Delamination Techniques for Sustainable Packaging: A Focus on Multilayer Aluminum-Based Food Packaging

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Introduction. The sustainable management of packaging materials has become a paramount concern in today's environmentally conscious world. Multilayer aluminum-based food packaging has emerged as a popular choice for preserving food freshness and extending shelf life among the myriad packaging options. However, the complex multilayered composition of these materials poses a formidable challenge to recycling efforts. Their recyclability is limited by the intimate bonding between the layers, making the efficient separation of individual components a task of paramount importance.

In response to this challenge, delamination techniques have garnered increasing attention within the field of sustainable packaging waste recycling options. Delamination strategies aim to disassemble multilayer materials into their constituent layers, thereby rendering them more amenable to recycling processes. By focusing on multilayer aluminum-based food packaging, this study endeavors to explore and evaluate delamination techniques that can facilitate the separation of layers, ultimately contributing to a more sustainable and ecologically responsible approach to packaging waste recycling.

The objective of this research is to investigate the effectiveness of various delamination techniques in the context of multilayer aluminum-based food packaging. Delving into the complexities of these materials, we seek to elucidate their structural properties, assess the feasibility of separation, and, in doing so, provide valuable insights into the advancement of sustainable packaging practices.

Within this study, we address the critical question of effectively dismantling the multilayered structure of aluminum-based food packaging, which typically comprises layers of aluminum, polymers, and other materials. The key challenges encompass minimizing waste and reducing the environmental footprint associated with packaging materials. Delamination techniques offer a promising solution, and this research aims to contribute to the growing body of knowledge on this subject, potentially unlocking new avenues for recycling and improving the overall sustainability of packaging practices.

By gaining a deeper understanding of the delamination techniques applied to multilayer aluminum-based food packaging, this study aspires to pave the way for more eco-friendly packaging waste recycling solutions and, in doing so, align with broader efforts to reduce waste and promote a more sustainable, circular economy.

Methodology. The delamination process was conducted within a laboratory-scale reactor comprising key components, including an ultrasonic bath, flask, and overhead stirrer. The multilayer aluminum-based food packaging samples were subjected to a series of experiments utilizing three distinct delamination solutions. These solutions consisted of nitric acid, lactic acid, and a combination of lactic acid and choline chloride.

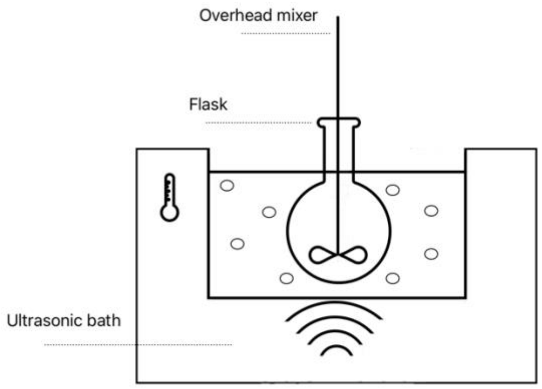

Fig. 1 A laboratory-scale reactor was utilized in the study.

1. Overhead Stirrer: The overhead stirrer was utilized to maintain consistent agitation within the flask, ensuring uniform exposure of the materials to the delamination solutions.

2. Flask: The flask served as a containment vessel for the packaging samples and the delamination solutions. It provided a controlled environment for the reactions to occur.
3. Ultrasonic Bath: The ultrasonic bath was employed to apply mechanical vibrations to the packaging materials, facilitating the initiation of delamination by disrupting the bonds between layers.

The experiments were meticulously designed, and the conditions for each solution were optimized to achieve effective layer separation. The results of these experiments hold promise for advancing the recycling capabilities of multilayer aluminum-based food packaging and, in turn, promoting sustainable practices within the food packaging industry.

Results. All experimentation aimed at the dissection of multilayer packaging films yielded results of varying degrees of success. A comprehensive investigation into the effectiveness of diverse chemical agents for the purpose of layer separation was undertaken.

The application of nitric acid, while indeed resulting in the successful disintegration of the multiple packaging layers, encountered an inherent predicament. This complication manifested in the concurrent dissolution of aluminum components, commingled with the adhesive materials and printing dyes contained within the multilayer packaging structure.

Upon closer scrutiny, it was observed that the utilization of lactic acid, either pure or in conjunction with choline chloride, demonstrated a pronounced capability in disassembling the aluminum component from the multilayer packaging, thereby mitigating the issue faced with nitric acid. However, it was discerned that the polymer layers, integral to the packaging structure, remained interconnected, and the printing layer remained remarkably intact throughout this process.

In the aftermath of dissection using lactic acid, an intriguing observation was made. The polymers proved resistant to facile purification, primarily due to a residual oleaginous residue left by the lactic acid. This saturated trace proved to be exceptionally obstinate, rendering the polymers challenging to cleanse thoroughly. This quandary persisted even when a mixture of lactic acid and choline chloride was employed. The tenacity of the saturated residue was notably recalcitrant to remediation in either scenario.

In juxtaposition, using nitric acid, while endowing the resultant materials with a similar saturated impression, provided a modicum of advantage in terms of purification. The relatively greater solubility of nitric acid in water enabled a more expedient removal process, thereby rendering it comparatively more amenable to practical separation procedures.

Conclusion. In summary, this study explored delamination options for multilayer aluminum-based food packaging to enhance its recyclability. Three delamination solutions were employed: nitric acid, lactic acid, and a lactic acid and choline chloride combination. Results indicated that nitric acid effectively separated layers but caused aluminum dissolution issues. Lactic acid, alone or with choline chloride, showed promise in disassembling aluminum components. However, the polymer layers remained interconnected, and a stubborn saturated residue presented purification challenges. Nitric acid, despite a saturated residue, offered more efficient purification due to its higher water solubility. These findings emphasize the complexity of delaminating such materials and the need for further research to develop effective recycling methods while addressing residue challenges, contributing to sustainable packaging practices.

References.

Šleiniute, A.; Denafas, G.; Mumladze, T. Analysis of the Delamination Process with Nitric Acid in Multilayer Composite Food Packaging. Appl. Sci. 2023, 13, 5669. https://doi.org/10.3390/app13095669

Mumladze, T., Yousef, S., Tatariants, M., Kriūkienė, R., Makarevicius, V., Lukošiūtė, S.-I., Denafas, G. (2018). *Sustainable approach to recycling of multilayer flexible packaging using switchable hydrophilicity solvents. Green Chemistry, 20(15), 3604–3618.* doi:10.1039/c8gc01062e

Yousef, S., Mumladze, T., Tatariants, M., Kriūkienė, R., Makarevicius, V., Bendikiene, R., & Denafas, G. (2018). *Cleaner and profitable industrial technology for full recovery of metallic and non-metallic fraction of waste pharmaceutical blisters using switchable hydrophilicity solvents. Journal of Cleaner Production, 197, 379–392.* doi:10.1016/j.jclepro.2018.06.

Nieminen, J., Anugwom, I., Kallioinen, M., & Mänttäri, M. (2020). *Green solvents in recovery of aluminium and plastic from waste pharmaceutical blister packaging. Waste Management, 107, 20–27.* doi:10.1016/j.wasman.2020.03.014