaging materials



Study of the oxygen barrier properties of PET via ultrasonic spray coating of ZnO nanoparticles

Authors

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Abstract:

Polyethylene terephthalate (PET) has been widely used as packaging material due to its versatility, durability and low cost. It also owns good gas barrier properties. Various processing methods such as physical vapor deposition and chemical vapor deposition with nanoparticles have been used to optimize the barrier properties of different polymers. In this study, ultrasonic spray coating a wet-chemical deposition method is employed to deposit zinc oxide nanoparticles (ZnO NPs) on a commercial PET film in order to enhance its oxygen gas barrier properties. To achieve a uniform coated layer of ZnO NPs on the PET substrate, the ink concentration and spray coating parameters were both optimized. An ink with 2.5 wt.% ZnO NPs was prepared in 1 wt.% polyvinyl alcohol (PVA), isopropanol (IPA) and de-ionized (DI) water. The spray coating process was optimized for following parameters: path speed (10 mm/sec), pump flow rate (0.1 ml/min), generator power (2.5 watts), nozzle to substrate distance (75 mm), hot plate temperature (30 °C) and amount of coated layers (50x). Scanning electron microscopy (SEM) results showed a uniform coated layer of ZnO NPs on the PET substrate. Oxygen transmission rate (OTR) tests were performed at 23 °C and 0% relative humidity (RH). This study demonstrates that the OTR value of 50x ZnO NPs coated PET substrate is decreased.

Keywords: Poly(ethylene terephthalate) (PET), ultrasonic spray coating, oxygen transmission rate (OTR)

Topics: Packaging for food & agriculture Packaging materials



Aroma Compounds Characterization of Dried “Tom Yum” Soup Herbs in Different Packaging Materials by Gas Chromatography-Mass Spectrometry Combined with Sensory Evaluation Techniques

Authors

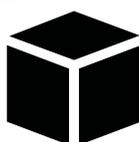
Pimonpak Chockdamrongsuk (KASETSART UNIVERSITY), Punphavee Supharintanakit (KASETSART UNIVERSITY), Vanee Chonhenchob (KASETSART UNIVERSITY) and Pat-tarin Leelaphiwat (KASETSART UNIVERSITY).

Abstract:

The effects of different packaging films on the loss of aroma intensity in dried “Tom Yum” soup herbs were investigated in this study. “Tom Yum” soup herbs set was selected as a food product since it is among the most internationally recognized Thai dishes and contains key aroma compounds present in fresh herbs, including lemon-grass, galangal, kaffir lime leave and chili. Aroma is important factor in the consumer acceptability of food product and easily lost by the product-package interactions. However, only a few studies have reported the changes in sensory quality along with the instrumental results. The mixture dried herbs were mixed based on the commercial formula ratio, packed in the multilayer films and stored at 25 °C for 56 days. The head space volatiles of mixture herbs extracted by solid phase microextraction (SPME) were performed on a gas chromatography–mass spectrometry (GC-MS) once a week. In the meanwhile, the sensory analysis was evaluated by a quantitative descriptive analysis (QDA) method. The key aroma compounds found in mixture dried herbs included eucalyptol, citronellal, citral and α -bergamotene. The results showed that the packaging film types showed the effect on the quality of dried “Tom Yum” soup herbs. The concentration of key aroma compounds were highest in the polyethylene terephthalate/aluminium/low density polyethylene (PET/Al/LDPE) followed by polyethylene terephthalate/low density polyethylene (PET/LDPE), oriented polypropylene/polyamide/low density polyethylene (OPP/PA/LDPE) and low density polyethylene (LDPE) respectively. The aroma profiles of dried “Tom Yum” soup herbs analyzed by GC-MS showed that the concentration of identified aroma compounds decreased during storage for 56 days. The principle component analysis (PCA) was used to analyst the relationship between the aroma attributes by sensory evaluation and the aroma profiles identified by GC-MS. The results suggested that the aroma attributes of “Tom Yum” seasoning powders were associated with the GC-MS aroma profiles.

Keywords: dried herbs, aroma, GC-MS, packaging materials, sensory

Topics: Packaging for food & agriculture



Improving recycled PET polymeric blends through the incorporation of commercial nanoreinforcements

Authors

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Abstract:

In recent years, recycling of polymers is a major challenge because turned out to be one of the relevant strategies to reduce the emission of gases during the manufacture, transport and disposal of solid waste. Nevertheless, the incorporation of recycled polymers decreases physical properties of blends, specifically mechanical properties.

Thus, in this work, the effect of increasing post-consumer bottle recycled poly (ethylene terephthalate) (RPET) in extruded blends with virgin PET (vPET) on optical, thermal (DSC and TGA) and mechanical properties of films was investigated. Furthermore, in order to improve these properties, nanocomposites of RPET with commercial nano-reinforcements were also extruded. Morphological (XRD diffractograms) and mechanical properties of vPET/RPET nanocomposites were studied.

The index of opacity and the color of the films towards the red and yellow tones were slightly increased by RPET addition and even more with the incorporation of nanoclays. Regarding mechanical properties, decrease of the stiffness and tensile strength of the vPET/RPET films without clay was caused by increasing RPET proportion, especially at concentrations greater than 80% of RPET. The ductility was increased by the occurrence of the "stress oscillation" phenomenon (SO) during the tensile test. SO was promoted with the increase in the concentration of RPET. However, the presence of clay inhibited neck propagation by SO, possibly due to the creation of tension zones that produce premature breakage of the material.

Keywords: recycled polymers, poly (ethylene terephthalate) (PET), post-consumer PET, nanoclay, mechanical properties

Topics: Packaging for food & agriculture Packaging materials Packaging sustainability



Flexible Low-Batch Size Manufacturing of Molded Paper Packaging with Barriers

Authors

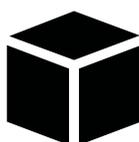
Kiril Kirilov (Danish Technological Institute), Alexander Bardenstein (Danish Technological Institute), Stanislav Landa (Danish Technological Institute), Jesper Petersen (ecoX-pac A/S), Thierry Delagoutte (Centre Technique du Papier) and Olivier Mas (Cellulopack SAS).

Abstract:

The conventional technology of molded cellulose packaging is based on toolsets comprising concave and convex mold metal parts and a fine hand-made metal wire net. This toolset needs to be tailor-made for each new packaging design, and the mold changeover is a time consuming and expensive operation. A flexible cost effective timesaving process of manufacturing the toolsets for wet molding of cellulose has been developed. It comprises parts of molds assembled from a universal set of metal bricks. A thermoplastic mockup of a molded object is then thermoformed in a newly assembled mold. Next, a laser with a computer-controlled beam steering perforates this mockup. Finally, the perforated mockup serves as a net in the molding toolset. The tests revealed that the changeover time of molding tools has become a matter of hours without compromising the high quality of the molded packaging. This makes it possible to test and optimize the packaging using low-batch size production. However, molded paper containers have no barriers against permeation of moisture and oxygen, and they are not suitable for food packaging as such. The next step is therefore the application of multilayer barrier coatings to achieve a required product shelf life. Different methods exist to impart proper barriers to paper; the one we have implemented is chosen for its full biodegradability. It combines biodegradable water-based polymer coatings with nanoscale inorganic films made by a plasma-enhanced chemical vapor deposition (PECVD) method. The water-based polymer coatings have good barriers but are unstable against water. Our PECVD process uses a silicon-containing chemistry and imparts a coating, which improves both water tightness, oxygen and moisture barriers. It has therefore become possible to achieve oxygen and moisture permeation that is adequately low for food packaging by combining the two methods.

Keywords: molded cellulose packaging, flexible molding toolset, thermoforming, laser perforation, biobased barrier coating, plasma coating, PECVD

Topics: Packaging machinery & systems Packaging materials Packaging sustainability



Next level of corrugated board research

Authors

Astrid Odeberg Glasenapp (RISE), Johan Alfthan (RISE), Lennart Salmén (RISE), Jasna S. Stevanic (RISE), Elisabeth Björk (RISE), Claes Holmqvist (RISE), Li Yang (RISE) and Jesper Berthold (RISE).

Abstract:

Abstract: For the first time in the Bioeconomy research program at RISE, corrugated board has an own research area. Research is building around the main driving forces in the corrugated board value chain like e-commerce, improved box performance and digital printing. The main weakness of corrugated board, its moisture sensitivity, is also addressed.

These main driving forces and weaknesses of corrugated board are mirrored in the themes of this large research program area:

Fibre sorption and deformation mechanisms

Fundamental knowledge on the mechanisms behind moisture sorption and deformation on fibre level is developed to increase moisture and creep resistance through modification of paper materials. State of the art methods for characterization of the fibre ultra- and nano-structure such as Fourier transform infra-red spectroscopy (FTIR), small angle X-ray scattering (SAXS), and wide angle X-ray scattering (WAXS) give new insights on mechanisms and clarify effects of moisture as well as chemical modifications.

Papermaking for improved base sheets

Concepts that are explored are fibre-based strength additives produced with novel refining techniques, and modified ZD-profiles in the sheet for better mechanical properties.

Box mechanics

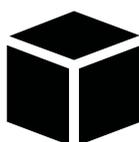
Mechanical performance of structures such as corrugated board boxes can be predicted through physically based mathematical modelling by taking the behaviour of the constituent materials as well as the geometry into account. Appropriate material models for the corrugated board are identified and finite element models for simulation of corrugated board packaging performance are developed.

Tool for inkjet printability on corrugated

There is a genuine need for improved inkjet printability on corrugated materials thanks to rapid development in e-commerce as well as digitalization along the corrugated value chain. Effective measurement methods and knowledge around ink-substrate interactions are developed to enable board producers and converters to have effective product development and predictable printability on not only liners but also on corrugated materials.

Keywords: corrugated board, moisture, box mechanics, inkjet Printing, fibre sorption

Topics: Packaging materials



Perforations on Boxes – Some Fundamental Facts

Authors

Anton Hagman (RISE Bioeconomy) and Thomas Trost (RISE Bioeconomy).

Abstract:

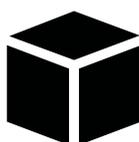
The grocery retail industry is striving with low margins and an ever-increasing competition from e-commerce applications. Therefore, as a mean to save time, money and increase the efficiency in the supply chain, perforated shelf-ready packages (SRP) has since a long time been used. However, there is also problems related to this perforation; it weakens the transport packaging and makes it more sensitive to damage on the way to the shelf. The current guidelines are focused on appearance of the box on the shelf, e.g. how much of the product is seen and evenness of perforate edge, and not on the mechanical properties of the box.

Today there exist much knowledge about perforations inhouse in the die cutting industry. This knowledge is however unattainable for outsiders. Further the question arises about how well founded said knowledge is. The scientific literature offers little information about the basics of perforation and how it affects the mechanical properties of the board and box. This study is an attempt to build knowledge, useful to converters and industrial users, in a systematic way.

In this paper several different perforations patterns have been studied from a mechanical point of view. The experiments were designed to answer some basic questions about how different nick lengths and distances affects the strength of the perforation e.g. at different cut/uncut ratios. Among methods studied were tensile testing, bending stiffness, compression testing and edge compression test. The different methods were compared regarding sensitivity to discriminate between different perforation patterns and give a useful classification of the perforation.

Keywords: Corrugated, Shelf Ready Packaging (SRP), Perforation, Package testing

Topics: Packaging materials



Hygroexpansion, Lacquer Coating and Surface Roughness Affect the Electrical Resistivity and Gas Barrier of Physical Vapor Deposited Aluminum Coatings on Paper

Authors

Martina Lindner (Fraunhofer).

Abstract:

For food packaging, high gas barrier is required and can be achieved by physical vapor deposition of aluminum on polymeric substrates. To achieve high gas barriers, these aluminum coatings have to be virtually defect-free. However, due to decreasing mineral oil resources, the usage of polymeric substrates must be reduced and could in some applications be replaced by paper.

But when aluminum is applied to paper and lacquer coated paper, hygroexpansion and substrate roughness can impair the aluminum coating. Both effects manifest as an increase in electrical resistance and gas transmission.

The sheet resistance of aluminum coated onto four different rough paper surfaces was measured via eddy currents at different relative humidities (0–95%). The effective resistivity was calculated based on the measured resistance and aluminum mass per unit area, combined with a value for aluminum density from the literature. The substrate roughness correlated with the effective resistivity.

Paper hygroexpansion was described based on Guggenheim, Anderson and De Boer equation and a linear correlation between hygroexpansion and paper water content. It was shown, that hygroexpansion is affected by the lacquer coating and its penetration depth. At humidities of up to 50%, hygroexpansion (up to 2%) linearly correlated with the increase in effective resistivity, which is related to the mechanical straining and deformation of aluminum. At higher humidities, aluminum started to crack first on rough substrates and later on smooth substrates. Thinner aluminum coatings cracked at lower hygroexpansions (~1%).

Oxygen permeation was found to be influenced by the interplay of hygroexpansion and aluminum cracking as well as moisture uptake of the lacquer coating. The findings highlight the need for information about substrate roughness, humidity, lacquer type and hygroexpansion when 1) eddy current measurement results are compared, and 2) a high gas barrier of aluminum coated paper is envisaged.

Keywords: resistivity, physical vapor deposition, sheet resistance, EVOH, paper coating, penetration, porosity, sorption, humidity

Topics: Packaging materials



Sorting as a key factor for high quality of recycled polypropylene

Authors

Tanja Radusin (NOFIMA), Jorunn Nilsen (NORNER Research AS), Marit Kvalvåg Pettersen (NOFIMA) and Siw Bodil Fredriksen (NORNER Research AS).

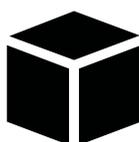
Abstract:

Polypropylene (PP) is one of the most important polymers, with 20% share in European plastic demand. One half of all PP is used for packaging and thus ending as post-consumer waste (PCW). It is known that PP undergoes thermomechanical, thermo-oxidative and shear induced degradation during packaging production and through mechanical recycling. This research has been conducted within the Future Pack project, with focus on improvements of recycled PP (rPP) quality using knowledge-based sorting prior to mechanical recycling process. PP was sorted from PCW into four sub-fractions according to the processing techniques used: injection molded, thermoformed (transparent and black) and bottles. All samples were washed, dried, grinded and compounded prior to further characterization and analysis.

Melt flow properties are very important in packaging production, and virgin PP materials have flow properties specified for each application. Melt Flow Index (MFI), describing the flow properties of the material, was measured for all samples. Injection moulded samples had MFI 63 g/10min, whereas both the thermoformed fractions and the bottle fraction were < 4 g/10min. A commercial PCW rPP containing all the fractions had MFI 13 g/10 min and thus not fit for use neither in bottles, thermoformed nor in thin walled injection moulded packaging. The MFI as well as the mechanical properties (stiffness and impact strength) for the detailed sorted materials were close to the respective virgin materials. Thermal stability was evaluated by thermogravimetric (TGA) analysis, showing that Tonset was on the same level for all samples, while thermoformed samples showed two step degradation. Similarly, from DSC all samples gave characteristic PP curves while thermoformed samples showed one melting peak prior to PP melting temperature implying contamination with other polymers. This research gave new knowledge and data regarding the importance of better sorting for improved quality rPP for use in the high-quality packaging stream.

Keywords: sorting, recycling, polymer quality, recycled polypropylene

Topics: Packaging materials Packaging sustainability



Box compression strength of packages in different climates

Authors

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Abstract:

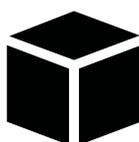
Packages made of five folding box boards made on the same paperboard machine have been analysed. The paperboards were from the same product series but had different grammage (235, 255, 270, 315, 340 g/m²) and different bending stiffness. The paperboards are normally used to make packages, and since the bending stiffness and grammage varies the packages performance will be different. In this study, two different load cases were defined and Box Compression Tests (BCT) were performed at different levels of relative humidity (30, 50, 70, 90 % RH) and were evaluated as a function of moisture ratio.

The result showed a linear relation between the box compression strength and the moisture ratio. In addition, when the data was normalized with the measurements for the standard climate (50 % RH) and was evaluated as a function of moisture ratio, the result indicated that the normalized box compression strength for all the paperboards and both of the load cases could be expressed as a linear function of moisture, dependent of two constants a and b.

Consequently, the study indicates that it is possible to estimate the Box compression strength at different climates of a package made of paperboard, by knowing the box compression strength for the standard climate (50 % RH and 23 °C) and the constants a and b.

Keywords: Paperboard, moisture, mechanical properties, package performance

Topics: Packaging materials



In-situ changes of thermo-mechanical properties of poly(lactic acid) film immersed in aqueous-alcoholic solutions

Authors

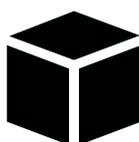
Uruchaya Sonchaeng (School of Packaging, Michigan State University, East Lansing, MI, USA, 48824), Rafael Auras (School of Packaging, Michigan State University, East Lansing, MI, USA, 48824), Susan Selke (School of Packaging, Michigan State University, East Lansing, MI, USA, 48824) and Maria Rubino (School of Packaging, Michigan State University, East Lansing, MI, USA, 48824).

Abstract:

Poly(lactic acid) (PLA) has been widely used as a commercial polymer for packaging. However, PLA usage is limited since its thermal and mechanical properties may be affected by environmental conditions such as temperature, humidity, and chemical exposure. The glass transition temperature (T_g) of PLA may decrease when PLA is in contact with organic solvents. Furthermore, PLA shows hydrolytic degradation when exposed to water. In this study, the thermo-mechanical properties (i.e., loss and storage moduli) and the T_g s of a neat amorphous PLA film were measured using a dynamic mechanical analysis (DMA) with and without immersion in select alcohols (numbers of carbon atoms in the main chain between 1–6) and their aqueous solutions. The DMA measured T_g of PLA at dry conditions was 62.7 ± 1.6 °C. The largest T_g reduction was observed in methanol immersion ($T_g = 14.3 \pm 0.9$ °C) and the smallest reduction in 1-hexanol immersion ($T_g = 41.0 \pm 0.1$ °C). PLA immersion in straight-chain alcohols showed a potential trend of smaller T_g reduction with higher number of carbon atoms in the alcohol chain. Initial results may indicate that structural configuration and position of the hydroxyl group in alcohols do not affect changes in the T_g (i.e., T_g in 1-propanol = 29.6 ± 0.8 °C and T_g in 2-propanol = 30.0 ± 2.3 °C). In case of aqueous solutions, the T_g s of PLA when immersed in water, 50% 2-propanol, and 100% 2-propanol were 53.3 ± 3.8 °C, 33.6 ± 0.3 °C, and 30.0 ± 2.3 °C, respectively, indicating that reduction in T_g is concentration dependent. This work provides an initial understanding of the in-situ changes in thermo-mechanical properties of PLA in contact with alcohols and alcohol aqueous solutions, which is useful for the design and development of PLA as a packaging material.

Keywords: solvent immersion, glass transition temperature, compatibility, DMA, PLA

Topics: Packaging materials



Fluorescent Bioplastic Film from Konjac Glucomannan Mixed with Chitosan and Turmeric for Security Food Packaging

Authors

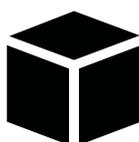
Suchapa Netpradit (King Mongkut's University of Technology Thonburi), Krittika Tanprasert (King Mongkut's University of Technology Thonburi) and Montri Ingkasarnmanee (King Mongkut's University of Technology Thonburi).

Abstract:

In present, food packaging has been pirated by imitation or counterfeiting, adversely to food industry and consumers have been harmed. The good solution was the film from konjac glucomannan mixed with chitosan and turmeric by produce bio-packaging to protect environment and piracy. Konjac is a kind of starch while chitosan is a plasticizer and turmeric contains fluorescent curcumin. The objectives of this research were 1) to determine the proper ratio of konjac to chitosan as well as drying time for film forming, 2) to determine the fluorescent effect of turmeric on the film, and 3) to evaluate the effect of turmeric on film properties. The research showed that 0.5% chitosan and 0.5% konjac (w/v) was the most appropriate ratio in 1% acetic acid solution as its clear solution without any sediment. Drying at 50 C for 12 hours resulted in film forming with the best tensile properties compared among 8, 10, 12 and 14 hours. The addition of turmeric solution (1% turmeric powder in ethyl alcohol) resulted in fluorescent film under UV light and the highest fluorescent degree was observed in film containing 4% (v/v) of the turmeric solution in konjac/chitosan film solution. More addition of turmeric solution yielded more fluorescent degree, however it adversely more affected tensile strength, % elongation and puncture resistance of konjac/chitosan film, due to the less solid content of konjac and chitosan. The konjac/chitosan film containing turmeric can be heat sealed as LDPE film and dissolved in hot water with temperature at least 92 C, corresponding to its softening point. Therefore, the fluorescent bio-film has possibility to be used as dry condiment packages that can contain some security feature for content authentication. If this bio-film is controlled for health safety, it may be applied as edible packaging to minimize the packaging waste.

Keywords: Fluorescent Bioplastic Film, Chitosan, Food Packaging, Konjac Glucomannan, Security, Turmeric

Topics: Packaging materials



Diffusion of organic molecules in poly lactic acid (PLA) films

Authors

Frank Welle (Fraunhofer), Johann Ewender (Fraunhofer), Raphael Auras (School of Packaging, Michigan State University) and Uruchaya Sonchaeng (School of Packaging, Michigan State University).

Abstract:

Poly lactic acid (PLA) is one of the main bio-based packaging materials. The barrier properties towards oxygen and moisture is well known. On the other hand, barrier properties of PLA towards organic molecules are rare in the scientific literature.

Objective

Aim of the study was the determination of the diffusion of organic molecules (n-alkanes, 1-alcohols) in PLA.

Methods

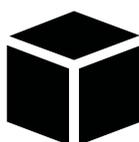
Diffusion coefficients were derived from permeation tests on 20 μm and 30 μm PLA films according to the lag time method. Homologous rows of n-alkanes (n-pentane to n-tetradecane) and 1-alcohols (1-propanol to 1-octanol) were tested on both films.

Results

Diffusion coefficients at various temperatures were determined from the lag times of the permeants. The films were characterized for their crystallinity. Correlations between the molecular volume V of the permeants and the diffusion coefficients DP allow the prediction of diffusion coefficients of other, non-tested molecules. The results will be useful for the prediction of the migration of polymer constituents in PLA packaging materials. In addition, activation energies of diffusion EA were calculated according to the Arrhenius approach. The activation energy of diffusion EA follows a correlation with the molecular volume V of the investigated permeants. In addition, the pre-exponential factor D_0 follows correlation a correlation with the activation energy of diffusion EA . The results of this study for PLA (e.g. EA , DP) were compared to literature data on polyethylene terephthalate (PET) and polyethylene naphthalate (PEN).

Keywords: Barrier testing, Migration, Diffusion coefficients, Activation energy

Topics: Packaging materials



Effect of zeolite 5A incorporation on poly(butylene adipate-co-terephthalate)/ thermoplastic starch blend

Authors

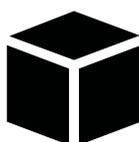
Kannika Yimnak (Kasetsart University) and Amporn Sane (Kasetsart University).

Abstract:

The objectives of this study were to investigate the effects of glycerol concentration and zeolite 5A (Z5A) incorporation on properties of poly(butylene adipate-co-terephthalate)/thermoplastic starch (PBAT/TPS) films. Z5A was used as a compatibilizer for improving mixing between PBAT and TPS. The samples were prepared with PBAT/TPS blend at ratios of 40/60 and 60/40, glycerol contents in TPS were varied in 35 and 40 phs and Z5A concentration of 3 wt%. Melt-mixing was carried out through two different incorporation sequences in a twin screw extruder: sequences I (SI) premixing of PBAT with Z5A prior to melt blending with TPS; and sequences II (SII) premixing of TPS with Z5A prior to melt blending with TPS. Melt blending of PBAT with high glycerol content in TPS and incorporation of Z5A into PBAT/TPS via SI and SII routes resulted in increased mixing between PBAT and TPS. The Tensile properties of PBAT/TPS/Z5A (58.2/38.8/3) increased when compared with PBAT/TPS (60/40), especially in SII composite film the tensile properties was close to neat PBAT, due to the better dispersion of TPS in PBAT. Melting temperature (T_m) of TPS shifted to lower temperature and closer to T_m of PBAT, particularly when SII composite containing 40 phs of glycerol, implying that this blending improve the distributive mixing between PBAT and TPS.

Keywords: PBAT, TPS, Zeolite, Mixing, Sequence

Topics: Packaging materials



Surface Modification of Coconut Fiber for Reinforced Thermoplastic Starch Foam

Authors

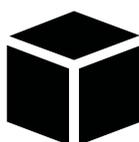
Kanyapat Klairasamee (Department of Packaging and Materials Technology, Faculty of Agro-Industry, Kasetsart University), Lerpong Jarupan (Department of Packaging and Materials Technology, Faculty of Agro-Industry, Kasetsart University), Piyawanee Jariyasakoolroj (Department of Packaging and Materials Technology, Faculty of Agro-Industry, Kasetsart University) and Vanee Chonhenchob (Department of Packaging and Materials Technology, Faculty of Agro-Industry, Kasetsart University).

Abstract:

Cushioning materials and thermal insulators can be used to support any packaging system for better protection and preservation of the product within a desired period. However, most of the cushions and insulators are commonly made of polystyrene (PS) that is known to cause a negative effect to the environment throughout its life-cycle. Therefore, bio-based materials have gained more attentions to be chosen as the substitution. Packaging materials from agricultural products such as cassava starch is used to produce a bio-based foam due to its natural abundance and cost effectiveness. But the starch-based foam still experiences the limitation in terms of poor mechanical properties and moisture absorption. Reinforcing such a composite matrix by natural fiber obtained from the coconut coir has a potential to improve the properties of the bio-based material. This research is therefore aimed to develop the starch-based foam from thermoplastic starch (TPS) incorporated with the surface modified coconut fiber (SCF). The TPS/SCF expandable extruded pellets were produced by mixing the cassava starch with glycerol/distilled water/kaolin and sodium bicarbonate with varied contents of SCF (1, 2, 3, 4 and 5 phr) mixture. The processing of TPS/SCF foam was used a twin-screw extruder under the conditioned temperature ranged from 65 to 100 with the screw speed at 100 rpm. The TPS/SCF foam was produced by compression molding with the conditioned temperature at 160 °C for 5 min and pressure at 130 bar. The TPS/SCF foam obtained was further investigated for the morphology by a scanning electron microscope (SEM). The results showed that the SCF has a good dispersion and compatibility with the TPS foam matrix. The properties of TPS/SCF foam with compressibility tests indicated the trend of SCF additions increased not only the compressive strength, but also the thermal conductivity of the foam-structure indicated the trend by K-Value.

Keywords: Thermoplastic starch, Foam, Surface modified, Coconut fiber

Topics: Packaging materials



Biaxial orientation of biodegradable PLA/PBAT/TPS blend for packaging application

Authors

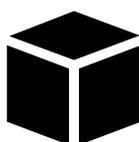
Porawee Katanyoota (Department of Packaging and Materials Technology, Faculty of Agro-Industry, Kasetsart University), Piyawanee Jariyasakoolroj (Department of Packaging and Materials Technology, Faculty of Agro-Industry, Kasetsart University) and Amporn Sane (Department of Packaging and Materials Technology, Faculty of Agro-Industry, Kasetsart University).

Abstract:

Thermoplastic starch (TPS) is a promising biodegradable material to be used in flexible packaging application when blending with biodegradable polyesters including polylactic acid (PLA) and poly(butylene adipate-co-terephthalate) (PBAT) to improve the mechanical and moisture barrier properties of TPS. However, PLA/TPS/PBAT blend still has poor mechanical properties and gas barriers due to random molecular orientation of polymers. The objective of this work is to improve the properties of PLA/TPS/PBAT blend by biaxial stretching. To prepare biaxially oriented (BO) films, PLA/TPS/PBAT resins were prepared by melt blending of PLA, TPS and PBAT using a twin-screw extruder, followed by sheet extrusion and biaxial stretching. The effect of PLA:TPS:PBAT ratio (20:40:40 and 40:40:20), stretching speed (22.5, 75 and 150 mm/s) and annealing time (0, 60 and 180 s) on morphological, mechanical, thermal and gas barrier properties was investigated. All biaxial stretching experiments were carried out at constant annealing temperature and draw ratio of 90 °C and 4 x 4, respectively. The obtained BO films were characterized by scanning electron microscopy, X-ray diffraction, differential scanning calorimetry, and dynamic mechanical analysis. Results obtained from tensile testing revealed that tensile strength of PLA/TPS/PBAT (40:40:20) blend increased from 17.49 to 28.50-43.17 MPa after biaxial stretching process. And, increased tensile strength up to 40% was obtained when increasing stretching speed from 22.5 to 150 mm/s. The increase in tensile strength was possibly caused by increased crystallinity content while reduced crystallite size of BO films. Furthermore, biaxial stretching improved moisture barrier of PLA/TPS/PBAT (40:40:20) blend by at least 43%.

Keywords: Biodegradable, Biaxial, Microstructure, Polymer blend

Topics: Packaging materials Packaging sustainability



Development of a biodegradable thermoformed tray for food waste handling

Authors

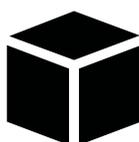
Carlos Diaz (Rochester Institute of Technology), Swati Hegde (Rochester Institute of Technology), Thomas Trabold (Rochester Institute of Technology), Elizabeth Dell (Rochester Institute of Technology) and Christopher Lewis (Rochester Institute of Technology).

Abstract:

With multiple initiatives to keep food-waste away from landfills, packaging systems that are compatible with the alternative end of life scenarios (e.g., composting, biodegradation) are required. The aim of this study was to evaluate the ability to manufacture a fully biodegradable sheet for thermoforming at a pilot scale. Here, the effect of blending polylactic acid (PLA) with a bio-additive (polyhydroxyalcanoate PHA based compound), a rubbery biopolymer (polycaprolactone PCL), and calcium carbonate on the mechanical performance and thermophilic anaerobic biodegradation was investigated. Calcium carbonate was added at low (5 wt.%) and high (30 wt.%) concentrations. Additionally three types of calcium carbonate were evaluated (i.e., different particle size and surface treatments). Sheet with a nominal thickness of 0.4 mm was manufactured in a Leistritz cast extrusion system and subsequently thermoformed into trays using a Sencorp thermoformer. The extent of anaerobic biodegradation was higher in samples containing 20% PCL, however the time to reach 50% degradation was delayed. The sample containing only PLA and the bio-additive exhibited the shortest time to achieve 50% degradation (34 days), though the extent of degradation was lower after 60 days. Calcium carbonate did not affect the biodegradation rate and showed slightly improved biomethane potential compared to the PLA control. There was not a significant change in tensile strength due to calcium carbonate type at 30 wt.% loading. However, a 2 fold increase in elongation at break (from 15 to 30%) was observed indicating an effect from the surface treatment and particle size. Calcium carbonate content (5 vs. 30 wt. %) increased the optimum forming temperature from 300 to 350 °F. The results demonstrate the feasibility of manufacturing a fully biodegradable thermoformed containers with high mineral content.

Keywords: Anaerobic biodegradation, polylactic acid, calcium carbonate, bioplastics

Topics: Packaging materials



PLA/NR/TPS ternary blend: A promising bio-based material for secondary packaging

Authors

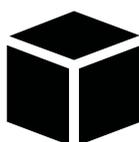
Sukanya Wongwat (Kasetsart University) and Rangrong Yoksan (Kasetsart University Institute for Advanced Studies).

Abstract:

Previously, our research group has reported the development of poly(lactic acid)/thermoplastic starch (PLA/TPS) blends for not only rigid (injection-molded products), but also for semi-rigid (thermoformed trays) and flexible packaging (films). However, these materials still have some limitations similar to their individual starting material (PLA and TPS), e.g. brittle and hydrophilic. Therefore, this presentation aims to demonstrate the properties improvement of PLA/TPS blend by incorporating natural rubber (NR), which is elastic and hydrophobic polymer. In addition, Thailand is the largest NR exporter, nevertheless, the price of natural rubber decreased because of large volume of production resulting in imbalance of demand and supply. Therefore, blending NR with PLA and TPS not only improves the properties of PLA/TPS blend, but also increases the value and expands the utilization of NR. PLA, NR and TPS with various weight ratios were blended in an internal mixer before extruding into sheet using an extruder. Flexibility of the ternary blends increased significantly with increasing NR concentration. The blend showed improved hydrophobicity when NR was added, while better oxygen barrier property of PLA was obtained when NR and TPS were blended. PLA/NR/TPS ternary blend could be converted into thermoformed tray and possibly applied as secondary packaging.

Keywords: Poly(lactic acid), Thermoplastic starch, Natural rubber, Ternary blend, bio-based packaging, Extrusion, Thermoforming, Secondary packaging

Topics: Packaging materials



Improving mechanical and barrier properties of thermoplastic starch-based blown films for flexible packaging

Authors

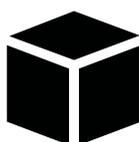
Khanh Minh Dang (Kasetsart University) and Rangrong Yoksan (Kasetsart University Institute for Advanced Studies). Improving mechanical and barrier properties of thermoplastic starch-based blown films for flexible packaging.

Abstract:

Currently, the development of thermoplastic starch (TPS) and thermoplastic starch-based composite films produced by blown film extrusion has been spurred by a growing interest in renewable sources and environmentally benign material as well as an alternative option to reach industrial-scale demand. Thus, the aim of this current presentation is to demonstrate the improvement of processability, mechanical properties and barrier properties of TPS blown film either by incorporating plasticizer with different types and contents or by making composite with polyesters and commercial clay. The obtained TPS film containing larger-sized polyol plasticizer exhibited double-layered wall, while that containing smaller-sized polyol plasticizer was single-layered film. Furthermore, the film with smaller-sized polyol showed improved thermal resistance, enhanced stiffness and better water vapor barrier properties. In the case of TPS/polyester/bentonite composite films, SEM images confirmed the good dispersion of clay in the film matrix, thus this provided improved water vapor and oxygen barrier properties of TPS/polyester blend films even at low concentration of clay. The composite film also exhibited better tensile strength and Young's modulus than the corresponding film without addition of clay. Thus, the obtained TPS and TPS-based composite films offer real potential applications as an oxygen barrier layer and biodegradable packaging films, respectively.

Keywords: Thermoplastic starch, Poly(lactic acid), Poly(butylene adipate-co-terephthalate), Clay, Blown film extrusion, Flexible packaging

Topics: Packaging materials



How Changes in Consumer Package Design Impact Environmental Sustainability

Authors

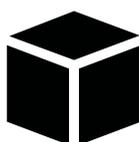
Jonghun Park (Ryerson University).

Abstract:

This research project investigates trends in the environmental sustainability of U.S. consumer packaging from the 2010s. The environmental impact of current packaging is compared to corresponding packaging produced in the early 2010s using life cycle assessment (LCA). The scope of the LCA in this study includes raw material extraction, manufacturing, distribution, and end-of-life phases for the primary packaging. Four life-cycle impact indicators are used in the LCA: fossil fuel usage, greenhouse gas emission, human impact, and freshwater ecotoxicity. The results show that there has been a significant reduction in consumer packaging material in the past few years, so that currently used packages generate less environmental impact than packages used in the past for all impact indicators. This information will help packaging designers and researchers forecast future shifts in the consumer packaging industry.

Keywords: packaging sustainability, packaging material reduction, life cycle assessment

Topics: Packaging sustainability



Improving the collection of Packaging waste through smart containers and pay as you throw systems

Authors

Cesar Aliaga (ITENE), Ana Moya (ITENE), Laura Blasco (ITENE) and Miguel Angel Alvarez (ITENE).

Abstract:

The European plastic market is not currently aligned with the circular economy. More than 25.8 million tonnes of plastic waste are produced per year in the EU28 being recycled only 29.7%. This represents a losses of €10.56bn) as well as a high environmental impact; 23.8 Mt of CO₂.

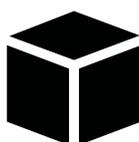
Low recycling rates of plastic are mainly due to the situation of packaging waste (i.e. main plastic waste fraction). Therefore, the H2020 project PlastiCircle is focussed on the development and implementation of a holistic process to increase recycling rates of packaging waste. This will allow to reprocess again plastic waste in the same value chain. This process is based on four axes: collection (to increase quantity of packaging collected), transport (to reduce costs of recovered plastic), sorting (to increase quality of recovered plastic), and valorization in value-added products (e.g. Foam boards and automotive parts).

In the first area of research (collection), PlastiCircle has developed the following items which help to reward citizens according to their performance in plastic packaging waste segregation at home: (1) A module which can be installed in conventional containers and transform them in "smart" containers which are able to identify the citizens, (2) a characterization protocol in order to evaluate the quality and quantity of each citizen's waste and a (3) compensation procedure in order to give rewards (transport tickets, cinema tickets, etc.) to citizens who have classified better their packaging waste at home.

These developments in collection have the potential to increase packaging collection from 79.3% to 87%. Moreover, the implementation of the complete PlastiCircle approach in Europe on collection, transport, sorting and recycling have the potential to increase collected plastic in 826,210t (reaching 14.14 Mt) and valorization in 1.13Mt. The valorization of this new material, represents a market value of €2.03bn-€5.65bn.

Keywords: Packaging, plastic Waste, pay as you throw collection, smart container

Topics: Packaging sustainability



Leakproofness of dangerous goods packagings - comparison of worst-case limit leakage rates and sensitivity of the bubble test

Authors

Eva Schlick-Hasper¹, Thomas Goedecke¹, Matthias Kraume²

1. Federal Institute for Materials Research and Testing (BAM), Berlin, Germany

2. TU Berlin, Chair of Chemical and Process Engineering, Berlin, Germany

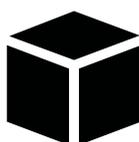
Abstract:

This work focuses on the question if the bubble test prescribed in the Dangerous Goods Regulations has sufficient sensitivity to detect leakage rates which could result in the formation of explosive atmospheres during transport. The sensitivity of the bubble test is not directly comparable with other leak testing methods because of its different flow conditions. Therefore, a normalized minimum detectable leakage rate under Helium test conditions is calculated for the bubble test. This sensitivity of the bubble test under reference conditions is compared with limit leakage rates for a worst-case transport scenario. The sensitivity of the bubble test is not sufficient to prove the limit leakage rates for 6-L packagings. The formation of explosive vapour-air-mixtures cannot be excluded. Therefore, more sensitive leak testing methods should be considered for smaller packaging design types.

Keywords: bubble test, dangerous goods packagings, explosive atmosphere, leakproofness, limit leakage rates

Topics: Hazardous and dangerous goods.

Paper from the peer review stream, will be published in Packaging Technology & Science





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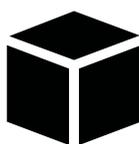
SERVING SOCIETY
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ON PACKAGING

TOPICS POSTER PRESENTATIONS

- Active & intelligent packaging
- Distribution packaging
- Logistics & supply chain
- Medical, cosmetic & pharmaceutical packaging
- Novel packaging
- Packaging design, ergonomics & human factors
- Packaging for food & agriculture
- Packaging materials
- Packaging printing & graphics
- Packaging standards & legislation
- Packaging sustainability

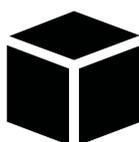
Active & intelligent packaging

- Development of capacitive-based sensors for packaging applications
- Spoilage bacteria on chicken fillets packaged with different atmospheres
- Modeling of the biopolymer-specific coefficient in Brandsch-Bio diffusion model for bio-polymeric food packaging
- Functional Coatings, Inks and Adhesives to Improve Packaging Properties
- Active packaging to preserve the quality of fresh fruits
- Fabrication of Novel Bioactive Cellulosed-based Films Derived from Quercetin-Loaded Nanoparticles



Distribution packaging

- Damage by long duration accelerations phenomena on packaging a system
- Biobased Biodegradable Packaging for Cold Chain Maintenance in B2C and B2B Delivery of Temperature-Sensitive Products
- Characterization of horizontal acceleration events occurring during transport
- Record and analysis of constraints encountered in pallets handling by forklifts
- An evaluation of distribution practices in the retail supply channels for CPGs in India



Logistics & supply chain

• Damage by long duration accelerations phenomena on packaging a system

• Study of the Strength Relation between X-PLY Corrugated Board and Base Paper

• An evaluation of distribution practices in the retail supply channels for CPGs in India

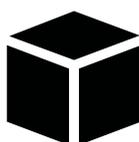
Medical, cosmetic & pharmaceutical packaging

• Biobased Biodegradable Packaging for Cold Chain Maintenance in B2C and B2B Delivery of Temperature-Sensitive Products

Novel packaging

• METHODOLOGY FOR DISCRETIZING THE DESIGN PROCESS

• Active packaging to preserve the quality of fresh fruits



Packaging design, ergonomics & human factors

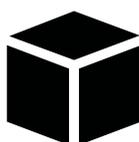
• Image and Warning Messages Design on Cigarette Packs that Affects Smokers

• Packaging research in the Australian Fight Food Waste Cooperative Research Centre

• METHODOLOGY FOR DISCRETIZING THE DESIGN PROCESS

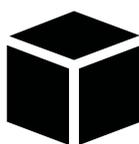
• A New Package Design Paradigm with 3D Image Reconstruction and Convolutional Neural Networks

• Generational preferences on sustainable packaging concepts



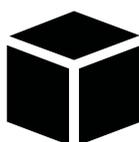
Packaging for food & agriculture

- Optimization of the gas composition for an extended shelf life of fresh shiitake (*Lentinula edodes*) stored at room temperature
- Packaging research in the Australian Fight Food Waste Cooperative Research Centre
- Biobased Biodegradable Packaging for Cold Chain Maintenance in B2C and B2B Delivery of Temperature-Sensitive Products
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- Modeling of the biopolymer-specific coefficient in Brandsch-Bio diffusion model for bio-polymeric food packaging
- Study of the influence of cure conditions on the physical mechanical properties of lacquers applied to internal surfaces of metal packages
- Functional Coatings, Inks and Adhesives to Improve Packaging Properties
- Active packaging to preserve the quality of fresh fruits



Packaging materials

- Evaluation of moulded pulp trays using compression test and novel twist test
- Production of tea bag paper from corn stalk pulp
- Biobased Biodegradable Packaging for Cold Chain Maintenance in B2C and B2B Delivery of Temperature-Sensitive Products
- Alternative approach for polystyrene biodegradation by selected bacteria
- Study of the influence of cure conditions on the physical mechanical properties of lacquers applied to internal surfaces of metal packages
- Toxicological Profile of Nanomaterials Applied to Packaging
- Study of physical and mechanical properties of low density polyethylene mixed with Ag-zeolite nanoparticle
- Active packaging to preserve the quality of fresh fruits
- Water Resistance Improvement of Paperboard Packaging by Micro-nano Surface Roughness Modification



- Injection-molded packaging from non-vulcanized natural rubber/polyethylene blends

Packaging printing & graphics

- Functional Coatings, Inks and Adhesives to Improve Packaging Properties

Packaging standards & legislation

- Characterization of horizontal acceleration events occurring during transport

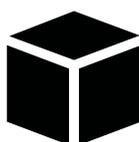
Packaging sustainability

- Possibilities on prediction of plastic's fragmentation time

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- Biobased Biodegradable Packaging for Cold Chain Maintenance in B2C and B2B Delivery of Temperature-Sensitive Products

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- Alternative approach for polystyrene biodegradation by selected bacteria

-
- Functional Coatings, Inks and Adhesives to Improve Packaging Properties



Development of capacitive-based sensors for packaging applications

Authors

Indranil Basak (Hasselt University, Institute for Materials Research (IMO) & IMEC vzw – Division IMOMECE), Mieke Buntinx (Hasselt University, Institute for Materials Research (IMO), Packaging Technology Center IMO-IMOMECE & IMEC vzw) and Wim Deferme (Hasselt University, Institute for Materials Research (IMO) & IMEC vzw – Division IMOMECE).

Abstract:

Stretchable electronics have been making progress in, for example, photodetectors, temperature sensors and pressure sensors. To prepare these sensors, drop-on-demand (DoD) inkjet printing can be applied. DoD inkjet printing can fabricate circuits with high resolution (20 μm line width), is easy to use and very cost-effective. However, ink formulation is complicated and the property window for jettability is small. Therefore all parameters (viscosity, surface tension, density, ...) need to be optimized when formulating a functional ink.

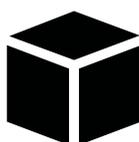
The aim of this study is to develop a highly conductive inkjet printable polymer-based ink by mixing poly(3,4-ethylenedioxy-thiophene):polystyrene sulfonate (PEDOT:PSS) in different proportions with selected solvents. Jettable inks were printed on plasma-treated thermoplastic polyurethane (TPU) stretchable foils in different configurations using a Dimatix DMP-2800 inkjet printer and sintered in an oven. Sheet resistances as low as 25,5 Ω/sq were measured by Van der Pauw when only one layer was printed. By printing 5 layers, the sheet resistance could be reduced to 4,9 Ω/sq . In addition, surface roughness and transparency were measured by atomic force microscopy and spectrophotometry respectively.

To show its applicability towards 3D integration for packaging applications, capacitive-based sensors with three layers printed on top of each other for better conductivity were printed on a TPU foil. This was subsequently integrated on a 3D printed geometry by a vacuum forming device. After integration, the 1x1 cm^2 square was converted into 1.3x1.3 cm^2 , resulting in a total stretch of 30%. The resistance change upon stretching was investigated and shows promising results.

The developed inkjet printable and stretchable conductor shows the capability to be formed around 3D parts, which can be useful for innovative 3D-packaging applications or other markets. Sensors (e.g. humidity, temperature, touch) with capacitive reading can be designed and printed on stretchable foils for packaging applications.

Keywords: capacitive sensor, printed electronics, PEDOT:PS

Topics: Active & intelligent packaging



Spoilage bacteria on chicken fillets packaged with different atmospheres

Authors

Anlaug Ådland Hansen (Nofima), Birgitte Moen (Nofima) and Solveig Langsrud (Nofima).

Abstract:

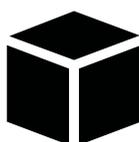
It is important to ensure good quality preservation of refrigerated stored food, to obtain a sustainable, safe and economically profitable production chain. Fresh chicken is an increasingly popular source of muscle foods, but the shelf life is limited by bacterial spoilage. By better control of initial microbial composition and factors that affect the microbial development, like packaging and storage temperature, shelf life can be improved. The aim of the study was to describe and define the most important spoilage bacteria on chicken fillets packaged with 100% N₂ and 60% CO₂/40% N₂.

Several bacteria represented by seven genera (*Carnobacterium*, *Pseudomonas*, *Serratia*, *Hafnia*, *Brochothrix*, *Lactococcus* and *Shewanella*) were isolated from chicken fillets from two different producers. Their spoilage potential was investigated by inoculating them on fillet pieces prepared under strictly hygienically conditions, and modified atmosphere packaged (N₂ with or without CO₂) and stored at 4 °C (13 days). A HDPE tray (RPC Bebo, Norway) with Biaxer top web (Wipak Oy, Finland) were used (tray sealing machine T200, Multivac, Germany). The gas/product volume ratio was 4/1. The fillets were sampled after storage and analyzed by headspace gas analysis (Checkmate 9900 O₂/CO₂ analyzer, PBI Dansensor, Denmark), bacterial plate count (PCA, Oxoid, U.K.), high-throughput sequencing of bacterial 16S rDNA (MiSeq, Illumina) and sensory profile of odour attributes (10 trained assessors) and volatile components (dynamic headspace GC-MS).

The results showed that growth of *Pseudomonas*, *Hafnia* and *Serratia* genera were inhibited by CO₂. Fillets packed with 100% N₂ were spoiled by *Hafnia*, *Brochothrix* and *Shewanella*. In conclusion, packaging with CO₂ inhibited growth of potential spoilage bacteria identified and seemed to result in less negative associated odour compared to packaging with 100%N₂.

Keywords: modified atmosphere packaging, spoilage bacteria, shelf life

Topics: Active & intelligent packaging Packaging for food & agriculture



Modeling of the biopolymer-specific coefficient in Brandsch-Bio diffusion model for bio-polymeric food packaging

Authors

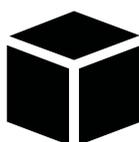
Xi Chen (Jiangnan University), Liao Pan (Jiangnan University), Li-Xin Lu (Jiangnan University), Jun Wang (Jiangnan University), Xiaolin Qiu (Jiangnan University) and Yali Tang (Jiangnan University).

Abstract:

Brandsch diffusion model was one of the most effective and commonly used models for evaluating and predicting diffusion coefficient (D) of diffusate diffusing from polymer packaging. However, different from polymer packaging, most bio-polymeric packaging were hydrophilic and would swell dramatically contacting water which was the primary ingredient of food. Therefore, the classic Brandsch diffusion model was not suitable for bio-polymeric packaging which were having a booming increase share in food packaging investigations. In this study, a Brandsch-Bio diffusion model was proposed for evaluating the diffusing behavior in bio-polymeric food packaging. In this model, a novel biopolymer-specific coefficient (B_p) was defined as the product of biopolymer-contact solvent decided-weight (w) of biopolymer specific and polymer-specific coefficient (A_p). Variable w could take value 0 or 1. Different decided-weights indicated different significant influence of biopolymer-contact solution on biopolymer specific. w variable of 0 represented that the biopolymer specific was significantly influenced by biopolymer-contact solvent (such as water), while w variable of 1 represented that the biopolymer specific was not significantly influenced by biopolymer-contact solution (such as absolute ethanol). Besides, the expression of A_p connected the technological parameters with D . The results indicate that the presented model shows a good agreement with experimental data, and the proposed coefficients (B_p and w) could be applied for production practices of bio-polymeric food packaging.

Keywords: Brandsch-Bio diffusion model, biopolymer-specific coefficient, biopolymer-contact solution decided-weight, bio-polymeric food packaging

Topics: Active & intelligent packaging Packaging for food & agriculture



Functional Coatings, Inks and Adhesives to Improve Packaging Properties

Authors

Inmaculada Lorente (ITENE), Teresa Calvo (ITENE), Alicia Pinazo (ITENE), Leticia Requena (ITENE), Lluís Pascual (ITENE) and Nuria Herranz (ITENE).

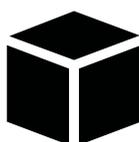
Abstract:

Sustainability, food waste reduction and interaction with consumer are must drivers for the development of new packaging solutions. Coatings, inks and adhesives, as auxiliary materials of packaging systems, give an opportunity to enhance packaging properties and to address them to circular economy guidelines. Bio-based inks, grease and/or water barrier coatings for paper-based materials and oxygen barrier adhesives formulations for flexible packaging solutions are some of current developments to achieve this aim.

In addition, inks and adhesives include the improvement of the packaging communication through the supply chain via printed electronics approach. Anti-counterfeiting, consumer engagement and traceability are pursued with this type of developments. Specifically, conductive inks, printed antennas and conductive adhesives are being considered to simplify existing RFID tag labels to be used in packaging materials. Details of all these developments for coatings, inks and adhesives related to their formulation and characterization tests for each functionality (Cobb index, Oxygen Transmission Rate and electrical resistivity) will be explained with this work as an example of huge possibilities that auxiliary materials can offer to the packaging industry developed in BIOCONDUCTIVE and ADHINK research projects.

Keywords: Coatings, Adhesives, Bio-based, Barrier, Printed Electronics

Topics: Active & intelligent packaging Packaging for food & agriculture Packaging printing & graphics Packaging sustainability



Active packaging to preserve the quality of fresh fruits

Authors

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Abstract:

Fresh fruits and vegetables are highly perishable products. Microbial decay is the main factor that compromises the overall quality of fresh produce. Conventional packaging has some shortcomings in preserving quality, safety and shelf life of this kind of perishable products. Such new packaging developments should be aimed at to either avoid or slow down the possible contamination with pathogen bacteria, yeast and molds.

Objective

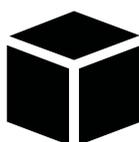
In this research, funded by IVACE in the project FRUIT4U, an active packaging incorporating different antimicrobial natural substances against common microorganism was developed. This active packaging was addressed to extend the shelf-life and the quality of fresh strawberries and other kind of berries.

Methods

The active packaging solution was obtained by coating different materials (cardboard, pads and bubbled wrap) with a carrier that contained the active substances.

In a first stage, the antimicrobial effect was measured in vitro against different model microorganism. In a second stage an in-vivo assay was made with fresh fruits using the active and conventional packaging to compare the quality, shelf life and sensorial properties of both systems.

In addition, the different active materials were characterized in terms of mechanical, thermal and optical properties, in order to ensure that both physical and optical properties are kept. The presence of active substance in the material was quantified by HPLC-UV.



Results

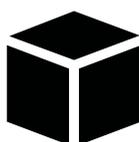
Materials and packaging materials were produced by coating. The use of natural antimicrobial substances in the packaging material provided an antibacterial activity against mesophilic bacteria, yeast and moulds (specifically to *Botrytis cinerea* and *Rhizopus stolonifer*) keeping the quality and freshness of fruit during longer time in comparison with those packaged with conventional packaging. Moreover, the antimicrobial packaging material showed also good physical and optical properties, similar than those with the conventional material.

Acknowledgments

This project has received funding from IVACE (IMEDEEA/2018/107)

Keywords: Active packaging, Antimicrobial effect, Berries, shelf life, preservation

Topics: Active & intelligent packaging Novel packaging Packaging for food & agriculture Packaging materials



Fabrication of Novel Bioactive Cellulosed-based Films Derived from Quercetin-Loaded Nanoparticles

Authors

Kanthika Nantapreecha (Kasetsart University), Amporn Sane (Kasetsart University) and Panuwat Suppakul (Kasetsart University).

Abstract:

Quercetin (QC) nanoparticles (NPs) with an average size of ~60 nm investigated by transmission electron microscopy (TEM) and average sizes of ~500 nm investigated by dynamic light scattering (DLS) were successfully produced by rapid expansion of a subcritical solution into liquid solvents (RESOLV). The antioxidant activities of QC-NPs were compared with QC and commercial antioxidant (i.e. BHA and BHT) by 2,2-diphenyl-1-picrylhydrazyl assay (DPPH) and ferric reducing antioxidant power assay (FRAP). The results demonstrated that a half maximal effective concentration (EC50) of QC-NPs, BHA and BHT by the DPPH assay were 4.92, 10.35 and 16.53 $\mu\text{g}/\text{mL}$, respectively, whereas the FRAP assay revealed that antioxidant activities of QC-NPs, BHA and BHT were 289.78, 127.87 and 37.24 TE $\mu\text{M}/\text{mL}$. The antioxidant activities of QC-NPs-incorporated cellulosed-based films against the DPPH and FRAP assays significantly increased ($p < 0.01$) with increasing of antioxidant activity concentrations. With concentrations of 0.1-0.5 wt %, QC-NPs impregnated methylcellulose films unveiled DPPH and FRAP values in ranges of 37.04-75.22% and 42.42-292.99 TE $\mu\text{M}/\text{mL}$, respectively. Additionally, it was found that correlation coefficients (r) between TPC and DPPH and between TPC and FRAP were 0.8421 and 0.9985, respectively, whereas its between DPPH and FRAP were 0.8338.

Keywords: Active Packaging, Antioxidant Activity, Nanoparticles, Quercetin, RESOLV

Topics: Active & intelligent packaging



Damage by long duration accelerations phenomena on packaging a system

Authors

Victor Huart (METROPACK), Anne-Sophie Bonnin (METROPACK), Jean-Baptiste Nolot (ESIREIMS-ESIEC : Ecole Supérieure d'Ingénieurs de Reims, Reims, France), Nicolas Krajka (METROPACK), Jérôme Pellot (METROPACK), Jean-Charles Candore (ESIREIMS), Serge Odof (ESIREIMS) and Damien Erre (ESIREIMS).

Abstract:

Goods transportation across the world confronts the packaging to a multitude of mechanical stresses.

These stresses generate different types of damages with the risk to destruct the products. All these stresses represent a various type of accelerometric phenomena with different effects on the packaging.

Main transport stress studies on packaging are focused on the damage due to the shocks, the shakes and vibrations. These phenomena are very short in terms of duration (shocks or shakes) or composed of very fast oscillations (vibrations).

In actual transport, it exists accelerometric stresses with a "long" duration. For example, when a truck accelerate/brakes on the road or when it passes on a roundabout, the acceleration stress is applied during an important duration on the goods.

This phenomenon impacts the load stability and potentially damages the products. These damages are generated without an on-goods shock origin.

For a few years, this type of long phenomenon is more and more studied. In this work, we will see where the phenomena appear mostly and in which conditions.

We also will see how to reproduce these phenomena and also if it's possible, point of view damages, to reproduce the effects of these phenomena with common test tools as inclined plane or rotational flat drop.

Keywords: long duration accelerations, damages, pallet stability, shocks, transport

Topics: Distribution packaging Logistics & supply chain



Biobased Biodegradable Packaging for Cold Chain Maintenance in B2C and B2B Delivery of Temperature-Sensitive Products

Authors

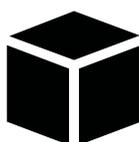
Karina Kjeldgaard-Nielsen (Danish Technological Institute), Stanislav Landa (Danish Technological Institute) and Alexander Bardenstein (Danish Technological Institute).

Abstract:

Sustainable packaging solutions for cold chain maintenance in delivery of temperature-sensitive food and medical supplies have been developed and tested within commercial B2C and B2B supply chains using postal services. The solutions do not make use of EPS that is a conventional transport packaging material for cold-chain delivery and comprise only bio-based biodegradable packaging materials, for instance grafted paper and corrugated cardboard, biodegradable bioplastics, cellulose-fibre heat-retention lagging, and moisture absorbers. These packaging elements are combined to meet both the cold chain requirements set by the specific product application and the technical requirements, which take into account the delivery conditions, such as ambient temperature variations, air humidity, method of delivery, and human-rated factors. Particularly, for companies making the switch from EPS containers, it is important to look at what labelling or training will be needed on the part of postal service personnel to properly handle the shipping that does not have the conventional “cold chain” appearance. The development covered such product applications as fresh fish, fresh and processed meat, as well as temperature-sensitive medical sensors. The fresh fish and meat required retention of 0...+2 degree Celsius for 24 hours, the temperature of refrigerated processed meat products should be kept at +2...+5 degrees for 24 hours, and the operational warranty of the medical sensors is secured by maintenance of +2...+8 degrees during a 48-hour shipment. The results of the field tests revealed that the performance of developed solutions does not yield to that of EPS containers. During the tests, the temperature requirements were met for 30 hours for fresh fish and meat, 28 hours for processed meat product and 52 hours for the medical sensors.

Keywords: Packaging for temperature-sensitive products, Cold chain delivery, Transport packaging, Biobased packaging materials

Topics: Distribution packaging Medical, cosmetic & pharmaceutical packaging Packaging for food & agriculture Packaging materials Packaging sustainability



Characterization of horizontal acceleration events occurring during transport

Authors

Kyle Dunno (RIT - Packaging Science Program) and Changfeng Ge (RIT - Packaging Science Program).

Abstract:

This paper addresses a method to characterize low-level horizontal acceleration events occurring during the transport of packaged goods. These events, which vary in intensity and duration, take place several times during a single shipment as a result of vehicles accelerating, braking, and turning. As unit loads and package systems move through the supply chain, they encounter these events from being handled and transported by different vehicle types. These events challenge the stability of unit loads, and therefore it is important to additionally understand how they respond and behave as a function of these different inputs.

Objective

To characterize horizontal acceleration events occurring during transport in order to produce laboratory test methods to evaluate the stability of unit loads and other package systems.

Methods

Two vehicle types were instrumented with a DC-response accelerometer to capture the input accelerations from three different events: accelerating, braking, and turning. Additionally, a unit load system was instrumented with a DC-response accelerometer to understand how a system responds to the various inputs. The data was interpreted and corresponding levels of acceleration and durations were reported for each vehicle and load type.

Results and Conclusions

Results show that:

- 1) 95% of vehicle horizontal accelerations occur at 0.4g or less. The duration of vehicle events ranges from 1.25 – 4.75 seconds.
- 2) Test parameters are proposed based on the probability density function from each vehicle
- 3) Response event signatures can be used as a verification tool for laboratory simulation tests

Through the characterization of these events, laboratory simulations could be developed to better understand how unit loads and other packaging systems respond to being challenged horizontally during transport. Further understanding of these events will lead to fewer load failures and a safer supply chain.

Keywords: Load stability, acceleration, horizontal impacts, transport packaging

Topics: Distribution packaging Packaging standards & legislation



Record and analysis of constraints encountered in pallets handling by forklifts

Authors

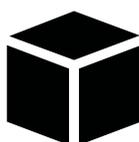
Jean-Baptiste Nolot (ESIREims - ESIEC - Université de Reims Champagne Ardenne), Anne-Sophie Bonnin (METROPACK), Victor Huart (METROPACK), Serge Odof (ESIREims - ESIEC - Université de Reims Champagne Ardenne), Nicolas Krajka (METROPACK), Jérôme Pellot (METROPACK) and Damien Erre (ESIREims - ESIEC - Université de Reims Champagne Ardenne).

Abstract:

From production to detail, packaging systems undergo mechanical, physical and climatic constraints. There is therefore a need in testing packaging systems before any launch to ensure their protective performance. Warehouses, loading docks and unloading docks are critical to packaging systems. On the one hand, surface defects such as potholes, bumps and gutters on the ground of the warehouse generate phenomena to the packaging system when carried by a forklift. On the other hand, loading or unloading goods to or from trucks can lead forklift operators to quickly operate, causing phenomena to the packaging system. That is why protocols, such as International Safe Transit Association (ISTA) or American Society for Testing and Materials (ASTM), for packaging systems shipping integrate forklift handling course. For the purpose of this study, forklifts have been equipped with on-board data loggers which aim is to record accelerations in any direction. These records have been carried out for three typical courses: a logistic warehouse, the 3B ISTA handling course and the D4169 ASTM handling course. The handling courses have been carried out by four different operators. The data thus collected have been analysed in order to determine the typical Power Spectral Densities (PSD) and transient events, both in horizontal and vertical, of these kinds of courses.

Keywords: Packaging system, Forklift handling course, Recording, Vertical acceleration analysis, Horizontal acceleration analysis, Vibration, Shock, Transient events

Topics: Distribution packaging



An evaluation of distribution practices in the retail supply channels for CPGs in India

Authors

Jay Singh (California Polytechnic State University), P. V. Narayanan (SIES School of Packaging and Packaging Technology Center) and Koushik Saha (California Polytechnic State University).

Abstract:

While it leads the global retail opportunity index as the greatest underserved market in the world, the Indian logistics/supply chain sector has yet to even meet the requirements of the urban population due to challenges such as supply chains built on slow transit networks fed by poor roads, ineffective ports, non-existent warehouse standards and minimal distribution infrastructure.

The supply chain related distribution specific activities of thirteen CPG manufacturers, retailers and eCommerce companies were explored through this study.

In India, it is common for manufacturers to first ship CPGs to their own depots (warehouses) from where they are moved to local distributors, wholesalers or stockists who then supply them to the retailers and smaller stores for sale to consumers. In some cases, where the manufacturer does not own their own depots, it deploys “carrying and forwarding” agents who then supply the products to the distributors. Aside from the unique supply chain models adapted by the CPG industry players, there were numerous related observations noted through this study for the traditional and eCommerce retail sectors.

With the tremendous variability in the primarily unorganized retail sector of India, there seems to be one primary distribution testing standard, Indian Standard (IS) 7028. While IS 7028 provides individual hazard element related test procedures, there is currently no “pre-shipment” test protocol available for the Indian distribution simulation. Based on the experiences through this project and interviews with the packaging teams at the thirteen CPG related companies in India, it is the strong recommendation of the authors of this study that a pre-shipment standard, accounting for the evolving supply chain activities, be developed for the organized retail industry in India.

Keywords: India, Supply chains, CPG, Distribution, Pre-shipment testing

Topics: Distribution packaging Logistics & supply chain



Study of the Strength Relation between X-PLY Corrugated Board and Base Paper

Authors

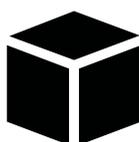
Xuejia Li (Jiangnan University), Jing Qian (Jiangnan University; Jiangsu Key Laboratory of Food Advanced Manufacturing Equipment and Technology) and Lingmin Qiu (Jiangnan University).

Abstract:

X-PLY corrugated paperboard is a kind of a corrugated paperboard with three layers of orthotropic corrugated sandwiches structure. This paper explores the relation between the edgewise compression strength of X-PLY corrugated board and the strength of base paper. In theory, the edgewise compression strength of X-PLY corrugated board of two direction is the sum of the ring crush strength of the base paper in identical direction simply. The researches of this paper only are aimed at the paperboard of BCA. It is found that the longitudinal edgewise compression strength of X-PLY corrugated is lower than that of ordinary corrugated paperboard, but the strength higher than the ordinary in transverse direction. And there are great gaps between the actual edgewise compression strength of ordinary corrugated paperboard and X-PLY with the sum of the strength of base paper by experiments. Base on the linear relation between the strength of ordinary corrugated paperboard and X-PLY with that of base paper, the correlation coefficients are obtained through the regression analysis in further experiments. Finally, the verification of the regression formulas show a good result by the comparison of the theoretical value with test date.

Keywords: X-PLY corrugated board, edgewise compression strength, transverse compression strength, regression equation

Topics: Logistics & supply chain



METHODOLOGY FOR DISCRETIZING THE DESIGN PROCESS

Authors

Laura Esteban (itene), Patricia Navarro (ITENE) and Jose Ignacio Garrigós (ITENE).

Abstract:

The CONSUPACK methodology focuses on the definition of a packaging development methodology that allows consumers' perceptions to be incorporated into the design process in order to increase their potential capacity to present and sell the product, increase their competitiveness on supermarkets' shelves and improve their position in the market compared to their competition. A decision tree has been developed to link perceptual stimuli to the different characteristics of the target audience, such as design forms, colours, ergonomics, etc. In this way, the packaging design will cease to be the result of the designer's individual intuition, subjectivity and experience, discretizing the process to standardize it, which can be transferred to the group of people involved in the different phases of creating a package and, therefore, reproduced in a systematic way, reducing the time and costs of the process.

Keywords: consumer perception, packaging design, design methodology, design process, discretizing, case study, user experience, ergonomics

Topics: Novel packaging Packaging design, ergonomics & human factors

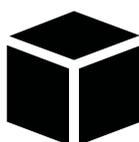


Image and Warning Messages Design on Cigarette Packs that Affects Smokers

Authors

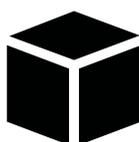
Wannarat Wirachkul (King Mongkut's University of Technology Thonburi), Asst. Prof. Dr. Nucharin Luangsa-Ard (King Mongkut's University of Technology Thonburi) and Thanasit Rujiratharapun (King Mongkut's University of Technology Thonburi).

Abstract:

The purpose of this research were: 1) to redesign images and warning messages on cigarette packs 2) to study smokers' opinions towards images and warning messages on new packs, comparing with images and warning messages on an old pack. The research study was aimed at Krongthip brand which is manufactured in Thailand and very popular among smokers. The images and warning messages were analyzed and redesigned to 3 new prototypes for comparative study. The sample group was 100 smokers in Thung Khru district. The results of this study showed that the highest scored pack was a new pack which had images of wounded oral cavity and the blind's face with warning messages "Smoking causes oral cancer" and "Smoking causes blindness" since the smokers didn't know that smoking could cause permanent blindness, therefore the new pack created impact on their fears due to unfamiliarities. For comparison of images and warning messages between new packs and the old pack, the resulted showed that representatives had more concerns about harmful effects of smoking on health and wanted to quit smoking since images on new packs was more dreadful. For the considering packs' effects on decreasing a number of smokers and restrains them from buying cigarettes, it was found that there was no difference. between new packs and old pack. As most of representatives had been smoking for long time, packs' formats had no impact on their decisions about quit smoking; it just created awareness of harmful effects on health.

Keywords: Package Design, Images and Warning Messages, Cigarette Packs

Topics: Packaging design, ergonomics & human factors



Packaging research in the Australian Fight Food Waste Cooperative Research Centre

Authors

Karli Verghese (RMIT University).

Abstract:

The Fight Food Waste Cooperative Research Centre in Australia, is a ten-year national research centre established in 2018 that aims to improve the competitiveness, productivity and sustainability of Australian industries. It will reduce food waste throughout the supply chain, transform unavoidable waste into innovative high-value co-products and engage with industry and consumers to deliver behavioural change. Winning this fight has a \$20 billion annual prize by increasing industry profitability, tackling food insecurity and enhancing Australia's reputation as a sustainable and trusted producer of premium food products. Comprising 44 industry partners, 8 university partners and 5 State governments the CRC Program fosters high quality research to solve industry-identified problems through industry-led and outcome-focused collaborative research partnerships between industry entities and research organisations. With partner cash and in-kind contributions, along with \$30 million of federal funding, the FFW CRC is now the largest national collaboration globally fighting food waste.

This presentation will provide an overview of the CRC and will then focus upon the packaging research projects that are being undertaken. It will describe how these industry led projects are being developed. The research project topics include packaging design criteria; shelf life; date labelling; cold chain integrity; consumer perceptions of packaging; new packaging material development; and food waste mapping.

More details at <https://fightfoodwastecrc.com.au/>

Keywords: Australia, food waste, packaging research, role of packaging, consumer perceptions of packaging

Topics: Logistics & supply chain Packaging design, ergonomics & human factors Packaging for food & agriculture Packaging sustainability



A New Package Design Paradigm with 3D Image Reconstruction and Convolutional Neural Networks

Authors

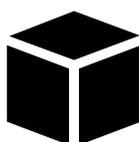
Hae Chang Gea (Rutgers University) and Tian Jin (Rutgers University).

Abstract:

Currently, packaging design process requires designers to communicate ideas with CAD modelers using verbal descriptions, online pictures, draft sketches, or simple CAD models. In return, CAD modelers provide their suggestions based on their engineering knowledge as well as manufacturing constraints. This iterative process will continue until the final design is completed. The process is not very efficient due to the back-and-forth design reviews along with rebuild-error-prone adjustment stage. In this paper, a novel packaging design framework is presented to simplify the design process by creating easy-to-edit parametrized models from pictures of existing packages based on photogrammetric reconstruction and deep learning. The proposed process starts with a series of pictures being taken around existing packages. After a series of reconstruction algorithms including image feature extraction and matching, image rectification and stereo matching, camera locations and poses estimation, and 3D points triangulation and registration, a point cloud model of the packages can be reconstructed. These point cloud models can be classified and linked to various existing basic CAD models using a trained multi-layer 3D convolutional neural network. Then, these basic CAD models will adjust its featured dimensions automatically based on the scanned models and can be used for further editing. Experimental results demonstrate that our framework acquires point cloud of high density, accuracy and robustness, geometry and packaging classified at high accuracy, and thus providing a new paradigm for a more efficient packaging design process.

Keywords: Packaging Design, 3D Image Reconstruction, Neural Networks

Topics: Packaging design, ergonomics & human factors



Generational preferences on sustainable packaging concepts

Authors

Iris Borgman (University of Twente).

Abstract:

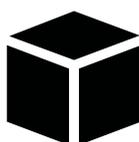
Awareness regarding environmental issues is increasing among consumers, which also applies to the young consumers of generation Y (born 1980-1995), often referred to as Millennials. Existing studies have made evident that this generation is seeking more and more for sustainable options within the great abundance of products and services. Moreover, they are willing to pay more for sustainable products from brands that are regarded as environmentally conscious. As for the packaging, they highly value pro-environmental aspects of a package, however, their view of such packaging is different from other generations. Additionally, Millennials have a high preference for experiential designs and value the appeal and aesthetics of packaging. The combination of Millennials' positive attitude towards sustainable product-packaging combinations and their preference for appealing packaging emphasize that research should focus more on the packaging design.

Currently, there are some insights into packaging features that convey sustainability according to Millennials and other generations, depending on the type of study. However, this is mainly based on theoretical research and a link with the actual design is missing. Therefore, the purpose of this paper is to look from a design-focused perspective and present consumers with actual packaging designs instead of focusing on descriptions of the packaging. Packaging features regarding sustainability, extracted from existing studies, are integrated into design concepts and consequently evaluated by different generational groups of respondents. The results reveal how different generations respond to the sustainable packaging concepts and whether their choices are in line with existing studies.

This research increases the understanding of differences in generational preferences of sustainable packaging. Packaging designers and developers are, in particular, provided with design-oriented tools to assist in designing packaging that clearly communicates sustainability to young consumers.

Keywords: Packaging design, Sustainability, Millennials, Generations, Marketing

Topics: Packaging design, ergonomics & human factors



Optimization of the gas composition for an extended shelf life of fresh shiitake (*Lentinula edodes*) stored at room temperature

Authors

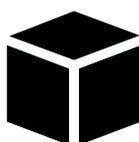
Susanna Miescher (Zurich University of Applied Sciences) and Selcuk Yildirim (Zurich University of Applied Sciences).

Abstract:

Fresh Shiitake have a shelf life of approximately three days when displayed in the shops at room temperature. One approach to extend the shelf life of mushrooms includes the control of the ambient gas composition through modified atmosphere packaging. A change in the ratio of the permeability for carbon dioxide and oxygen of the packaging, the beta-value, would allow a specific permeability and thus the adjustment of the optimum gas composition for the highly respiring shiitake. However, there is a lack of agreement in the literature considering the optimal gas composition for the storage of mushrooms in particular for shiitake. The aim of the present study was to determine the optimal gas atmosphere for an extended shelf life of fresh shiitake at room temperature. To determine the most eligible gas atmosphere, shiitake were stored in an airtight tent for 96 hours in gas compositions kept at a constant level with 2-10% O₂ combined with 30-60% CO₂ (gas composition range was selected based on the results of a preliminary study). The quality of the shiitake was examined before and after storage on the quality parameters color, texture, weight loss, and development of the mushrooms. All tested gas mixtures caused a smaller change in color and development stage compared to the mushrooms stored under ambient gas composition. Overall, oxygen values of 1-4% and carbon dioxide values of 30-50% were shown to be suitable to prolong the shelf life of shiitake stored at room temperature. Gas composition of 2% O₂ + 40% CO₂ was found to be the most suitable and it significantly reduced the darkening of the veil to ΔL^* values of -8.39 ± 0.6 compared to normal atmosphere with ΔL^* values of -35.76 ± 1.41 . Additionally, this gas atmosphere showed an inhibition of textural softening and weight loss.

Keywords: Shiitake, *Lentinula edodes*, Modified atmosphere packaging, Shelf life, Controlled atmosphere

Topics: Packaging for food & agriculture



Study of the influence of cure conditions on the physical mechanical properties of lacquers applied to internal surfaces of metal packages

Authors

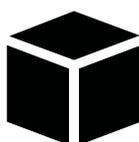
Daniela Yamashita (Packaging Technology Center - Institute of Food Technology), Paula Corsato (Packaging Technology Center), Fiorella Dantas (Packaging Technology Center) and Sílvia Dantas (Packaging Technology Center - Institute of Food Technology).

Abstract:

Lacquers are polymers applied onto the surface of metallic packages to function as a barrier to the conditioned product contact with the metallic surface in order to protect it from interaction and to avoid can failure and food waste. Their performance is influenced by the application conditions since the coating barrier depends on the cross linking that is formed as well as the resin own characteristics. This study evaluated three epoxy phenolic lacquer formulations (A, B and C) applied onto tinfoil in laboratory. Five cure temperatures were used: 200°C – specified by the producer, two under-cure temperatures (180°C; 190°C) and two over-cure (210°C; 220°C). Different evaluation methods of the cure degree were applied, including resistance to Methyl Ethyl Ketone (MEK) and Butyl Glycol (BG) solvents, determination of the extract content with extraction by acetone in closed system as well as the method of absorption of colorant methyl violet. Findings have shown that the gradient of temperature variation of 10°C results in clear differences in the dry coating layer, that varied from 7.82 g/m² to 7.09 g/m², from 6.34 g/m² to 6.04 g/m² and from 6.93 g/m² to 6.51 g/m² between the lowest and highest temperature of cure for lacquers A, B and C, respectively. Regarding the cure degree, dissolution by MEK was effective in differentiating the cure condition for samples B and C and under-cure condition for sample A. BG method is suitable to indicate under-cure for samples A and B and is not applicable to sample C. Dye absorption resulted in differentiation only for over-cure in sample A and is not suitable for evaluating samples B and C. Solvent extraction showed to be suitable to the three lacquers and there were different percentages of extractions among them in the temperature range studied. The results confirmed the influence of the EP lacquer composition in the cure evaluation performance.

Keywords: Lacquer, Cure degree, Temperature, Interaction, Metal package

Topics: Packaging for food & agriculture Packaging materials



Evaluation of moulded pulp trays using compression test and novel twist test

Authors

Anton Hagman (RISE Bioeconomy).

Abstract:

Within the industry there exists great experience of producing moulded pulp trays, this includes adjusting process parameters to achieve a consistent output from the tray making machines. However, the evaluation of the results is at this point based on hands on methods that ultimately relies on subjective opinions of what makes a good tray. This includes visual inspection of the trays, as well as a twisting the trays by hand to evaluate stiffness. Such methods might suffice to achieve a consistent output, but are not suited for structured development work, which requires objective measures.

One obvious measurement is a compression test, like a box compression test. However, this test does not tell the whole story, and differs from the hands-on tests used today. Because of this a twist test was developed to emulate the hands-on testing presently used to assess the quality of moulded pulp trays. The test is performed in a tensile tester, by putting the tray in a sample holder which supports two diagonal bottom corners while a beam is pressing against the opposite upper diagonal corners. This forces the tray to bend.

Plotting the results from these two tests against each other, results in a practical graph that can be used to evaluate both pulp and process properties, as well as tray weights. This plot reveals that some information remains hidden if only compression tests are performed.

Finally, such a graph lends itself to define boundaries for what is an acceptable tray.

Keywords:

Molded pulp, Tray, Mechanical testing, Product development

Topics: Packaging materials



Production of tea bag paper from corn stalk pulp

Authors

Nucharin Luangsa-Ard (Department of Printing and Packaging Technology, King Mongkut's University of Technology Thonburi), Nattiya Kongpreecha (Department of Printing and Packaging Technology, King Mongkut's University of Technology Thonburi) and Sasipimon Dokdawruang (Department of Printing and Packaging Technology, King Mongkut's University of Technology Thonburi).

Abstract:

Corn is the third most important crop in the world. It is a short-lived crop, after corn ears are harvested, its stalk will be landfilled or destroyed by burning in order to prepare soil for next plantation. Apart from burning, landfilling, or making bio-compost, corn stalk could be produced into pulp for papermaking. This research was aimed to find the optimal condition for production of tea bags from corn stalk pulp and to compare physical & mechanical properties between corn stalk tea bag and commercial tea bag. The experiment was done by cooking corn stalk in opened soda pulping process. The produced corn stalk pulp was refined for 30 and 60 seconds to form two types of 23.5 ± 0.02 gram. corn stalk paper. Then physical, mechanical properties and morphology of the corn stalk papers together with their performance between commercial tea bag and tea bag from corn stalk paper were analyzed. The result showed that the optimal condition to produce corn stalk pulp was to use sodium hydroxide concentration of 18% on O.D.wt., at 100 ± 5 °C for 150 minutes. The pulp yield was 21.7%. The comparison results of physical properties between commercial tea bag and tea bag produced from corn stalk pulp revealed that the basic weight of both papers were similar. Corn stalk pulp paper had lower thickness than commercial tea bag paper. For mechanical properties, the data showed that corn stalk pulp paper had lower tensile strength than commercial tea bag. For the morphology of corn stalk pulp paper, it showed that fiber formation and porosity of corn stalk pulp paper was similar to commercial tea bag paper. When compared the performance between commercial tea bag and tea bag of corn stalk pulp paper, there was not much difference between the two types of paper.

Keywords: corn stalk paper, tea bag paper, corn stalk pulp

Topics: Packaging materials



Alternative approach for polystyrene biodegradation by selected bacteria

Authors

Dries Gevers (UHasselt), Mieke Buntinx (UHasselt) and Roos Peeters (UHasselt).

Abstract:

Plastics pose a growing concern towards the environment. Mitigating actions are required as most of them do not report significant biodegradation. Biodegradable plastics are proposed as alternatives. Unfortunately, it remains difficult to compete with traditional petroleum based polymers.

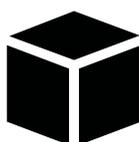
Besides technical and economic obstacles, intrinsic biodegradability also shows some negative effects. For applications like food packages, biodegradable polymers are single-use items. Recycling of biodegradable polymers is difficult and it contaminates current recycling stream. Reuse and recycling of plastics saves a lot of resources and associated greenhouse gas (GHG) emissions. These savings will be reduced by increased use of biodegradable plastics. It seems a catch 22: traditional petroleum based plastics are not biodegradable and accumulate in nature but their biodegradable alternatives exhibit other adverse effects on the environment by increased use of resources and GHG emissions.

An alternative approach could be to search for specific microorganisms capable of degrading current petroleum based plastics. While a practical method to apply them is not available yet, a first requirement is to search for useful microorganisms. This knowledge can contribute to the development of alternative biotechnological solutions for the environmental threats posed by plastics.

In this study the extraction and enrichment of polystyrene (PS) consuming bacteria is reported. After 2 enrichment cycles, five bacteria were identified using PS as their sole carbon source. In a subsequent mass loss experiment over 5 months period on PS film material, a small loss (0.5 wt.%) was detected. These results confirm bacterial degradation of PS. As biodegradation rates are relatively small, more research is required to make it applicable for plastic waste remediation.

Keywords: Polystyrene, Biodegradation, Bacteria

Topics: Packaging materials Packaging sustainability



Toxicological Profile of Nanomaterials Applied to Packaging

Authors

Arantxa Ballesteros Riaza (Packaging, Transport and Logistics Research Institute (ITENE)), Begoña Espiña (International Iberian Nanotechnology Laboratory (INL)), Carlos Fito López (Packaging, Transport and Logistics Research Institute (ITENE)) and Ivone Pinheiro (International Iberian Nanotechnology Laboratory (INL)).

Abstract:

INTRODUCTION New developments have arisen based on the use of the nanotechnology, which brings innovative opportunities in the packaging sector. However, nanoparticles can show potential hazard due to its inherent properties, or because of the toxicity derived from the molecules used in their functionalization. With this aim, the potential toxicity of engineered nanomaterials (ENMs) was assessed in the EU-funded project NanoDesk SUDOE.

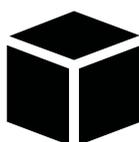
OBJECTIVE The main goal of this European project is to ensure that the engineered nanomaterials (ENMs) used does not pose risks to human or environmental health, guaranteeing a safe use for industry and consumers, as well as for the environment, from a life cycle approach, throughout the definition of the potential risk profile of most common ENMs used in packaging industry. Metal NPs, metal oxides, carbon-based materials and nanoclays were among the selected ENMs for testing.

METHODS To assess ecotoxicological impact, acute immobilization tests in *Daphnia magna* were performed. For the toxicity assessment, it had been used MTT Proliferation Assay (cytotoxicity), and the Comet Assay (genotoxicity). Three types of cell lines were used: adenocarcinomic human alveolar basal epithelial cells A549; spontaneously immortalized aneuploid human keratinocyte cell line HaCaT; and heterogeneous human epithelial colorectal adenocarcinoma cells Caco-2.

RESULTS Toxicological differences are observed between particles tested: for the environment (*Daphnia magna* studies), most critical ENMS are silver nanoparticles (EC50 0.03 mg/L); in human (experiments with cell lines), different types of graphene have high toxicity values at cellular level (EC50 1,74 mg/L; 2,75 mg/L) and at genetic level (up to 50% of cells affected). ENMs such as nanoclays or ZnO are those with the lowest levels of toxicity compared to other metal oxides or carbon-based materials. Complementarily to these analyses, there is a clear need of standardized protocols for the study of ENMs in order to make the results comparable.

Keywords: Nanotoxicology, Engineered Nanomaterials, Packaging, Risk assessment, Ecotoxicity

Topics: Packaging materials



Study of physical and mechanical properties of low density polyethylene mixed with Ag-zeolite nanoparticle

Authors

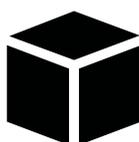
Pradtana Muangprakaew (Department of Printing and Packaging Technology at King Mongkut's University of Technology Thonburi.), Nucharin Luangsa-Ard (Department of Printing and Packaging Technology at King Mongkut's University of Technology Thonburi.) and Juntira Komasatith (Department of Printing and Packaging Technology at King Mongkut's University of Technology Thonburi.).

Abstract:

In this study, low density polyethylene (LDPE) film was mixed with Ag-Zeolite nanoparticle. The aims of this research were to test physical (yellowness, gloss, DSC, and SEM) and mechanical properties (tensile strength and elongation at break) of pure LDPE and LDPE mixed with Ag-zeolite nanoparticle at 0.5 and 1 % (by weight). In the experiment a twin screw extruder was used for blending LDPE resin with 0.5 and 1 %wt. of Ag-zeolite nanoparticle. After that a blown film extruder was then used for blowing 3 types of LDPE film (pure LDPE, LDPE with 0.5% and 1%wt of Ag-Zeolite) with thickness of approximately 0.5 to 0.6 mm. Thereafter, physical and mechanical properties of those produced film was investigated. The results showed that Ag-zeolite nanoparticle, which was added in LDPE film, did not affect on yellowness and gloss (60°) of those film. Likewise, it was also indicated that the Differential scanning calorimetry: (DSC) of LDPE with Ag-zeolite nanoparticle in both amount was also insignificantly changed when compared with the pure LDPE film. The results from a scanning electron microscope (SEM) pictures showed that there was difference dispersion of Ag-zeolite between LDPE films at 0.5 and 1 %wt of Ag-zeolite nanoparticle. Moreover, it was found that tensile strength values in machine direction (MD) of both pure LDPE and LDPE with Ag-zeolite nanoparticle films were insignificantly different while tensile strength in transverse direction (TD) were significantly decreased. In addition, the results showed that Ag-zeolite nanoparticle could also significantly decrease the elongation at break in both MD and TD of those LDPE with Ag-zeolite films.

Keywords: LDPE, Ag-zeolite nano particle, yellowness, gloss, DSC, SEM, tensile strength, elongation at break

Topics: Packaging materials



Water Resistance Improvement of Paperboard Packaging by Micro-nano Surface Roughness Modification

Authors

Wasin Thitsartarn (Kasetsart University), Namfone Lumdubwong (Kasetsart University) and Tunyarut Jinkarn (Kasetsart University).

Abstract:

Water barrier improvement of paper material is a big challenge in the packaging industry due to its hydrophilic nature. Surface modification by various coating and laminating technologies are currently applied to solve the problem. However, common coating technique may not give effective surface characteristics as expected. This work focused on the improvement of paperboard's water resistance property through the design for micro-nano surface roughness combination on the paperboard surface using the innovative electrospray coating. Coating substances were starch based compounds with electrosprayed polylactic acid (PLA) particles. Water contact angle, water absorption and water vapor transmission rate were evaluated. After the coating, different surface roughness characteristics were observed. Water contact angle tended to increase with the increase PLA concentration. In addition, nano-structure of PLA above the micro-structure of starch coated surface of the paperboard was proved to be more effective for the water barrier improvement. According to the test results, water contact angle was increased while water absorption and water vapor transmission rate were decreased. Therefore, micro-nano surfaces roughness modification of paper packaging can be designed in order to achieve a suitable water resistance property as needed.

Keywords: Water resistance, Surface roughness, Surface modification, Paperboard

Topics: Packaging materials



Injection-molded packaging from non-vulcanized natural rubber/polyethylene blends

Authors

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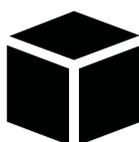
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Abstract:

For many decades, Thailand is one of the largest natural rubber (NR) producers and exporters in the world; however most exported NR is in the forms of cheap raw materials. The converting of NR raw materials into value-added products is thus very important. In general, NR-based products are obtained by compounding NR with various vulcanization chemicals, e.g. zinc oxide, sulfur, stearic acid, 2-mercaptobenzothiazole, etc. and then converting to the finished goods using compression molding process. This approach is time consuming and provides thermosetting products with some residual chemicals. In order to overcome those limitations, the present research therefore demonstrates the preparation of thermoplastic natural rubber and its properties. Herein, NR was melt blended with high density polyethylene (HDPE) in the absence of vulcanization, using HDPE:NR weight fractions of 60:40 and 50:50. HDPE/NR blends showed significantly improved extensibility (~85%) and better impact strength, but possessed reduced tensile strength, Young's modulus, hardness and heat distortion temperature as compared with HDPE. HDPE/NR blends could be converted into injection-molded products, e.g. tray, box, etc. In addition, high friction surfaces of these bio-based HDPE/NR materials could expand their applications to pallets and parts of distribution packaging.

Keywords: Natural rubber, Polyethylene, Blend, Injection molding

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Possibilities on prediction of plastic's fragmentation time

Authors

Anja Geburtig (BAM Federal Institute for Materials Research and Testing).

Abstract:

Depending on the specific plastic's ageing sensitivities, the durations which plastic components remain in the environment can be very long. As, in the past, the advantages in ageing resistance and durability were highly evaluated, we now face the problem of quite stable plastic waste within the environment.

However, there is only little knowledge on the real timescales until macroscopic fragmentation for the different kinds of plastic under various environmental conditions.

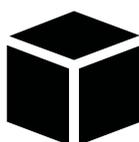
Here, weathering methods are presented, which have been used for the failure prediction in specific outdoor conditions. Issues of uncertainty, reproducibility, or validation are discussed.

For the prediction of the plastic's fragmentation, much longer time scales have to be considered. To do this within a limited project life span, various processes as well as their acceleration potential have to be evaluated separately, such as temperature increase or spectral shift.

The possibilities and limitations of such controlled acceleration will be discussed.

Keywords: plastics, fragmentation, weathering

Topics: Packaging sustainability



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