ABSTRACT BOOK

The 11th Packaging and Materials Innovation Symposium

pmis 2026

Bridging Science and Industry:
Smart Solutions for Real World Challenges

MARCH 12th

Preface

Welcome to the 11th Packaging and Materials Innovation Student Symposium 2026 (PMIS 2026), held under the theme “Bridging Science and Industry: Smart Solutions for Real World Challenges”. This symposium stands as a meaningful academic milestone and a proud tradition of collaboration between the Department of Packaging and Materials Technology and the Department of Materials Engineering–a partnership that reflects how modern innovation is truly created, where scientific understanding, engineering design, and industrial needs meet.

For more than a decade, PMIS has served not only as a platform for academic exchange, but also as a professional stage where our graduating students present the outcomes of years of dedication–long hours in laboratories, careful experimentation, iterative design, and persistent problem-solving. PMIS 2026 continues this mission by fostering a learning environment that strengthens technical communication, encourages constructive feedback, and builds confidence as students transition from the university to the workplace.

This year, we are proud to showcase 39 student projects, representing a wide range of smart and practical solutions that respond to real-world challenges. By bringing these disciplines together, the symposium highlights the importance of cross-functional thinking, where the structural performance of materials aligns with the functional and user-centered excellence of packaging and product design.

We are also honored to welcome our distinguished keynote speaker, Dr. Wannee Chinsirikul, who will share professional insights through the keynote address “Packaging and Materials Innovation: Real-World Journey, Inspiration & Beyond”. Her experience will provide valuable perspective on how academic foundations can evolve into impactful innovation, leadership, and industry-level solutions.

The success of this symposium is made possible through the dedication of our organizing committee, supportive staff, and faculty mentors, whose guidance has helped shape the intellectual growth and research skills of our students. We also express sincere appreciation to our partners for their generous support and continued trust in the value of education, research, and innovation.

May PMIS 2026 inspire collaboration, strengthen the bridge between science and industry, and encourage smart solutions that can truly make a difference in the real world.

Thank you for being an essential part of this important occasion.

Piyawanee Jariyasakoolroj
The 11th PMIS 2026 Organizing Committee

Welcome Message
for 11th pmis 2026

It is a great honor to welcome you all to the 11th Packaging and Materials Innovation Student Symposium. This event marks a significant milestone in our academic calendar.

For over a decade, this symposium has served as a vital bridge between the Packaging and Materials Technology (PKMT) and Material Engineering (MAT-E) departments. More than just a formal requirement, this is a professional stage designed to showcase the culmination of four years of rigorous study, late nights in the lab, and relentless problem-solving.

This year, we are proud to host 39 pioneering projects: 16 Projects from Material Engineering (MAT-E), and 23 Projects from Packaging and Materials Technology (PKMT). By bringing these two departments together, we mirror the reality of the modern industry, where the structural integrity of materials meets the functional brilliance of packaging design. Students, today is your day to demonstrate not just your technical expertise, but your ability to communicate complex ideas clearly to your peers and the evaluation committees.

We are incredibly fortunate to have a distinguished guest with us today. I would like to extend a warm welcome to Dr. Wannee Chinsirikul, Technology and Innovation Advisory from Neo Co. Ltd. She will be sharing her invaluable perspective in her keynote address: “Packaging and Materials Innovation: Real-World Journey, Inspiration & Beyond.” I encourage all students to listen closely; this is a rare opportunity to see how the theories you have studied translate into global innovation and leadership.

Finally, today is also a day of celebration for our PKMT students who stepped beyond the classroom to compete in the KU x Lucky Star Recycled Packaging Innovation Awards 2025. Later this afternoon, we will announce the winners and present awards to recognize your commitment to sustainability and creative excellence.

To all of our 4th-year students: Be confident. You have done the work; now, tell us your story. Thank you for sharing your projects and your passion with us today. Your excellent work is the foundation upon which you will build your careers as the next generation of engineers and technologists.

I wish you all a memorable experience at this symposium.

Associate Professor Dr. Lerpong Jarupan
Head of the Department of Packaging and Materials Technology
Faculty of Agro-Industry, Kasetsart University

Bridging Science and Industry:
Smart Solutions for Real World Challenges

Welcome Message
for 11th pmis 2026

PMIS is an annual symposium co-hosted by the Department of Packaging and Materials Technology (PMKT), Faculty of Agro-Industry, and the Department of Materials Engineering (Mat-E), Faculty of Engineering.

This year, I am pleased to have the Department of Packaging and Materials Technology as the main host. This year's theme, "Bridging Science and Industry: Smart Solutions for Real-World Challenges," reflects our shared goal for connecting knowledge from classrooms and laboratories with real needs in industry and society.

The symposium is designed as a learning stage for the fourth-year students from both PMKT and Mat-E departments to present their senior projects. More than just presentations, PMIS provides students a real experience of an academic conference – a place to exchange ideas, feel the energy of fellow students, and enjoy the synergistic outcomes between science, engineering, and technology.

I am truly impressed by the hard work and dedication of all students over the past year. Completing a senior project is not easy, and your efforts have made this symposium lively and meaningful. Students are an important part of what makes PMIS a dynamic and inspiring event every year.

Finally, I would like to express my sincere thanks to the host department, PMKT, as well as the key organizing members from both PMKT and Mat-E departments, for their commitment and teamwork in making PMIS 2026 possible.

I wish everyone an inspiring and memorable symposium!

Associate Professor Dr. Ratchatee Techapiesancharoenkij
Head of the Department of Materials Engineering
Faculty of Engineering, Kasetsart University

Content

Content

Content

Content

Overall Program

The 11th Packaging and Materials Innovation Symposium 2026

"Bridging Science and Industry: Smart Solutions for Real World Challenges"

12 March 2026

8:30-9:00	**Registration** Room 0410 Chuchart Kampoo Building, Faculty of Engineering, Kasetsart University				
9:00-9:30	**Welcome and Introduce to PMIS 2026** **Assoc. Prof. Dr. Suttipun Keawsompong** Dean, Faculty of Agro-Industry, Kasetsart University **Prof. Dr. Wanchai Yodsudjai** Dean, Faculty of Engineering, Kasetsart University **Assoc. Prof. Dr. Lerpong Jarupan** Head of Packaging and Materials Technology Department, Faculty of Agro-Industry, Kasetsart University				
9:30-10:30	**Packaging and Materials Innovation: Real-World Journey, Inspiration & Beyond** **Keynote speaker : Dr. Wannee Chinsirikul** Technology and Innovation Advisor (Packaging and ESG), NEO Factory Company Limited., Thailand Executive Advisor for Research Strategy and Lead Researcher Development, Metallurgy and Materials Science Research Institute, MMRI, Chulalongkorn University				
10:30-10:45	**Break**				
	MAS	**MPCT**	**MPEA**	**SESSIONS**	**ASM**
	Room 0403	**Room 0405**	**Room 0406**	**Room 0407**	**Room 0410**
10:45-11:10	MAS01-P04	MPCT07-M02	MPEA04-M04	MAS02-P05	ASM01-P06
11:10-11:35	MAS03-P07	MPCT01-P01	MPEA01-P02	MPCT06-M01	ASM05-M14
11:35-12:00	MAS12-M10	MPCT09-M07	MPEA06-M06	MAS04-P08	ASM03-P13
12:00-13:00	**Lunch**				

Overall Program

	MAS	MPCT	MPEA	SESSIONS	ASM
	Room 0403	Room 0405	Room 0406	Room 0407	Room 0410
13:00-13:25	MAS05-P16	MPCT03-P10	MPEA02-P03	MAS07-P19	ASM06-M15
13:25-13:50	MAS06-P17	MPCT11-M09	MPEA05-M05	MPCT10-M08	ASM04-P14
13:50-14:15	MAS13-M12	MPCT04-P11	MPEA03-P18	MAS08-P20	ASM07-M16
14:15-14:40	MAS09-P21	MPCT08-M03	MPEA07-M11	MPCT12-M13	ASM02-P12
14:40-15:05	MAS10-P22	MPCT02-P09	MPCT05-P15	MAS11-P23	
15:05-15:45	KU x Lucky Star Recycled Packaging Innovation Awards 2025 Lucky Star Weaving Co., Ltd				
15:45-16:00	Break				
16:00-16:30	Awarding and Closing Remark Assoc. Prof. Dr. Ratchatee Techapiesancharoenkij Head of Materials Engineering Department, Faculty of Engineering, Kasetsart University				

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KEYNOTE
SPEAKER

Bridging Science and Industry:
Smart Solutions for Real World Challenges

Dr. Wannee Chinsirikul

Current Positions

- Technology and Innovation Advisor(Packaging and ESG), NEO Factory Company Limited., a subsidiary of Neo Corporate Public Company Limited, Thailand
- Executive Advisor for Research Strategy and Lead Researcher Development, Metallurgy and MaterialsScience Research Institute, MMRI, Chulalongkorn University
- Standing Committee of the Faculty of Science andTechnology, Thammasat University
- Executive Board Member of the Asian Workshop on Polymer Processing (AWPP), International ResearchCommunity

Former Positions

- Executive Director ofNational Nanotechnology Center,NANOTEC, NSTDA, Thailand (2016-2024)
- President of Nanotechnology Association of Thailand (2022-2023)
- President of Asia Nano Forum (ANF) (2022-2023)
- Board Member of International Association of Packaging Research Institutes (IAPRI) (2014-2020)
- Director of Polymer Research Unit, MTEC, NSTDA, Thailand (2010-2016)
- Technology and Innovation Advisor, IRPC Public Company Limited, Thailand (2024-2025)

Educational Background

- Ph.D., Materials Science & Engineering (Polymer), Department of Materials Science and Engineering, The Pennsylvania State University, USA
- M.S., Polymer Science, Department ofMaterials Science and Engineering, The Pennsylvania State University, USA
- B.Sc., Second-class Honors, Polymer& Textile, Department of Materials Science, Chulalongkorn University, Thailand

Expertise

- Integrated Plastic Materials& Processing Technologies, Upcycling/Recycling and Sustainability for Practical Applications: Polymer Blends, Compounding & Processinginto Products, Film Extrusion/Plastics Packaging/Biobased and Biodegradable Plastics, Nanomaterials andTechnology, (Technical focus is ‘Structure-Property-Process’ Relationships)
- Research Management, IP Management, Business Development and Licensing Strategy

Awards and Honors

- President of Asia Nano Forum (ANF) 2022-2023
- President of Nanotechnology Association of Thailand 2022-2023
- Distinguished MAT SCI-CU Alumni Award 2024 (50th Anniversary of MAT SCI-CU), Materials Science Department, Faculty of Science, Chulalongkorn University
- Distinguished Science-CU Alumni 2011, Chulalongkorn University Science Alumni
- Outstanding Technologist Award 2005 by Foundation for the Promotionof Science and Technology underthe Patronage of His Majesty the King, Thailand
- Recipients of International and National Awards for Science,Technology and Innovation in the field of “Active Packaging Materials and NaturalRubber-Innovative Dewatering Technology by Extrusion”

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MAS

Materials for Sustainability

Bridging Science and Industry:
Smart Solutions for Real World Challenges

Development of Red Seaweed-Based Films for Food Packaging

Phitchaya Thongin[1], and Thitiporn Kaewpetch[1]*

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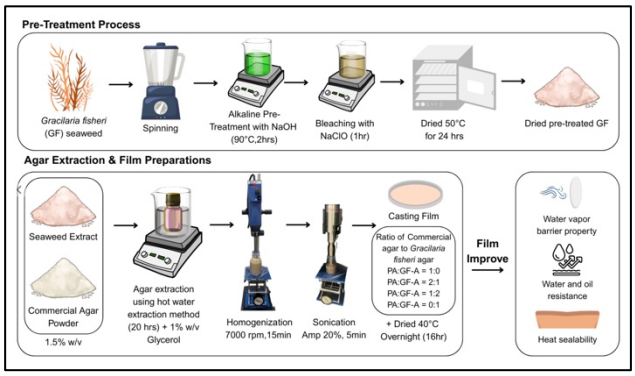
Due to environmental concerns of plastic waste, global demand of alternatively biodegradable plastics have significantly increased. Gracilaria fisheri, a red seaweed, is a valuable biobased resource containing agar polysaccharides which are potentially developed for biodegradable packaging. This study aimed to develop agar-based biopolymer films derived from G. fisheri for food packaging applications. The films were prepared from agar solutions extracted from G. fisheri (GF-A) and compared with commercial agar (PA) and their mixtures (PA:GF-A). The results demonstrated that GF-derived agar films exhibited the darkest color among all formulations. SEM analysis revealed that GF-A films possessed the roughest surface morphology. FTIR spectra confirmed similar functional groups between GF-A and PA, indicating comparable chemical structures. In terms of mechanical performance, GF-derived agar films showed significantly lower tensile strength and elongation at break than PA and PA:GF-A films; however, they exhibited a markedly higher Young's modulus than the blended formulations, reflecting increased stiffness. Regarding barrier properties, GF-A films presented WVTR values comparable to PA but displayed higher OTR than the other formulations. Notably, GF-A films demonstrated the lowest water and oil solubility among all samples. Thermal characterization further revealed an increasing trend in glass transition temperature (Tg) along with higher residual weight and delayed degradation in TGA, indicating enhanced thermal stability. Moreover, GF-A films achieved effective heat sealing at lower sealing temperatures compared to PA and PA:GF-A films. Collectively, these results highlight the potential of G. fisheri-based agar films as environmentally friendly alternatives for oil-rich food packaging applications.



Keywords: Biodegradable films, Red seaweed, Agar, Oil sachets

Effect of Cellulose Nanocrystals and Nanofibers Incorporated into Gracilaria fisheri-Derived Agar Coatings on the Surface Properties of Paper Packaging

Aphinya Kromdee[1], Pitiphat Deeha[1], and Thitiporn Kaewpetch[1]*

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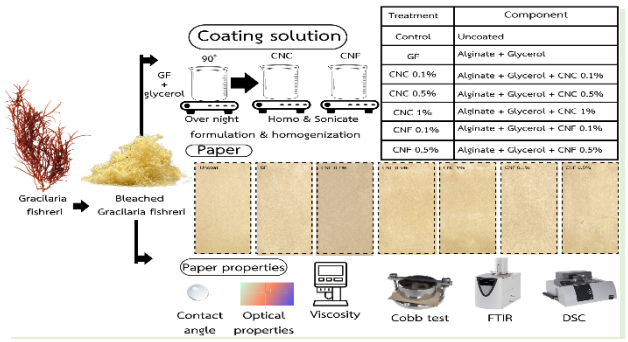
Paper-based packaging is a sustainable alternative to plastics but suffers from poor water and oil resistance due to its porous and hydrophilic structure. Bio-based agar coatings derived from Gracilaria fisheri seaweed offered an environmentally friendly solution. Many studies used cellulose nanocrystals (CNCs) and cellulose nanofibers (CNFs) to improve barrier and surface properties. In this study, CNCs and CNFs were incorporated into G. fisheri-derived agar coating solutions, which was then coated on paper packaging. Their effects on the surface properties of the coated paper, particularly water and oil resistance, were investigated. The result shows that the incorporation of CNCs and CNFs into the derived agar solution increased significantly increased the viscosity of the coating formulations, particularly with CNFs due to their higher aspect ratio and network-forming ability. After the solutions were coated onto paper substrate, the coatings containing CNCs and CNFs exhibited a slight increase in water and oil contact angles compared with coatings formulated only with G. fisheri-derived agar. Nevertheless, the measured contact angles remained lower than those of uncoated paper. In terms of absorption, the addition of CNCs and CNFs led to increased water absorption, which was due to an increase in –OH groups, as evidenced by FTIR. In contrast, oil absorption showed no significant change compared with the agar-only coating.



Keywords: Polysaccharides, Biodegradable coating, Agar, Cellulose nanocrystal, Cellulose nanofiber

Development of Paper-Based Packaging Materials as an Eco-Friendly Alternative for Solid Dosage Medicines

Saurawee Yathaninyakorn[1], and Nattinee Bumbudsanpharoke[1]*

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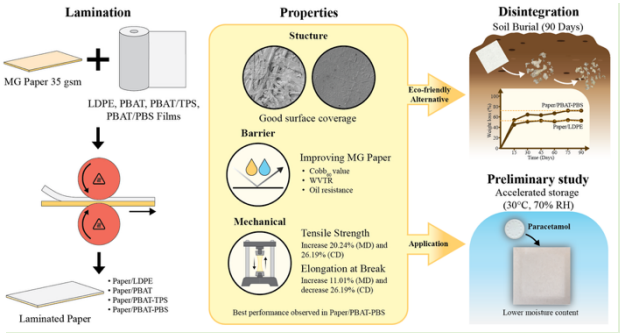
[*]corresponding author: nattinee.bu@ku.ac.th



Biodegradable packaging is currently garnering significant attention across various sectors as a potential solution to the persistent waste issue caused by single-use packaging. However, the development of eco-friendly packaging alternatives has largely been confined to food applications. Therefore, this research investigates the feasibility of applying biodegradable materials to packaging for solid tablets, a product category with substantial global consumption. Machine Glazed (MG) paper was selected as the primary substrate due to its recyclability and ability to naturally biodegrade should it escape waste management systems. To enhance functional properties, the MG paper was laminated with biodegradable films—specifically poly(butylene adipate-co-terephthalate) (PBAT), PBAT/thermoplastic starch (TPS), and PBAT/poly(butylene succinate) (PBS)—and compared against conventional low-density polyethylene (LDPE). Microstructural analysis via Scanning Electron Microscopy (SEM) revealed that all biodegradable film laminates exhibited good coverage comparable to the Paper/LDPE control. Regarding barrier properties, the Paper/PBAT-PBS laminate demonstrated superior water resistance, characterized by a negligible Cobb60 value (0.07 g/m²) and water vapor permeability (3.60 g·mm/m²·day·kPa) among the biodegradable samples. In terms of mechanical properties, the Paper/PBAT-PBS laminate exhibited higher tensile strength than Paper/LDPE in both the machine direction (MD) and cross direction (CD), surpassing the control by 20.24% and 26.19%, respectively, while maintaining comparable elongation at break values. Furthermore, soil burial tests confirmed that the Paper/PBAT-PBS laminate achieved the highest biodegradation rate, with a weight loss of 71.67% after 90 days. Preliminary study results for the accelerated storage of paracetamol tablets (30°C, 70% RH) found that tablets packaged in Paper/PBAT-PBS sachet had lower moisture content than the control samples from the commercial pack.

Keywords: Pharmaceutical Packaging, Eco-Friendly Materials, Laminated Paper, Biodegradable Materials

Feasibility Study on Valorizing Hemp Fiber Waste from the Textile Industry into Bio-Based Cushioning Materials

Narapat Pasarnphan[1], Thitivorrada Chokwatcharapaisarn[1], and Nattinee Bumbudsanpharoke1*

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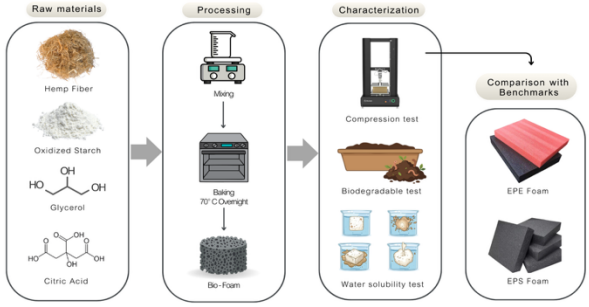
This research investigates the feasibility of valorizing crude hemp fiber waste generated by the textile industry for use in packaging materials. Crude hemp fiber was explored as a potential raw material for biodegradable cushioning applications in transportation, with the objective of replacing petroleum-based foams such as expanded polystyrene and extruded polyethylene. The study intentionally utilized crude hemp fiber without chemical pulping or bleaching processes in order to minimize secondary chemical waste generation. The research focused on evaluating the feasibility of cushioning material formation and mechanical performance through variations in formulation composition, including hemp fiber content and functional additives. Citric acid (CA) was employed as a crosslinking agent, glycerol as a plasticizer, and sodium lauryl sulfate (SLS) as a foaming agent. The results indicated that a fiber concentration of 20% (w/v) provided an optimal balance between structural integrity and processability. SLS was found to be essential for the formation of a porous foam structure, while the incorporation of 3–5% (w/v) CA significantly enhanced compressive strength through esterification reactions with starch and cellulose molecules. Although the formulation containing 5% CA exhibited the highest rigidity, the 3% CA formulation demonstrated superior elasticity and recovery behavior when plasticized with glycerol. Overall, the synergistic effects of fiber content and additive composition demonstrate the strong potential for transforming crude textile hemp waste into functional bio-composite foam materials, offering a sustainable and industrially viable alternative to conventional synthetic cushioning materials.



Keywords: Bio-foam, Hemp Fiber, Starch, Biodegradable Packaging, Valorization

Development of Edible Film Based on Thermoplastic Starch Incorporated with Agar from *Gracilaria fisheri* via Blown Film Extrusion

Suparada Lounlek[1], Kananat Kitkongkhajorn[1], and Rangrong Yoksan[1]*

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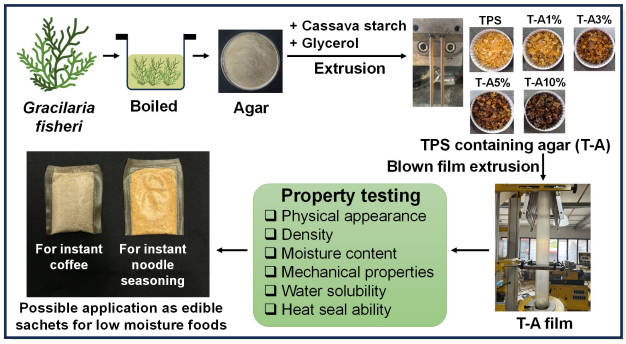
[*]*corresponding author: rangrong.y@ku.ac.th*



Gracilaria fisheri, a species of red seaweed, represents a promising renewable resource for developing sustainable packaging materials. The current study aims to develop a biodegradable packaging film based on thermoplastic starch (TPS) incorporating agar derived from Gracilaria fisheri. TPS films containing agar at loadings of 1, 3, 5, and 10% were fabricated via a blown-film extrusion. The effects of agar on the properties of TPS were investigated. The addition of agar hardly affected the den-sity of TPS (1.452–1.474 g/cm³), but increased the moisture content by 40–67%. Nevertheless, the film containing 3% agar had the lowest moisture content. The impact strength of TPS film was markedly improved by 960–1380% with agar incorporation, reaching the highest value at 5% agar loading. Ten-sile strength and stiffness of TPS film tended to decrease, while elongation increased with increasing agar content. The film with 5% agar exhibited the highest elongation (900% in MD). Agar incorporation reduced the water solubility of TPS film. Among agar-containing samples, 1% and 3% agar-filled films showed the fastest dissolution rates at 60°C and 100°C, respectively. The heat-sealing ability of film was significantly improved with agar addition up to 3%; however, higher agar loadings caused film shrinkage near the sealing area. The developed TPS film incorporating 3% agar offers a balanced com-bination of mechanical performance, desirable water solubility, and perfect heat sealing, showing po-tential as a sustainable edible packaging material for low moisture foods, such as sachets for instant coffee and seasoning powder and oil for instant noodles.

Keywords: Gracilaria fisheri, Thermoplastic starch, Agar, Edible film, Blown film extrusion, Food packaging

Development of degradable Mycelium-based Cushion

Viralpatchara Hatthasak[1], and Lerpong Jarupan[1]*

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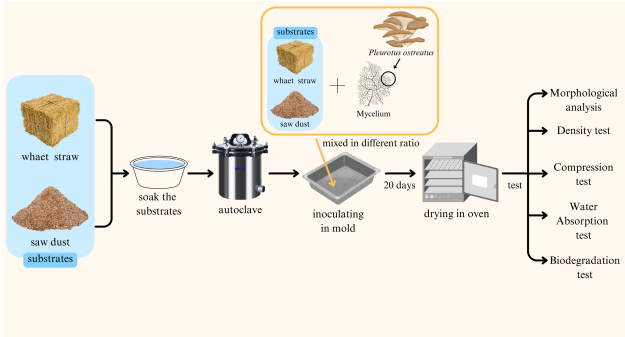

The ubiquity of single-use packaging, particularly expanded polystyrene (EPS) foam, presents a critical environmental challenge due to its persistence in global supply chains. This study investigates sustainable, biodegradable alternatives by developing fungal-based cushioning materials using Pleurotus ostreatus mycelium as a natural binder combined with agricultural waste. The objective was to investigate the effect of different substrate ratios between sawdust and rice straw on the physical and mechanical properties of the mycelium-based composite. The study examined the impact of varying substrate ratios on the physical and mechanical properties of the material. Five formulations were prepared with varying sawdust-to-rice straw ratios (100:0, 75:25, 50:50, 25:75, and 0:100). The fabrication process involved substrate sterilization, incubation under controlled conditions, molding, and thermal inactivation to stop fungal growth. The results showed that while substrates with higher sawdust content yielded higher density, they exhibited increased friability and weaker internal bonding. In contrast, a higher rice straw content facilitated superior mycelial adhesion and fibrous network formation due to its porous structure, despite having a lower material density. Additionally, samples from both substrate types showed good biodegradation in natural soil, indicating that the material is environmentally friendly after disposal. Overall, the study shows that a 25:75 ratio of sawdust-to-rice straw offers the optimal trade-off for cushioning applications, suggesting that this material serves as a viable biodegradable substitute for synthetic EPS, supporting circular economy practices through the up-cycling of agricultural residues.

Keywords: Mycelium, Bio-composite, Cushioning Materials, Sawdust, Rice Straw

Utilization of Recycled Polypropylene in 3D Printing Processes

Pakteema Kaewket[1], Sarinthip Nathaisong[1], and Lerpong Jarupan[1]*

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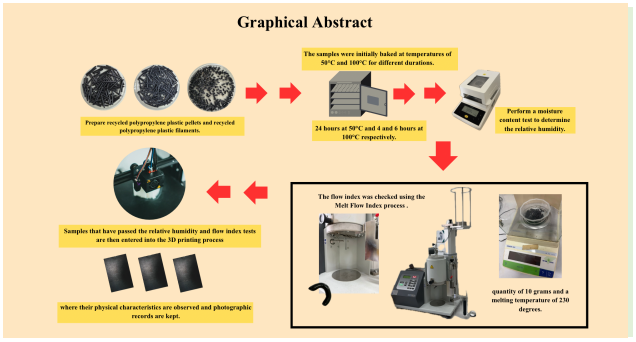
[*]corresponding author: lerpong.j@ku.ac.th



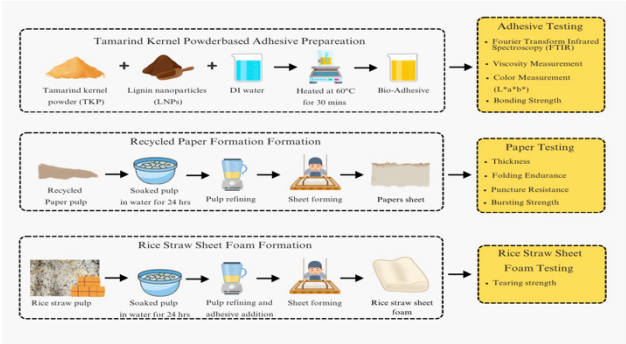
The global challenge of plastic waste management necessitates the development of high-value recycling strategies for post-consumer materials. This research focuses on recycled polypropylene (rPP), a thermoplastic valued for its low density, high strength-to-weight ratio, and excellent impact resistance. Despite these advantages, the integration of rPP into 3D printing workflows requires a systematic evaluation of its processing stability. The objective of this research is to evaluate the printability and performance of rPP by examining key physical and process parameters. Specifically, this research investigates moisture content, relative humidity, and molten melt flow index (MFI) and analyzes how these factors influence flow behavior, extrusion stability, and surface quality during filament production and printing. Minimizing environmental moisture content and relative humidity to near-zero is expected to reduce defects such as bubbles, voids, and poor layer adhesion, thereby improving surface flatness and structural integrity. Furthermore, MFI is used to assess the flowability and processability of rPP prior to printing, serving as an indicator of optimal processing conditions. This research aims to provide best practices for using polypropylene recycled in additive manufacturing by establishing a relationship between MFI, moisture content, relative humidity, and printability. Successful results will support sustainable material utilization and contribute to the development of a circular economy through the future applications of higher-value recycled plastics.

Keywords: Recycled polypropylene, Mechanical properties, Printability, 3D printing, Additive manufacturing

Development of Bio-Adhesive from Tamarind kernel powder and Lignin for Rice-Straw-Based foam

Taknatchapong Munvichatorn[1], Jittrapa Khrueanobphakhun[1], and Vanee Chonhenchob[1]*

[1]Department of Packaging and Materials Technology, Faculty of Agro-Industry, Kasetsart University, Bangkok 10900, Thailand
[*]corresponding author: vanee.c@ku.ac.th



Synthetic adhesives widely used in the packaging industry are primarily derived from petroleum-based materials, which are difficult to degrade and pose environmental concerns. This research aims to develop a bio-based adhesive as an alternative to synthetic adhesives by utilizing agricultural waste materials, namely tamarind kernel powder (TKP) and ligninnanoparticles (LNPs), which are abundantly available industrial by-products. These materials were used to develop an environmentally friendly bio-adhesive for packaging applications. The fundamental properties of TKP solutions at concentrations of 4%, 5% and 6% (w/v) were compared. The results indicated that a concentration of 5% (w/v) was the most suitableas adhesive, exhibiting a viscosity range of 0.64–1.22 Pa·s and appropriate flow behavior for practical use. Therefore, 5% TKP was selected as the base formulation, and three adhesive samples were prepared: 5% (w/v) TKP, 5% (w/v) TKP blended with 5% (w/v) LNPs, and 5% (w/v) TKP blended with 10% (w/v) LNPs.Viscosity measurements using a Brookfield viscometer demonstrated that the incorporation of LPNs significantly enhanced both viscosity and adhesion performance on paper surfaces compared to TKP adhesive. Fourier transform infrared spectroscopy (FTIR) analysis confirmed the formation of hydrogen bonding between hydroxyl (-OH) groups and LNPs and the molecular structure of TKP, resulting in stronger intermolecular interactions. These findings highlight the potential of TKP–LNPSs bio-adhesives for application in paper packaging. In addition, the TKP-LNPs bio-adhesive was used for developing rice straw sheet foam, offering a sustainable and environmentally friendly alternative for the packaging industry.

Keywords: Tamarind kernel powder, Lignin-nanoparticles, Adhesive, Rice straw, Bio-based foam

Development of Bio-Adhesive from Tamarind Kernel Powder Blended with Polyvinyl Alcohol for Rice Straw Bonding

Bongkhodchakhon Phummala[1], and Vanee Chonhenchob[1]*

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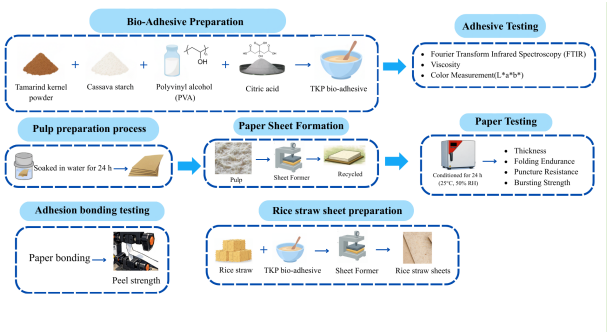
This study investigated the development of a bio-based adhesive from tamarind kernel powder (TKP) combined with polyvinyl alcohol (PVA) for bonding rice straw sheets. The goal was to reduce the use of petroleum-based adhesives and to add value to agricultural wastes. Tamarind kernel powder was selected as the primary raw material because it is a natural biopolymer derived from by-products of the food processing industry that have not been fully utilized. In addition, its high hydroxyl group content makes it suitable for adhesive development. Polyvinyl alcohol (PVA) was incorporated into the formulation to enhance bonding performance. PVA is a low-toxicity polymer that is partially biodegradable and considered environmentally friendly. The prepared adhesives were assessed for viscosity, functional group analysis using FTIR spectroscopy, and color measurement. Bonding strength was tested by applying on recycled paper developed in this study using peel strength testing. The results indicated that the formulation containing 5% (w/v) TKP combined with 1% (w/v) cassava starch, PVA, and citric acid exhibited the best bonding performance compared to other formulations. The developed adhesive was then applied to the fabrication of rice straw sheets for using as an environmentally friendly alternative for the bio-based materials industry from wastes.



Keywords: Bio-adhesive, Tamarind kernel powder, Rice straw, Polyvinyl alcohol (PVA)

Effect of Recycling Process Conditions on Decontamination Efficiency of Polyethylene Terephthalate for Food Contact Applications

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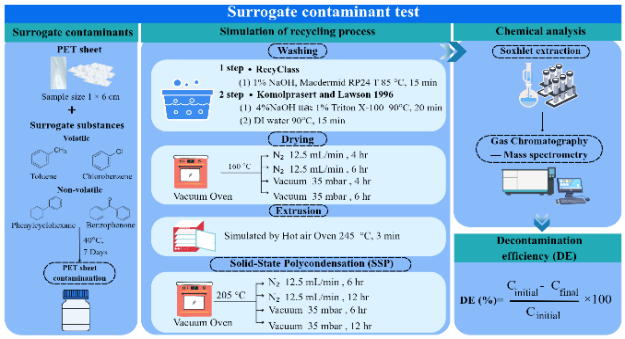

This study evaluated the removal efficiency of surrogate contaminants during a simulated polyethylene terephthalate (PET) recycling process using a challenge test approach. Processing parameters were investigated to assess decontamination performance and the safety of recycled PET (rPET) intended for food-contact applications. Representative surrogate contaminants were intentionally spiked into PET sheets prior to recycling, including volatile compounds (toluene and chlorobenzene) and non-volatile compounds (phenylcyclohexane and benzophenone). After washing process, removal efficiencies of volatile and non-volatile contaminants were 38–51% and 22–35%, respectively. After drying under vacuum for 4–6 hours, decontamination efficiencies increased to 81–86% for volatile substances and 24–64% for non-volatile substances, while drying under nitrogen atmosphere further improved removal to 82–89% and 49–73%, respectively. Simulated extrusion resulted in complete removal of volatile contaminants and 88% removal of non-volatile contaminants. Significantly increased cleaning efficiency of non-volatile contaminants was obtained after solid-state polycondensation (SSP) for 6–12 hours. Under vacuum conditions, the decontamination efficiencies of non-volatile contaminants increased to 81–92%. When SSP was performed under a nitrogen atmosphere, the removal of non-volatile compounds increased to 89–95%. The efficiency increased with SSP processing time.

Decontamination behavior of surrogate contaminants was strongly influenced by their boiling point and volatility. Low-boiling volatile compounds were removed more readily, whereas high-boiling non-volatile substances required elevated temperature, controlled atmosphere, and extended processing time. Overall, temperature, atmosphere, and processing time were identified as key parameters controlling the decontamination and safe use of rPET for food-contact applications.

Keywords: Polyethylene terephthalate, Surrogate contaminant test, Recycling process, Food contact materials, Gas chromatography-Mass spectrometry

Effects of Processing and Annealing on Crystalline Structure, Thermal Properties, and Soil Degradation of High Heat Polylactic Acid

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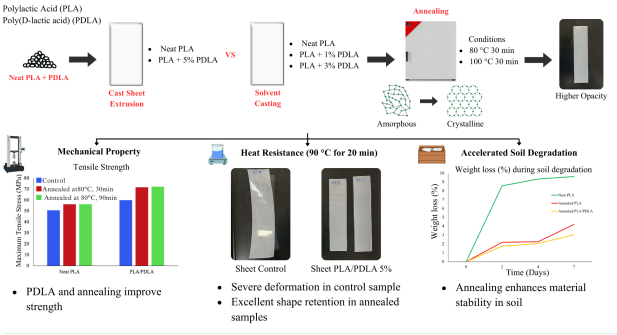
This research examines the effects of processing and annealing on the properties of high heat polylactic acid (PLA) by comparing neat PLA with PLA containing poly(D-lactic acid) (PDLA) as a nucleating agent. The influence of cast sheet extrusion and solvent casting methods was also investigated. Annealing and PDLA addition improved tensile strength. Extruded PLA/PDLA sheets annealed at 80 °C for 30 minutes exhibited the highest tensile strength, possibly due to the formation of stereocomplex crystallites. However, this improvement was accompanied by increased brittleness and reduced elongation at break. Increasing annealing temperature or duration did not significantly improve mechanical strength. In terms of thermal resistance, annealed extruded sheets maintained their shape during hot water immersion at 90 °C for 20 minutes, while control samples showed severe deformation. This behavior suggests improved thermal properties, potentially related to increased crystallinity. During accelerated soil degradation testing at 60 °C for 7 days, solvent-cast films degraded faster than extruded sheets due to their reduced thickness. PDLA addition and annealing slowed the degradation process, which may be associated with increased crystallinity. Some samples exhibited weight gain due to water absorption into the amorphous regions. This process is regarded as an initial step in hydrolysis, prior to microbial degradation and may explain the observed weight variation. Optimizing annealing conditions and PDLA content allows PLA to balance high heat performance during use with effective biodegradability at the end of its life cycle.



Keywords: High Heat Polylactic Acid, Packaging, Annealing, Nucleating Agent, Soil Degradation

Influence of Bed Temperature of Fused-Filament 3D Printing on the Formation of Polylactic Acid/Polybutylene Succinate and Polylactic Acid/Polybutylene Adipate-*co*-Terephthalate/Thermoplastic Starch Components

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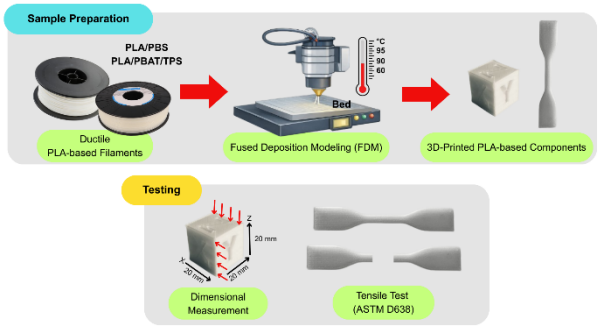
Fused Deposition Modeling (FDM) three-dimensional printing has been widely adopted due to its low cost and ability to fabricate complex geometries. However, non-uniform shrinkage during printing leads to deviations of the printed parts from the designed models. This limitation is also found in polylactic acid (PLA), a biodegradable polymer widely used as FDM feedstock, which also exhibits intrinsic brittleness and low impact resistance. To overcome these limitations, two PLA-based blend systems with different elongation characteristics—PLA/polybutylene succinate (PBS) and PLA/polybutylene adipate terephthalate (PBAT)/thermoplastic starch (TPS)—were prepared. The effect of bed temperature on the dimensional shrinkage of FDM-printed parts was investigated. Thermal properties, microstructure, degree of crystallinity, mechanical properties, and dimensional shrinkage were evaluated to better understand the shrinkage behavior of both polymer blend systems during printing. The results show that bed temperatures approaching the crystallization temperature (T_c) increase the crystallinity of the printed parts, which in turn influences dimensional shrinkage and mechanical strength.



Keywords: Fused Deposition Modeling (FDM); Polylactic Acid (PLA); Polymer Blends; Bed Temperature; Non-uniform Shrinkage

Development of a Binder from Waste Flexible Polyurethane Foam for Biomass-Based Composites

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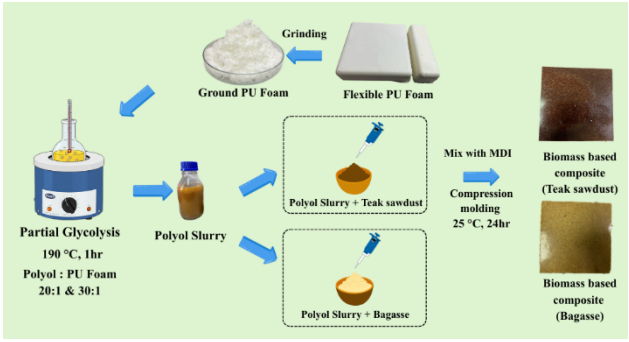
This research aims to develop a binder derived from post-industrial flexible polyurethane (PU) foam waste through a partial glycolysis process for application in biomass composites. The glycolysis was conducted at 190°C for 1 hour, with polyether polyol to PU foam ratios of 30:1 and 20:1. The study focuses on analyzing the degree of urethane bond cleavage within the resulting polyol slurry system, ensuring the preservation of specific molecular structures and functional groups essential for adhesion. The decomposition results and chemical structures were successfully verified using Fourier Transform Infrared Spectroscopy (FTIR) technique. Subsequently, the synthesized polyol slurry was blended with methylene diphenyl diisocyanate (MDI) at ratios of 1:0.3, 1:0.6, and 1:0.9 to produce the final binder. The performance of this recycled binder was compared against a binder made from virgin polyol by producing composite boards from two types of agricultural waste, teak sawdust and bagasse, using binder-to-waste ratios of 1:1 and 1:2. The mechanical properties and microstructure were then evaluated to analyze the influence of the recycled binder on the resulting material strength. This research demonstrates a sustainable approach to utilizing and adding value to polyurethane foam waste and agricultural residues.



Keywords: Flexible polyurethane foam, Partial glycolysis, Polyol Slurry, Binder, Biomass Composites

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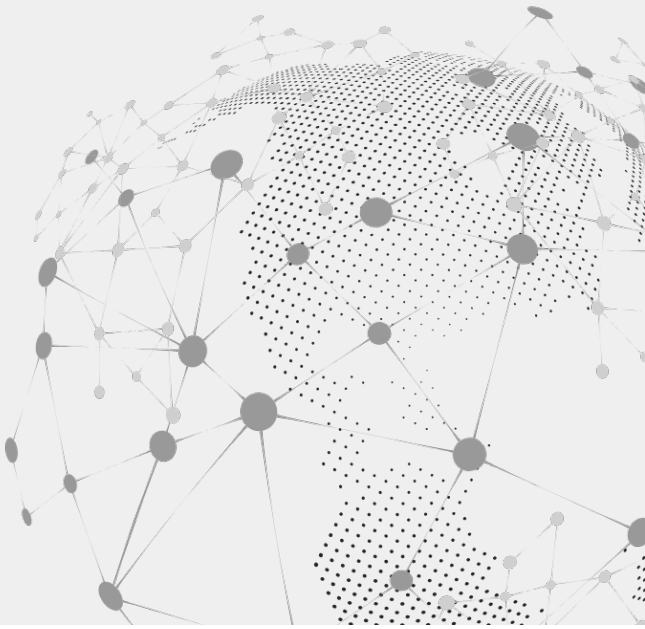

Bridging Science and Industry:
Smart Solutions for Real World Challenges

Active Performance of PLA/PBAT Laminated with PBAT/TPS/Nitrite Films for Beef Lidding film

Chawanwit Na phairee[1], Pawaris Dilokpornmethee[1], Nathdanai Harnkarnsujarit[1]*

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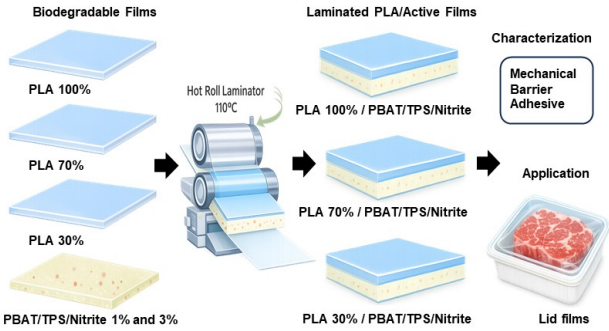
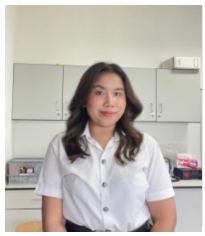
This study investigated the effect of nitrite concentration (1% and 3%) and PLA content (30%, 70%, and 100% wt.) on the properties and active performance of laminated lid films for beef packaging. PLA/PBAT films were laminated with an active PBAT/TPS film containing nitrite. This structure was designed to overcome the mechanical weakness and moisture sensitivity of TPS-based active films. The optimal lamination temperature was 110 °C. Mechanical properties, adhesion strength, water vapor permeability (WVP), and performance as beef tray-sealing lid films were evaluated. Decreasing PLA content reduced tensile strength but increased elongation at break, indicating greater flexibility. Increasing nitrite concentration also increased film flexibility. WVP increased when PLA content decreased and when nitrite concentration increased. Adhesion strength increased at higher nitrite levels in PLA 30% and PLA 70% laminates, which was consistent with SEM observations. However, PLA 100% laminates showed poor interfacial adhesion. During storage at 4 °C, non-laminated control films developed noticeable off-odors by day 3. Laminated films containing 3% nitrite delayed off-odor until day 5, and deterioration appeared on day 7. Total viable counts remained below 7 log CFU/g on day 3 in the 3% nitrite film, while other treatments exceeded this level. Indicating spoilage of packaged meat pH of beef packaged with 3% nitrite laminated films ranged from 5.62 to 6.08, compared with the initial value of 5.51. In contrast, samples sealed with 1% nitrite laminates and non-laminated PLA controls reached a maximum pH of 6.61, indicating greater quality deterioration. These results demonstrate the potential of laminated nitrite-incorporated bioplastic lid films to extend the shelf life of beef.



Keywords: Lid film, Bioplastic, Lamination, Shelf-life extension, Beef



Moisture-Triggered Chlorine Dioxide Release in Packaging Materials for Fresh Produce Preservation

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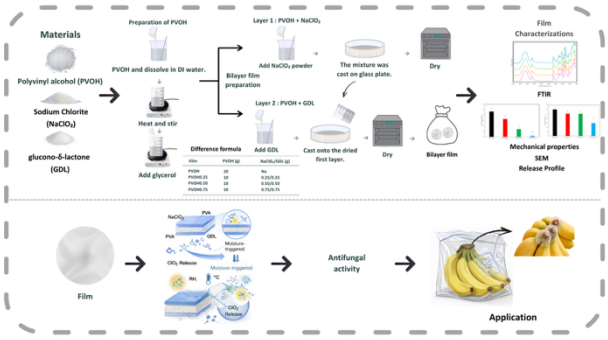

This study focused on the development of a moisture-triggered active packaging material capable of generating chlorine dioxide (ClO_2) in situ for antimicrobial applications. A bilayer polyvinyl alcohol (PVOH) film was engineered by incorporating sodium chlorite as the ClO_2 precursor and glucono delta-lactone (GDL) as a mild acid generator. To avoid premature reactions during film fabrication and storage, the two reactants were spatially separated into different PVOH layers. This bilayer configuration enables controlled activation of ClO_2 release under specific temperature and relative humidity conditions typically encountered in fresh-produce packaging environments. Four film formulations were prepared, including one control film (PVOH only) and three active films containing increasing $NaClO_2$/GDL loadings (0.25, 0.50, and 0.75 g per layer). The films were characterized in terms of structural, mechanical, and release properties, and their moisture-responsive functionality was evaluated. To validate the functional performance of the developed system, antifungal activity was first examined through in vitro assays against Fusarium sp. isolated from banana fruit. The active films were subsequently applied to banana samples to assess their effectiveness in inhibiting fungal growth under simulated postharvest conditions. Results showed that the moisture-activated films provided enhanced fungal inhibition compared with the control. Overall, the developed bilayer system demonstrates the feasibility of integrating controlled ClO_2-releasing functionality into packaging materials and highlights its potential for fresh-produce preservation and compatibility with modified atmosphere packaging technologies.

Keywords: Controlled release, Shelf life, Chlorine dioxide, Banana, Packaging system

Modeling and Validation of Ethylene Diffusion in Biodegradable Films for Avocado

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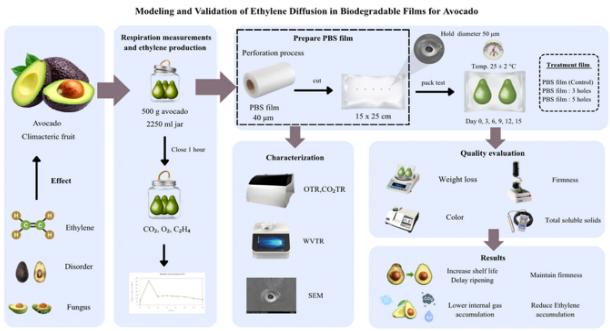

This study presents the modeling and experimental validation of ethylene diffusion and gas exchange behavior in micro-perforated biodegradable packaging films designed for avocado preservation. As a climacteric fruit, avocado exhibits high respiration activity and rapid ethylene production after harvest, necessitating effective control of internal atmosphere to delay ripening and maintain postharvest quality. Respiration rate and ethylene production were first determined using a closed-jar system to establish physiological source parameters. Biodegradable polybutylene succinate (PBS) films (40 µm thickness) were fabricated and laser micro-perforated (Ø50 µm) at three perforation levels: non-perforated, 3 perforations, and 5 perforations. Film transport properties, including oxygen transmission rate (OTR), carbon dioxide transmission rate (CO_2TR), water vapor transmission rate (WVTR), and ethylene permeability, were characterized and integrated into a diffusion-based mass transfer model describing gas transport through both polymer matrices and perforation pathways. Model simulations predicted ethylene accumulation and internal gas composition within the packaging system. These predictions were experimentally validated through packaging trials using two avocados (≈ 350 g) per package stored at 25 ± 2 °C. Fruit quality was evaluated via firmness, total soluble solids, titratable acidity, weight loss, peel color, and visual appearance during storage. Results demonstrated that perforation density significantly enhanced ethylene ventilation, regulated internal atmosphere, and delayed ripening. The strong agreement between modeled and experimental data confirms the feasibility of using micro-perforated biodegradable films as a sustainable strategy for ethylene management and shelf-life extension of avocado.

Keywords: Avocado, Ethylene, Microperforated film, Biodegradable film, Shelf life

Development of Ripeness Indicator for Monthong Durian using Polydiacetylene-Polyvinyl alcohol Film Integrated with Lenticular Label

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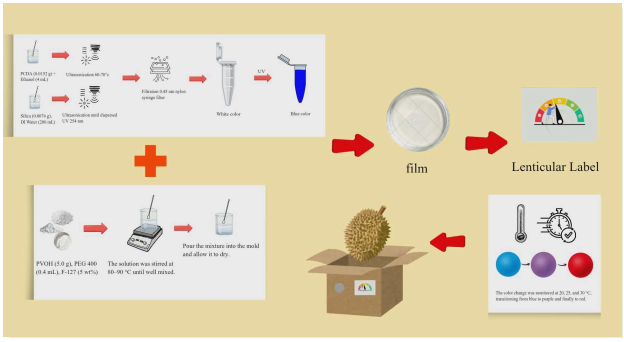

In recent years, intelligent labels have gained increasing attention as simple and effective tools for non-destructive food quality monitoring. Durian is a highly popular fruit in Thailand; however, ripeness evaluation still relies mainly on consumer experience and subjective judgment. Therefore, this study aimed at developing an intelligent label for monitoring durian ripeness using polydiacetylene (PDA) incorporated with polyvinyl alcohol (PVOH) film coupled with a lenticular label system. Indicator films were prepared using PVOH at a concentration of 5 wt%, with polyethylene glycol (PEG 400) added at 30% of total solids as a plasticizer and Pluronic F-127 at 5% w/v as a stabilizing agent. Polydiacetylene (PDA) solutions were prepared through a self-assembly process and stored at 4 °C for 24 hours. The prepared solutions exhibited suitable properties for film formation and color response evaluation. Three types of indicator films were designed to correspond to different durian ripeness levels. Color changes were quantified using total color difference (ΔE) values. The indicator system exhibited gradual and distinguishable color transitions from blue to red under the combined effects of time and temperature. Each indicator type showed different color change behaviors, reflecting variations in sensitivity and stability. The developed indicator functions as an indirect time–temperature indicator (TTI), with color changes governed by time–temperature effects correlated with durian ripening kinetics and activation energy (Ea). Selected a PDA incorporated with PVOH film coupled with a lenticular label demonstrates potential for application in food quality monitoring and differentiating durian ripeness levels under practical market conditions.

Keywords: Fruit Ripeness Detection, Lenticular, Monthong Durian, Polydiacetylene, Ripeness Indicator

Photocathodic Protection of ZnO/rGO–Acetylene Black–Epoxy Composite Coatings for Stainless Steel 304

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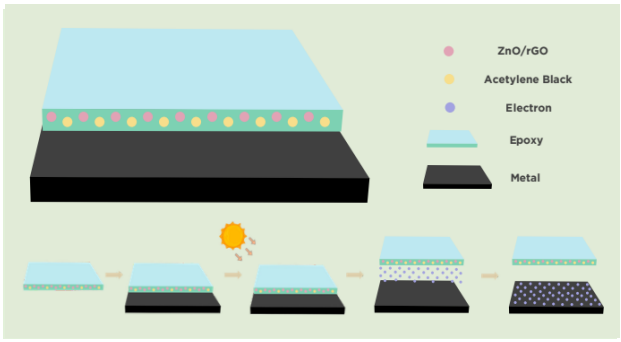

Photocathodic protection is a sustainable and environmentally friendly anti-corrosion technology that converts light energy into electrochemical energy for metal protection. This study the performance of composite coatings based on Zinc oxide (ZnO) and Reduced graphene oxide (rGO), combined with Acetylene black (AB) in epoxy for Photocathodic protection on Stainless steel 304 (SS304). A comparative evaluation of ZnO, ZnO/rGO, ZnO–AB–Epoxy, and ZnO/rGO–AB–Epoxy coatings was conducted to elucidate the roles of rGO and acetylene black in enhancing corrosion protection performance. The structural and morphological were characterized by X-ray diffraction (XRD) and scanning electron microscopy (SEM), confirming the successful synthesis of the composites. Optical analysis demonstrated improving a performance in the visible spectrum, as validated by UV-Vis spectroscopy. Electrochemical measurements in under light-on and light-off conditions in 3.5 wt.% sodium chloride solution demonstrated that the ZnO/rGO-AB-Epoxy coating provided the most effective corrosion protection. When the light on, Open Circuit Potential (OCP) exhibited a rapid and stable negative shift, indicating efficient transfer of photogenerated electrons from the coating to the metal substrate. This was further supported by Electrochemical Impedance Spectroscopy (EIS), which showed a significant reduction in resistance to the transfer of charges, and Tafel polarization curves, which showed enhanced corrosion resistance. Composites with rGO and AB enhanced charge carrier separation and electrical conductivity, resulting in the highest photocurrent density among all tested samples.

Keywords: Photocathodic Protection, Corrosion, Semiconductor materials, Composite Coatings

Conversion of Soybean Meal into Nitrogen-doped Porous Carbons for Sustainable Energy Applications

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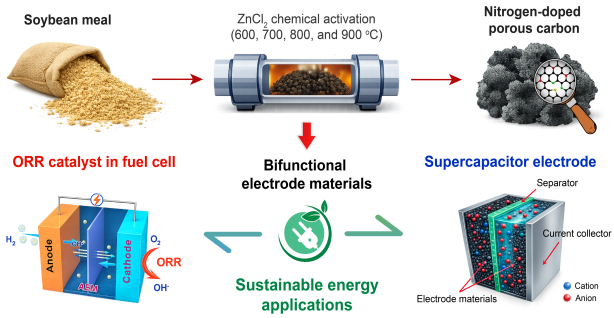
Soybean meal (SBM), an abundant agro-industrial byproduct, can be converted into functional carbon materials for sustainable energy applications. In this work, nitrogen-doped porous carbons were synthesized from SBM via ZnCl2 chemical activation at temperatures of 600–900 □C with self-nitrogen doping, followed by acid washing, as bifunctional electrodes for oxygen reduction reaction (ORR) catalysis in fuel cells and supercapacitors. Structural and morphological analyses revealed that the resulting carbons possess an amorphous framework with well-developed nanoporous structures. The specific surface area and total pore volume increased from 992 to 1,118 m2 g−1 and from 0.57 to 0.62 cm3 g−1, respectively, as the temperature increased from 600 to 800 °C due to enhanced pore development. However, further increasing the temperature to 900 □C led to a decrease in specific surface area (881 m2 g−1) and total pore volume (0.48 cm3 g−1), attributed to pore widening and partial structural collapse. The nitrogen-doping content slightly decreased from 3.31 to 2.92 atom% with increasing temperature, with nitrogen primarily present as pyridinic-N, pyrrolic-N, and graphitic-N species. Electrochemical evaluation of ORR activity and charge storage performance was conducted using a three-electrode system in 0.1 M and 6 M KOH electrolytes, respectively. The SBM-800 exhibited the best ORR performance, delivering the most positive half-wave potential and the highest current density. The ORR proceeded predominantly via a near four-electron pathway (n □ 3.4), attributed to its high surface area and abundant pyridinic-N and graphitic-N active sites. Moreover, it showed superior ORR durability compared to commercial Pt/C. In contrast, SBM-600 achieved the highest specific capacitance of 156.8 F g−1 at 1 A g−1, owing to its rich microporosity and nitrogen-induced pseudocapacitive surface redox reactions. Overall, this study demonstrates that rational tuning of pore architecture and nitrogen configuration enables the development of efficient and low-cost SBM-derived bifunctional carbon materials for energy conversion and storage.



Keywords: Soybean meal, Nitrogen-doped porous carbon, Oxygen reduction reaction, Supercapacitor, Biomass-derived carbon

Photoluminescence and scintillation properties of Ce-doped $Lu_{0.5}Gd_{0.5}AlO_3$ single crystals grown by the floating zone method, with co-host selection supported by material informatics

Tharittawat Tharasook[1], Keiichiro Miyazaki[2], Kensei Ichiba[2], Airo Fujii[2], Kundjanasith Thonglek[3], Takumi Kato[2], Daisuke Nakauchi[2], Noriaki Kawaguchi[2], Takayuki Yanagida[2], and Prom Kantuptim[1]*

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Using material informatics as a screening tool for co-host selection in the aluminate perovskite system, $Lu_xGd_{1-x}AlO_3$ was identified as a promising host material. Based on this informatics-guided selection. Undoped and Ce-doped $Lu_{0.5}Gd_{0.5}AlO_3$ (LuGdAP:Ce) single crystals were grown by the floating zone method. The coloration of the samples faded by annealing under reduction atmosphere, and the characterizations of the samples after annealing were evaluated. The characterizations included X-ray diffraction, photoluminescence (PL), and scintillation properties. In PL properties, the 0.3% Ce-doped sample exhibited a broad emission at 350 – 500 nm under 290 nm excitation, and the emission would be ascribed to 5d-4f transitions of Ce^{3+} ions. The undoped sample showed emission at 650 – 750 nm under excitation at 320 nm, and the emission would be due to charged oxygen vacancies emissions. In scintillation properties, all the Ce-doped samples showed a broad emission at 360–500 nm, which came from *5d-4f* transitions of Ce^{3+} ions. According to pulse height spectra under γ-ray irradiation from 137Cs, the scintillation light yield (*LY*) of the 0.3% Ce-doped was 1,610 ph/MeV, and the energy resolution was 54.4%. The 0.3% Ce-doped samples showed the lowest afterglow level at 20 ms after X-ray irradiation 2 ms among all the Ce-doped samples. Therefore, the optimal Ce-concentration was 0.3% in terms of the LY and afterglow.

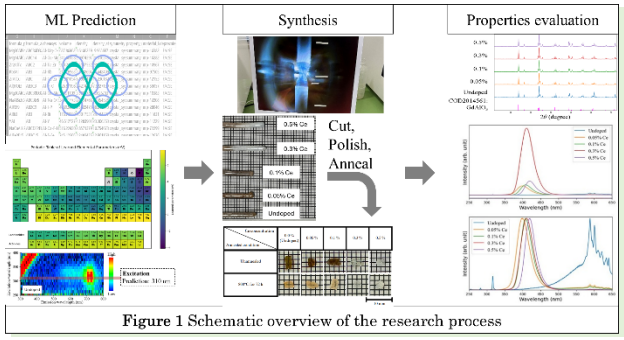

Figure 1 Schematic overview of the research process

Keywords: Scintillator, Ce^{3+}, Perovskite, Floating-zone, Material-informatic

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Bridging Science and Industry:
Smart Solutions for Real World Challenges

Alcoholysis-Based Chemical Recycling of PLA Film to Methyl and Ethyl Lactates as Green Solvents

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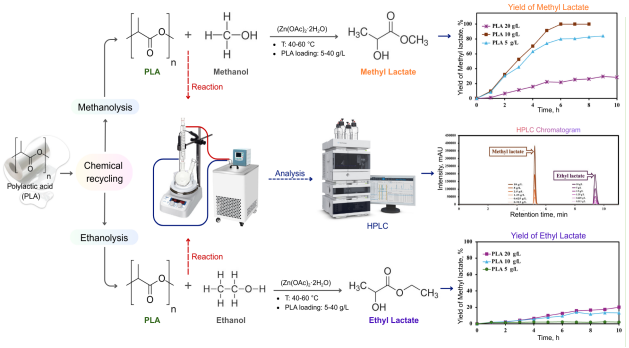

The widespread use of poly(lactic acid) (PLA) has led to a significant increase in PLA waste, while conventional mechanical recycling often suffers from material degradation and limited recyclability. Chemical recycling via alcoholysis offers an alternative route to convert PLA waste into value-added alkyl lactates as green solvents; however, a systematic study of both methanolysis and ethanolysis remains limited. Therefore, this research aims to investigate the effects of PLA loading and reaction temperature on methyl and ethyl lactate yields via methanolysis and ethanolysis, respectively, and to compare the efficiency of both approaches. The reactions are carried out in a round-bottom flask equipped with a reflux condenser using Zn(OAc)2·2H2O as a catalyst, and the products are collected over time and analyzed by HPLC. HPLC analysis shows that methyl and ethyl lactates appear at retention times of 5.23 and 9.39 min, respectively. As the PLA loading increases from 5 to 10 g/L, the yield of methyl lactate increases due to the higher number of ester linkages in PLA. However, a further increase in PLA loading to 40 g/L results in a decreased yield, which is attributed to increased viscosity, leading to limited mass transfer. As the reaction temperature increases, the methyl lactate yield increases due to enhanced reaction rates and ester bond cleavage. Under the same conditions, methanolysis provides higher product yields than ethanolysis due to the smaller molecular size and higher nucleophilicity of methanol. These results highlight the potential of alcoholysis for efficient alkyl lactate production from PLA under mild reaction conditions.

Keywords: Polylactic acid (PLA), Chemical recycling, Methyl lactate, Ethyl lactate, Green solvent

The study on properties of biobased polymer coated paper packaging for chilled and frozen application

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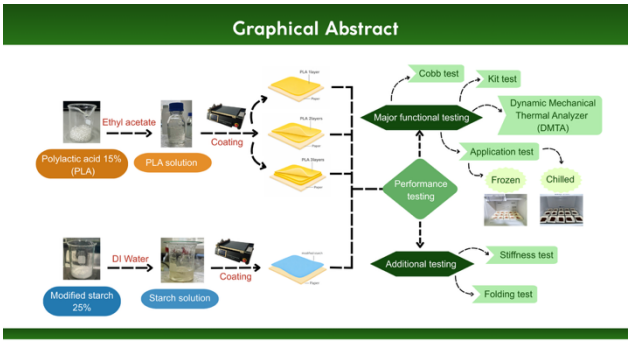
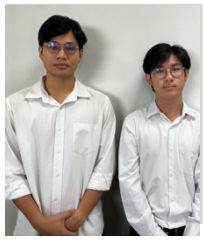


Currently, the use of biopolymer coatings for paper packaging has increased. However, applications at low temperatures may be limited by the lack of flexibility in the coating materials. This research aims to study the mechanical and dynamic mechanical properties of paperboard coated with biodegradable polymers, specifically Polylactic Acid (PLA), compared to Modified Starch (MS) for food packaging applications in chilled and frozen states. The samples were prepared by coating paperboard with 15% (w/v) PLA for 1–3 layers (coating weights of 3.87, 7.75, and 11.63 g/m²) and 25% (w/v) MS for 1 layer (coating weight of 8.25 g/m²). Physical, mechanical, and dynamic mechanical properties were tested using Dynamic Mechanical Thermal Analysis (DMTA) over the temperature range of -20 to 30°C. The results indicated that total thickness and coating weight increased with the number of coating layers. The 3-layer PLA-coated paper exhibited the highest water resistance (Cobb60 = 0.87 g/m²) and grease resistance (Kit No. 12). In contrast, the modified starch-coated paper showed poor water resistance (Cobb60 = 18.47 g/m²) and moderate grease resistance (Kit No. 9). Furthermore, PLA-coated paper demonstrated increased stiffness and folding endurance, particularly in the machine direction (MD). DMTA results revealed that at low temperatures, the PLA-coated paper exhibited slow recovery, high Loss Modulus (E"), and relatively low Storage Modulus (E'). The type of coating material and the number of layers significantly affected the dynamic mechanical properties of the coated paper samples, which may impact their performance in withstanding forces during transportation and storage.

Keywords: Paper Packaging, Biobased Polymers, Biodegradable Polymers, Chilled Food, Frozen Food



Applications Test of Paper-Based Packaging Surface Coated and Laminated with Biodegradable Biopolymers

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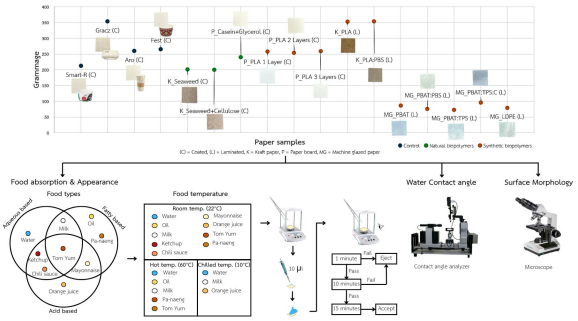

Research and development of paper packaging coated with biodegradable polymers are continuously increasing. This study aims to evaluate the performance of previously developed biodegradable polymer-coated paper packaging for food applications. The study investigated samples of paperboard, kraft paper, and machine-glazed (MG) paper coated or laminated with (1) natural polymers, such as seaweed solutions, cellulose, and casein; and (2) synthetic biodegradable polymers: such as PLA (polylactic acid) solutions, Oriented PLA films, PLA/PBS (polybutylene succinate) films, PBAT (poly(butylene adipate-co-terephthalate)) films, PBAT/PBS films, PBAT/TPS (thermoplastic starch) films, and PBAT/TPS/Clay films. The results were compared against commercial paper packaging. Testing was conducted by applying real food stimulants—including high-moisture, high-fat, and acidic foods such as water, oil, milk, orange juice, Tom Yum soup, ketchup, chili sauce, mayonnaise, and Panaeng curry—onto the coated or laminated surface. Food absorption and visual appearance were evaluated at 1, 10, and 15 minutes. Food temperatures were controlled at chilled (10±2 °C), room temperature (22±2 °C), and warm (60±2 °C) levels. The results showed that most food types were absorbed at room and warm temperatures. PLA-solution-coated paperboard and Oriented PLA-laminated kraft paper exhibited lower food absorption, similar to commercial packaging. Conversely, kraft paper coated with seaweed, cellulose, or casein, as well as MG paper laminated with PBAT, PBAT/PBS, PBAT/TPS, or PBAT/TPS/Clay, showed relatively high absorption. Consequently, these samples may not yet be suitable for liquid products. This testing methodology can be further developed using more aggressive or diverse food simulants over longer durations to better reflect real-world usage.

Keywords: Application Test, Paper Packaging, Coating, Lamination, Biodegradable Biopolymer

Assessment of Degradation, Microplastics Release, and Overall Migration from Polypropylene Food Containers under Repeated Use and Microwave Heating

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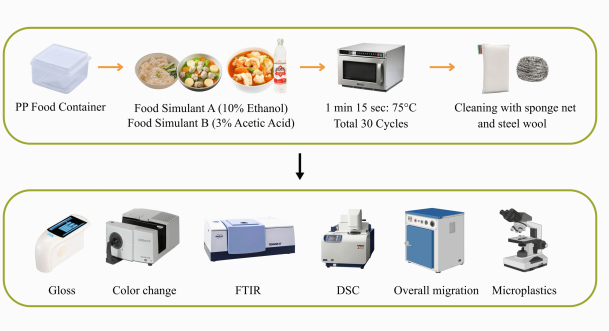
Migration and microplastics release from polypropylene (PP) food packaging during repeated use is a critical food safety concern, particularly when containers are exposed to microwave heating and repeated cleaning cycles. Elevated temperature conditions and mechanical abrasion during washing act as catalysts for polymer degradation, resulting in physicochemical alterations that lead to increased migration and the release of microplastics. Under Commission Regulation (EU) No. 10/2011, the Overall Migration (OM) limit is set at 10 mg/dm². This study evaluated the effects of simulated repeated use and cleaning severity on the physical properties, chemical structure, thermal characteristics, overall migration, and microplastics release of PP containers. Samples were tested after 0, 15, and 30 cycles using Food Simulant A (10% ethanol) and Food Simulant B (3% acetic acid). Each cycle involved microwave heating at 850 W for 1 minute and 15 seconds (approximately 75°C), followed by cleaning with either a sponge pad or steel wool to simulate under realistic use conditions. The Analysis included gloss, color change (ΔE*), FTIR, DSC, overall migration, and microplastics. The results show that increasing usage cycles and harsher cleaning significantly reduced gloss and increased color variation, indicating surface degradation. Microplastic release increased with repeated heating and more severe cleaning. Overall migration values ranged from 1.17 to 7.22 mg/dm², remaining below the regulatory limit. In conclusion, repeated heating and abrasive cleaning contribute to physicochemical degradation and influence migration behavior and microplastic release. Evaluating materials under realistic use conditions is essential to ensure packaging safety and guide recommendations on reusability.



Keywords: Erosion, Food simulants, Health Risk, Structural change, Container quality

Effect of Agar and Residue from *Gracilaria fisheri* on Properties of PBAT/TPS Blown Film

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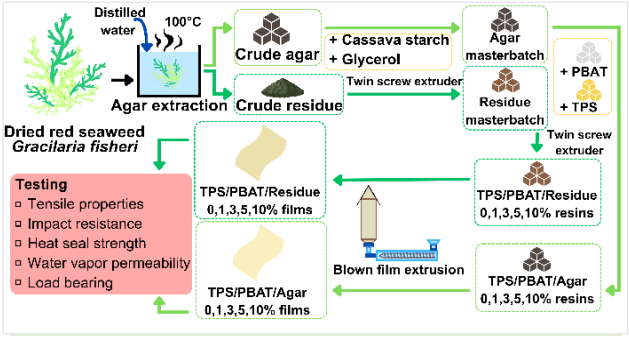

The present study investigates the effects of agar and residue derived from red seaweed *Gracilaria fisheri* on the characteristics and properties of polybutylene adipate-co-terephthalate/thermoplastic starch (PBAT/TPS) blown films. PBAT/TPS films containing agar and residue at loadings of 1%, 3%, 5%, and 10% were fabricated via blown-film extrusion. The incorporation of agar and residue increased the yellowness and opacity of the films; both parameters rose progressively as the filler content increased. Films containing residue exhibited greater yellowness and opacity than those containing agar. The incorporation of agar resulted in a reduced tensile strength and impact strength of the films. Among the agar-filled samples, the film containing 1% agar showed the highest tensile strength (6.4 MPa) and elongation at break (604.6%), whereas the film with 5% agar exhibited the highest Young's modulus (60.9 MPa). On the one hand, films containing residue showed decreased tensile strength, Young's modulus, and impact strength, particularly at high loading. The film with 1% residue displayed the highest elongation at break (559.1%) among the residue-filled samples. Water vapor permeability of the film increased by 1.3-178.8% by incorporating residue, suggesting potential packaging use for fresh produce with high respiration rates. Incorporating agar and residue hardly affected the heat-sealing ability of the film. Based on their balanced mechanical properties and adequate seal strength, PBAT/TPS films containing 1% agar, 5% agar, and 1% residue were selected for the fabrication of bottom-sealed bags. These bags were capable of supporting loads of at least 4 kg, demonstrating their potential applications as carrier/shopping bags.

Keywords: Polybutylene Adipate-co-Terephthalate, Thermoplastic Starch, Gracilaria fisheri, Agar, Blown film extrusion

Failure Analysis of Spray Can after Hydrostatic Test

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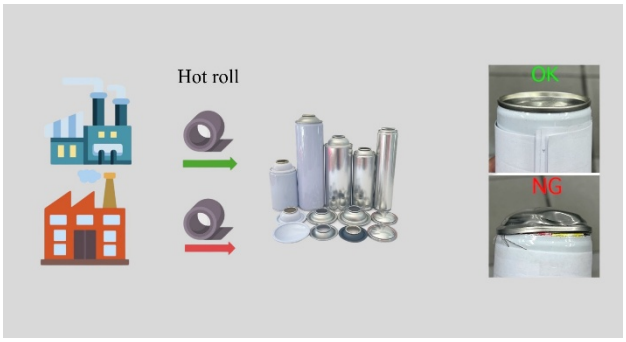

This research aims to investigate and analyze the causes of damage in the bottom components of insecticide spray cans manufactured from interstitial free (IF) steel after hydrostatic pressure testing. It was found that spray can bottoms produced from certain production batches exhibited permanent deformation after testing, whereas those fromother batches successfully passed the test, although all IF steels belonged to the same grade but were supplied from different sources. In this study, IF steels prior to forming from defective and non-defective batches were compared. The analysis focused on chemical composition, microstructure, grain size, and mechanical properties, including tensile strength, elongation, plastic deformation ability (n-value), and hardness. The results indicate that slight variations in chemical composition and microstructure significantly affect the mechanical properties of IF steel, particularly elongation and n-value. These properties play a crucial role in the stability of plastic deformation and the pressure resistance of spray can bottom. The findings of this study provide useful guidelines for raw material quality control and process improvement in the spray can manufacturing industry.

Keywords: IF steel; Hydrostatic Test; Tensile; Strain hardening exponent(n-value); Hardness

Effects of tempering on microstructure and hardness of solution-nitriding AISI H13 tool steels

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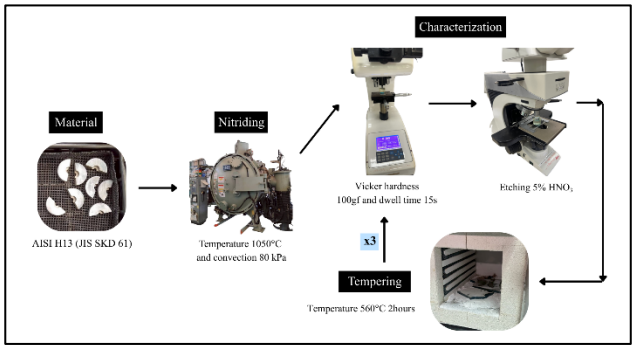
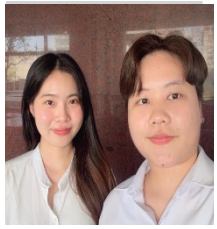
Nitriding process is a crucial process for improving surface hardness and wear resistance, but it is a lengthy process due to the slow diffusion of nitrogen. This research studies the influence of high-temperature nitriding to accelerate the nitrogen diffusion mechanism on the microstructure and hardening of AISI H13 hot-work tool steel (JIS SKD 61) that is general used in hot work tool, die casting and forging mold in Thailand. Experiment by Nitriding at 1050°C, Nitrogen pressure 80 KPa on the austenite phase before quenching resulted in a martensite structure with residual austenite and uniformly distributed spherical carbides, exhibiting a diffusion layer. Then tempering at 560°C three times resulted in a fully martensite structure, with the diffusion layer still present, but not achieving the same level of hardness as with conventional nitriding.



Keywords: AISI H13 tool steel, JIS SKD 61, Solution nitriding, Nitriding



Effects of Tempering on Microstructure and Hardness of Solution-Nitrided AISI 304 Steel

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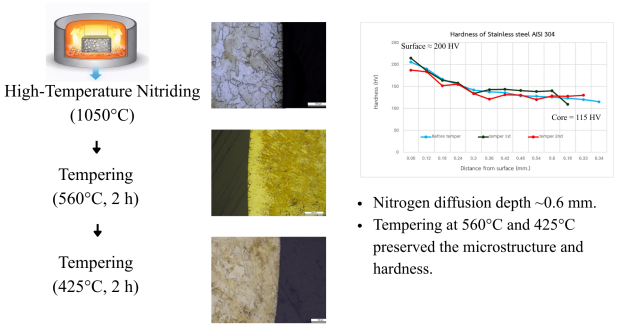
AISI 304 stainless steel is widely employed in manufacturing applications owing to its superior corrosion resistance and favorable mechanical properties. However, under prolonged continuous loading or frictional conditions, surface degradation may occur, leading to a reduction in service life. Therefore, surface modification prior to service is essential. This study investigates the effect of nitriding on the surface properties of AISI 304 stainless steel. The specimens were nitrided at 1050 °C for 1 hour to enhance surface hardness, followed by tempering at 560 °C and 425 °C for stress relief. Microstructural characterization was carried out using optical microscopy, and hardness was evaluated using the Vickers microhardness method. The results indicated that no clearly defined nitride layer was observed. The surface hardness reached approximately 187 HV with a diffusion depth of about 0.6 mm, while the average core hardness remained around 115 HV. Furthermore, no significant microstructural changes were detected after surface modification compared with the as-received condition.



Keywords: Surface treatment; Solution nitriding; Tempering; Stainless Steel AISI 304

Effect of Reheat Treatment on Microstructural Restoration in Modified Nickel Base Superalloys with Ru & Co Addition

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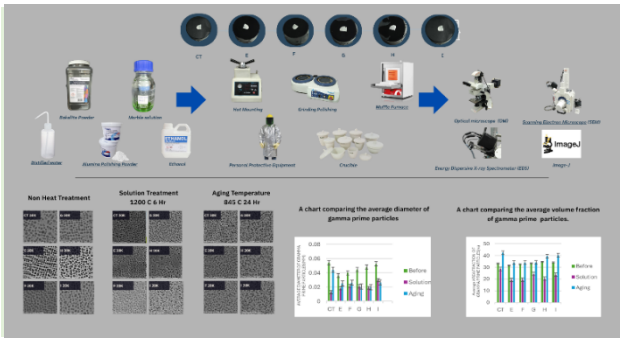
This study investigated the effects of heat treatment processes on the microstructural restoration of a nickel-based superalloy containing varying amounts of ruthenium and cobalt. The evolution of gamma prime precipitates, including their morphology, size, and area fraction, was examined in the as-received condition, after solution treatment, aging treatment, and under simulated high-temperature service exposure. The results showed that both ruthenium and cobalt significantly influenced the alloy microstructure. The addition of ruthenium controlled the morphology of gamma prime precipitates and suppressed their growth and coarsening, resulting in improved microstructural stability. In contrast, increasing cobalt content led to larger precipitate size and a higher area fraction. After solution treatment, the size and area fraction of gamma prime precipitates decreased in all specimens due to dissolution into the matrix. Aging treatment promoted uniform reprecipitation. Under simulated high-temperature service conditions, alloys containing ruthenium exhibited superior microstructural stability compared with alloys without ruthenium. Overall, ruthenium played a key role in enhancing stability and delaying degradation, whereas cobalt primarily increased precipitate size and fraction. These findings provide insight into the design and optimization of restoration heat treatment strategies for nickel-based superalloy components used in high-temperature applications.



Keywords: Nickel-based superalloy, Ruthenium, Cobalt, Gamma prime precipitates, Heat treatment

Effect of Reheat Treatment on Microstructural Restoration in Modified Nickel Base Superalloys with Re & Ru Addition

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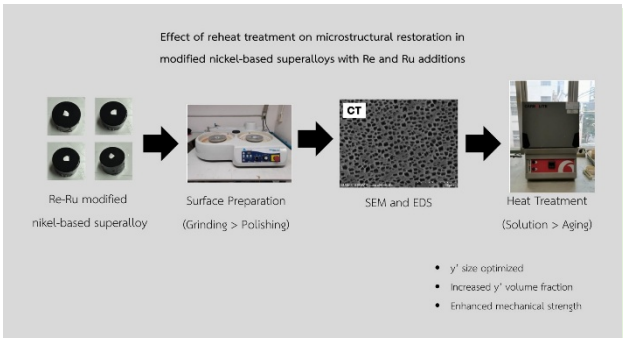
This research investigated the improvement of microstructural characteristics and properties of a nickel-based superalloy containing different additions of rhenium and ruthenium through heat treatment for microstructural restoration. The study focused on comparing the size of γ′ (gamma prime) precipitates in these alloys. The specimens were solution treated at 1200 °C for 6 hours followed by air cooling, subsequently subjected to precipitation hardening at 845 °C for 24 h with air cooling, and finally exposed to long-term ageing at 950 °C for 100 h. Microstructural characterization was performed using scanning electron microscopy (SEM) to examine the morphology, size, and area fraction of γ′ precipitates. The results revealed that variations in rhenium and ruthenium content had a significant influence on the microstructure of the nickel-based superalloys. Increasing the rhenium content retarded atomic diffusion within the matrix, resulting in a reduced γ′ precipitate growth rate and suppression of topologically close-packed (TCP) phase formation. Consequently, finer γ′ precipitates with a more uniform distribution were obtained. In contrast, the addition of ruthenium enhanced the stability of the γ′ phase and suppressed the formation of undesirable phases, leading to reductions in both γ′ precipitate size and area fraction.



Keywords: Nickel-based superalloys, Gamma prime particles, Area fraction

Surface Modification of Non-woven Poly(lactic acid) Fabric fromMelt-blown Technique for Agricultural Applications

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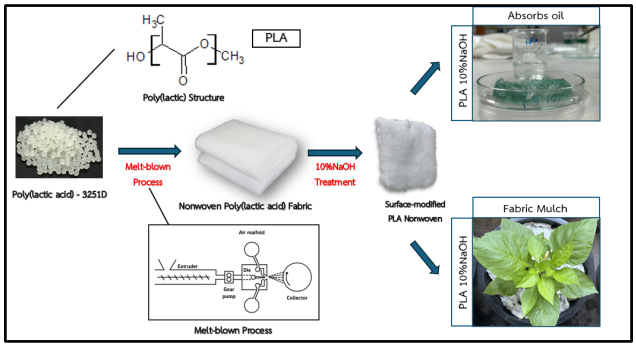

The accumulation of microplastics in soil and aquatic environments has become a major global concern due to their persistence and potential impacts on ecosystems and human health. In agriculture, extensive use of petroleum-based plastic mulching films contributes significantly to microplastic contamination, as these materials gradually degrade into small particles that remain in soil and may enter surrounding water systems. This highlights the urgent need for biodegradable and sustainable alternatives for agricultural applications. In addition, oil spills in aquatic environments continue to threaten water quality, marine organisms, and coastal ecosystems, emphasizing the importance of environmentally friendly materials with multifunctional capabilities. Poly(lactic acid) (PLA), a biodegradable polymer derived from renewable resources, has emerged as a promising alternative to conventional petroleum-based polymers due to its biodegradability and favorable processing properties.

This study investigates the surface modification of PLA non-woven fabric via alkaline treatment to improve its structural and functional properties for environmental and agricultural applications. The treatment aimed to increase surface roughness and reduce fiber diameter, enhancing pore structure within the non-woven matrix. Material characterization was conducted using scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FTIR), contact angle measurements, differential scanning calorimetry (DSC), accelerated QUV weathering, mechanical testing, and gel permeation chromatography (GPC). Results revealed reduced fiber size and increased hydrophobicity, leading to improved oil absorption efficiency and soil moisture retention. The modified PLA non-woven fabric demonstrates strong potential as a biodegradable agricultural mulching material and an eco-friendly alternative for sustainable environmental applications.

Keywords: Poly(lactic acid) (PLA), Non-woven fabric, Melt blown process, Oil absorption, Biodegradable mulching

Development of Bi-Sn-Sb Alloy for Well Plug and Abandonment

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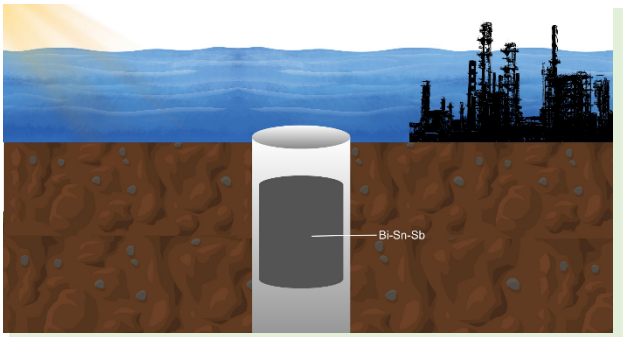

Near-eutectic bismuth–tin (Bi–Sn) alloys have been extensively investigated as well-plugging materials due to their low melting temperature, solidification-induced expansion, and favorable gas-sealing ca-pability. However, the application of Bi–Sn alloys is subject to several limitations, particularly under elevated temperature conditions. Previous studies have shown that increasing the solidification tem-perature leads to microstructural coarsening and the formation of primary tin (primary Sn) phases, re-sulting in a degradation of mechanical properties and overall material stability. To overcome these lim-itations, this study proposes a modified Bi–Sn alloy system through the addition of antimony (Sb). An-timony acts as a strengthening element in the solid solution and promotes a more refined and homoge-neous microstructure, while preserving the beneficial solidification expansion characteristic of bis-muth-based alloys. In this work, six Bi–Sn–Sb alloy compositions—45Bi–47Sn–8Sb, 47Bi–47Sn–6Sb, 50Bi–42Sn–8Sb, 52Bi–42Sn 6Sb, 55Bi–37Sn–8Sb, and 57Bi–37Sn–6Sb—were investigated to evaluate the effects of alloy composition on microstructural evolution and mechanical properties. Alloy samples were prepared by a melting and casting process using silicone molds. The chemical compositions were verified using X-ray fluorescence (XRF). Mechanical properties and thermal behavior were evaluated through tensile and compression testing, as well as differential scanning calorimetry (DSC). Micro-structural characterization was performed using optical microscopy (OM), scanning electron microsco-py (SEM), and energy-dispersive X-ray spectroscopy (EDS). The results of this study aim to provide insight into the role of antimony in modifying the microstructure and mechanical performance of Bi–Sn-based alloys and to support the development of improved bismuth-based materials for well-plugging application.

Keywords: Bismuth-Tin-Antimony alloy, Plug and abandonment, Mechanical properties

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Modelling and Prototyping, Emerging Technology & Applications

Bridging Science and Industry:
Smart Solutions for Real World Challenges

Sunscreen Packaging Design Integrated with Augmented Reality (AR) Technology to Promote Purchasing Decision of Generation Z Consumer

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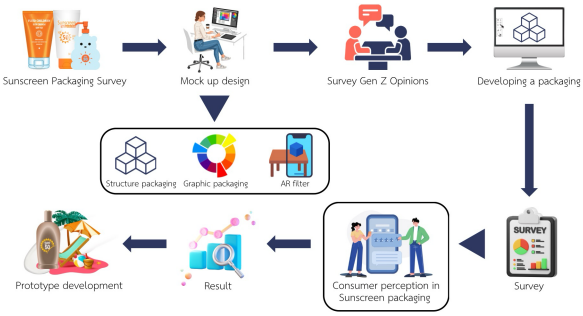
Graphical Abstract



In the cosmetic industry, packaging functions not only as a means of protecting and containing products but also as a crucial tool for information communication, brand image building, and influencing consumer purchasing decisions. However, most sunscreen packaging still relies on conventional communication through labels and graphic elements, which limits in-depth information delivery and interactive engagement. This limitation is particularly significant among Generation Z consumers, who value experiential interaction and digital engagement. Consequently, this study aims to design and develop sunscreen packaging integrated with Augmented Reality (AR) technology to promote purchasing decisions among Generation Z consumers. A design-based research approach was employed, beginning with a literature review to identify key factors related to packaging design, consumer behavior, and AR applications. A packaging prototype integrated with an AR interface was then developed to provide interactive product information and multimedia content. The prototype was evaluated through a questionnaire survey with 135 Generation Z consumers aged 18–27 in the Bangkok metropolitan area. Data were analyzed using descriptive statistics to assess perceived value, engagement level, and purchase intention. Preliminary findings indicate that integrating AR technology enhances packaging communication capability, increases consumer interest, and strengthens engagement. The results suggest that incorporating digital technology into packaging design can add value and positively influence purchasing intention among Generation Z consumers.

Keywords: Packaging Design, Sunscreen Packaging, Augmented Reality (AR), Purchasing Decision, Generation Z Consumers

Development of Packaging for Generation Alpha Incorporating Game-Based Augmented Reality Technology to Enhance Learning

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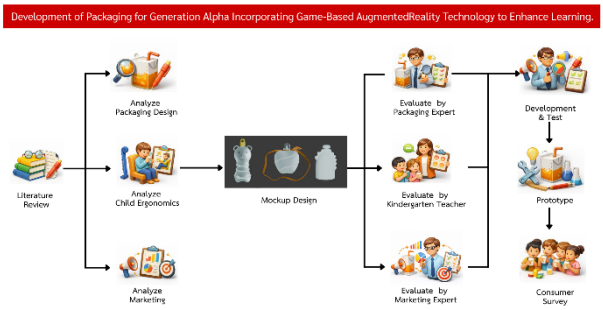
[*]corresponding author: janenutch.s@ku.ac.th



Children in Generation Alpha grow up in a digital environment where interactive media strongly influence learning behavior. Traditional packaging for children's beverages often lacks ergonomic suitability and interactive learning support. This study aimed to develop and evaluate fruit juice packaging for Generation Alpha that integrates ergonomic structural design with game-based Augmented Reality (AR) to enhance usability and learning experience. A design-based research approach was employed. Literature on ergonomic packaging, marketing principles, and AR technology was reviewed. Packaging structures were designed based on children's hand ergonomics and developed into physical prototypes. Graphic and logo elements were created to enhance visual communication. An AR game prototype was developed to promote fruit vocabulary learning. The prototypes were evaluated by packaging and marketing experts and later prepared for testing with children and parents. Findings indicated that curved ergonomic forms improved grip stability and reduced spillage compared with angular designs. However, manufacturing constraints affected formability and dimensional accuracy, requiring iterative redesign to ensure practical production feasibility. The integrated packaging and AR concept demonstrated strong potential to increase engagement, usability, and parental interest. The study confirms that combining ergonomic packaging design with interactive AR learning can enhance children's user experience and educational engagement, while highlighting the importance of aligning conceptual design with real-world manufacturing constraints.

Keywords: Game-Based Learning, Augmented Reality, Generation Alpha

Adjustable-Size Packaging Box for Electronic Products

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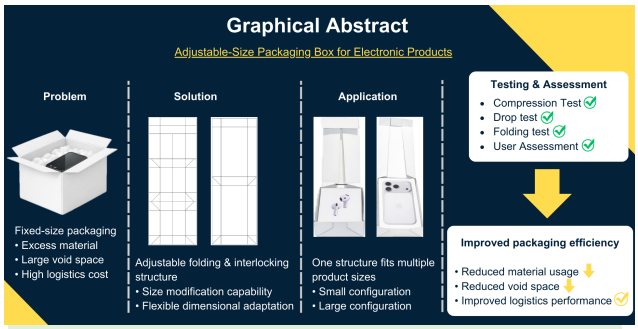

The rapid growth of the electronics industry has led to increasing product variety in terms of size, shape, and design, resulting in significant challenges in packaging management. Conventional fixed-size packaging boxes often fail to accommodate diverse product dimensions efficiently, causing excessive material usage, increased void space, higher logistics costs, and unnecessary environmental impact. Therefore, the development of flexible and adaptive packaging solutions has become essential to improve packaging efficiency and sustainability.This research aims to design and develop an adjustable-size corrugated packaging box for electronic products. The objectives are to enhance structural adaptability, reduce material consumption, and maintain sufficient mechanical strength during handling and transportation. The study begins with an analysis of user requirements and packaging constraints through questionnaires and a comprehensive review of related literature. Based on the collected data, a novel structural design incorporating multiple folding lines and integrated locking mechanisms is proposed. The prototype packaging box is then fabricated and evaluated through mechanical performance tests, including compression strength, folding endurance, dimensional stability, and drop impact resistance. Furthermore, material usage and production cost are compared with those of conventional fixed-size packaging boxes.The expected outcomes of this research include the development of an innovative packaging solution that effectively adapts to various product sizes, reduces material waste, optimizes storage and transportation efficiency, and supports sustainable packaging practices. The findings are anticipated to provide practical design guidelines for the electronics packaging industry and contribute to environmentally responsible packaging development.

Keywords: Adjustable packaging, Structural design, Electronic products, Packaging efficiency, Sustainable development

Chemical Solubility Properties of Glass Ceramics Using as Dental Restorative Materials

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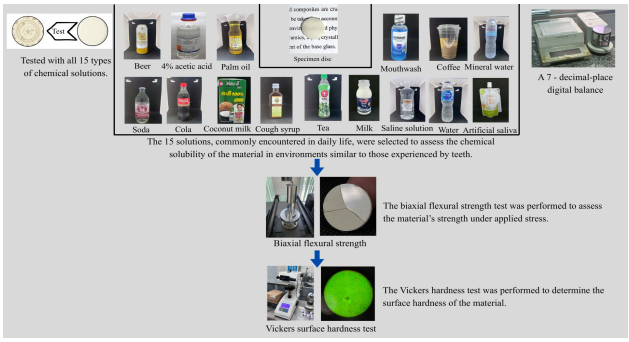
Glass-ceramics have been widely investigated for restorative dentistry due to their favorable mechanical performance and esthetic similarity to natural teeth. This study aimed to develop glass-ceramics with suitable mechanical, physical, and chemical properties for intraoral applications, with particular emphasis on chemical durability under simulated oral conditions. The materials were designed with fine crystalline phases uniformly distributed within a glassy matrix to enhance strength and durability. Chemical solubility was evaluated by immersion in 4% acetic acid (the standard test solution according to ISO 6872:2015), beer, cola, coffee, tea, artificial saliva and water, together with other food- and beverage-related solutions (a tota l of 15 solutions), to simulate the oral environment. Mechanical performance was assessed using biaxial flexural strength and Vickers hardness tests. The developed glass-ceramics exhibited excellent chemical resistance, The highest solubility was observed in beer (pH 4.08), reaching 89.47 µg/cm², while the in the 4% acetic acid (pH 2.80) resulted in 79.13 µg/ cm2. In contrast, neutral conditions such as distilled water (pH 7.15) showed minimal solubility of 1.40 µg/ cm2. Importantly, all measured solubility values presented below 100 µg/cm2, confirming strong chemical durability to reach requirements under simulated oral conditions. The average biaxial flexural strength was 302 MPa, indicating high structural reliability under loading. The Vickers hardness (5.24 GPa) exceeded that of human enamel (2.65-3.53 GPa), demonstrating strong load-bearing capability. Furthermore, the obtained properties reached the requirements of class 3a ISO 6872:2015 for dental ceramic materials. In conclusion, the developed glass-ceramics demonstrated high chemical durability and mechanical performance being strong potential for clinical application as restorative dental materials.



Keywords: Glass-ceramics, Yttria-stabilized zirconia, Chemical solubility, Restorative dental material, ISO 6872:2015

Geopolymer Mortar from Metakaolin, Fly ash and Tempered glass waste

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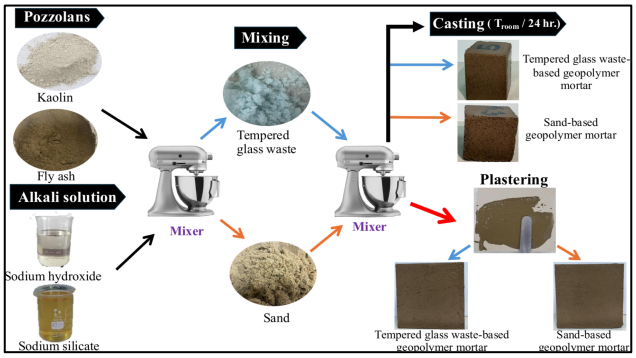
Tempered glass waste is a by-product of the automotive industry which its volume has continuously increased but effective reuse approaches are limited. This research focused on investigating the use of tempered glass waste as a fine aggregate in geopolymer mortar, with metakaolin and fly ash as aluminosilicate pozzolans to develop an alternative construction material with suitable mechanical and physical properties. The geopolymer mortar was synthesized using an alkali activator composed of sodium hydroxide and sodium silicate. The flowability, compressive strength at curing ages of 3, 7, and 28 days, integrity of geopolymerization, bulk density, apparent porosity, and water absorption were evaluated. In addition, the chemical composition and microstructure of the materials were analyzed using X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), and scanning electron microscopy (SEM). The results indicated that geopolymer mortars with tempered glass waste as a fine aggregate exhibited higher compressive strength than those with sand. This improvement was attributed to the angular morphology of the glass particles, to enhance mechanical interlocking and denser microstructure. The chemical stability test revealed no changes in color of water or sedimentation to indicate a complete geopolymerization reaction. The findings demonstrated that tempered glass waste could be effectively utilized as a fine aggregate in geopolymer mortar and showed strong potential for application as a sustainable construction material.



Keywords: Metakaolin, Tempered glass waste, Sand, Geopolymer mortar, Construction material

Optical and Chemical Properties of Glass-Ceramics for Restorative Dental Materials According to ISO 6872:2015

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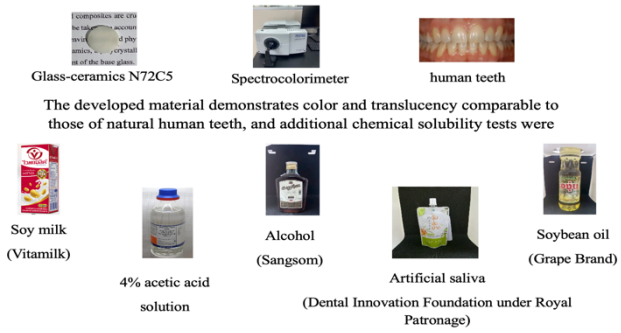
Glass-ceramics have continuously attracted attention as restorative dental materials due to their optical properties which are essential for both functional performance and aesthetic appearance. This study investigated the influence of chemical composition on the optical properties of mica-based glass-ceramics and their chemical solubility to evaluate their suitability for use as dental restorative materials under conditions simulating the oral environment. The glass-ceramics were prepared through a glass-melting process combined with controlled nucleation and crystallization treatments to develop an appropriate microstructure for dental applications. The optical properties of the materials were evaluated in terms of lightness, colour shade and translucency. The Translucency Parameter (TP) was used to indicate a material ability to allow light to pass through. A lower TP value indicates that the material is more opaque or less translucent, while a higher TP value indicates higher translucency. The Contrast Ratio (CR) is also used to describe opacity; a lower CR value indicates greater transparency, whereas a higher CR value indicates higher opacity. Colour measurements were performed using a spectrophotometer based on the CIE Lab system, where L* represents lightness (ranging from 0–100), a* indicates red (+) to green (−), and b* indicates yellow (+) to blue (−). The developed glass-ceramic exhibited L* = 88.25 ± 0.80, a* = −3.18 ± 0.35, and b* = 10.63 ± 0.12, indicating high lightness with a moderate yellowness, which are within the range of natural human enamel. The ceramic base specimen showed a TP value of 16.33 and a CR value of 0.68, which are close to those of natural human teeth (TP = 16.4 and CR = 0.65). In addition, the chemical solubility of the glass-ceramics was assessed using 5 common solutions. In a 4% acetic acid solution, the highest solubility value was 79.13µg/cm², soybean oil and soy milk had values in the range of 14.35 and 14.99 µg/cm², alcohol showed a solubility value of 45.52 µg/cm², whereas artificial saliva exhibited the lowest value at 1.43 µg/cm². These solutions were selected to simulate actual oral service conditions. The results showed that the developed glass-ceramics exhibited a uniformly distributed crystalline structure, resulting in suitable optical properties that closely resemble to those of natural teeth. At the same time, the materials demonstrated low chemical solubility, indicating good chemical stability and durability under everyday environmental conditions. These findings confirmed that the developed glass-ceramics complied with the requirements of ISO 6872:2015 and strong potential for application as dental restorative materials offering both aesthetic quality and long-term durability.



Keywords: Glass-ceramics, Optical properties, Chemical solubility, Restorative dental materials, ISO 6872:2015

The Analysis of "Royal System" Wall Unit and the Design/Analysis of Novel Wall Unit Designs

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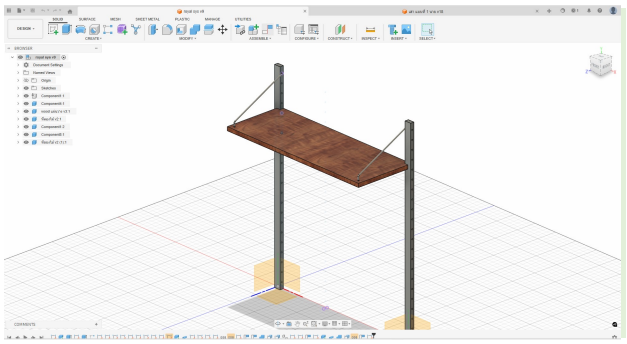

Current shelving furniture designs are diverse in both aesthetics and functionality. However, traditional designs relied heavily on craftsmanship without deep consideration of engineering principles or material strength. This research focuses on studying the "Royal System," an innovative wall-mounted shelving unit designed by Poul Cadovius. The objective is to analyze the mechanical behavior and structural integrity of the original system and apply this knowledge to design novel wall unit structures. This study employs Autodesk Fusion 360 for 3D modeling and ANSYS software for Finite Element Method (FEM) analysis. Static structural analysis is conducted to evaluate Equivalent Stress and Total Deformation under compressive and tensile loads. The results demonstrate the load-bearing capacity and critical points of the structures, verifying the engineering safety of the new designs.

Keywords: Limited 5 Keywords, Keyword1, Keyword2, Keyword3, Keyword4

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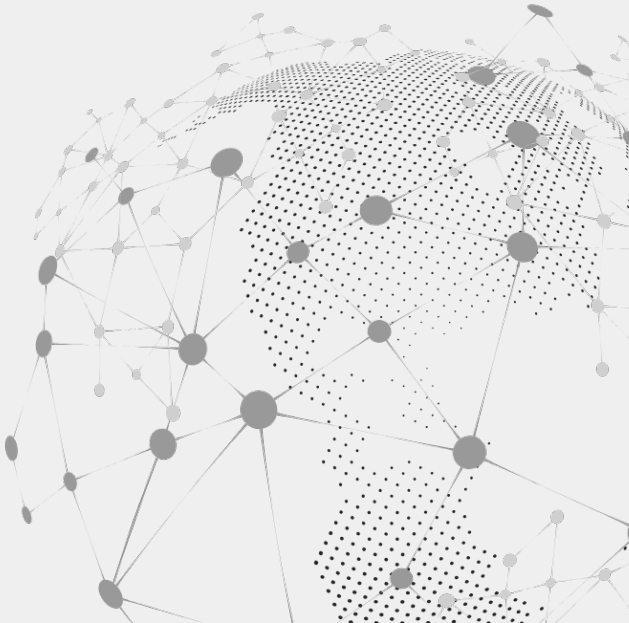

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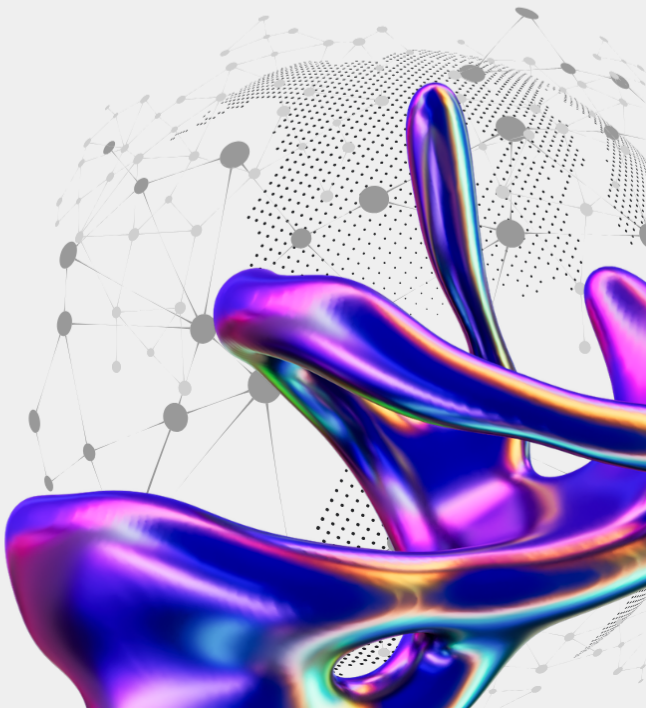

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