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Mini Review

Food Preservation Strategies: Use of Multilayer Films in Grain and Nuts Storage

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Abbreviations:

PE: Polyethylene; PP: Polypropylene; PET: Polyethylene Terephthalate; EVOH: Ethylene Vinyl Alcohol; PA: Polyamide; UV Radiation: Ultraviolet Radiation; TiO_2: Titanium Dioxide; LDPE: Low Density Polyethylene; HDPE: High Density Polyethylene; N_2: Nitrogen; O_2: Oxygen; Al_2O_3: Aluminum Oxide; SiO_2: Silicon Oxide

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Abstract

Food preservation, particularly for grains and high-fat foods such as nuts, is a critical issue to assure safety and quality throughout the entire production chain. In particular, these products are highly sensitive to oxidative rancidity. In this sense, the use of multilayer films for food packaging has emerged in the past years as a key strategy to enhance shelf life of sensitive products. These films offer significant barriers to external factors such as oxygen, moisture, and light, which are essential for preventing spoilage and maintaining nutritional quality and organoleptic characteristics. This review explores the role of multilayer films in storage of grains and nuts, focusing on film composition, functionality, and the challenges associated with their use and final disposal. The discussion also includes recent advances in the development of sustainable and recyclable multilayer films.

Introduction

Food packaging preserves the integrity and safety of products during distribution and storage. Particularly, some grains and nuts are susceptible to spoilage due to their high fat content, which makes them vulnerable to oxidative rancidity. Exposure to oxygen, high temperature, moisture and light accelerates degradation processes by triggering chemical reactions that produce lipid oxidation. These reactions can generate undesirable flavors, toxic compounds and also impoverish the nutritional quality of food by degrading vitamins and proteins. Consequently, the selection of appropriate packaging materials is crucial for maintaining the shelf life of grain and nut products [1].

Multilayer films are produced using advanced technologies such as coating, lamination, and coextrusion, among others, which allow combining polyolefin-based polymers (PE, PP or PET), including aluminum or cardboard layers in many cases. Each layer has a specific function to provide the mechanical and barrier properties required by the product. Moisture barrier properties are typically provided by PE and PP layers, which prevent the flux (in/out) of water vapor through the package. Oxygen barrier properties are often enhanced by the inclusion of

EVOH or PA, which are known for their low oxygen permeability. The aluminum layer acts as an excellent barrier to both gasses and light, particularly UV radiation. This layer is commonly used for protecting the fat-rich content of nuts from photodegradation, although this results in a non-visible packaging that is not always liked by consumers. Moreover, an adhesive layer is often needed to combine materials that are chemically incompatible as PE with aluminum or EVOH [2]. However, the inclusion of an aluminum layer and the use of adhesives in multilayer films present significant challenges in terms of recyclability and sustainability. Another alternative is TiO_2 and carbon black inclusion in polymer layers as additives to protect, mainly grains, against UV radiation. This review analyzes the use of multilayer films in the storage of grains and nuts; highlighting their benefits, limitations, and the potential for innovative solutions that mitigate the environmental issues associated.

Discussion

Multilayer flexible films have emerged as a crucial packaging solution for preserving sensitive products. Regarding grain storage, silo bag is a multilayer plastic system widely used for this purpose. It is produced through co-extrusion of at least three PE-based layers, which enables the auto-modified atmosphere generation. To prevent light-induced grain deterioration, the outer layer contains TiO_2, as anti-UV additive, which gives an opaque white color; meanwhile the inner layer incorporates carbon black to block UV radiation. This design effectively shields harvested grains from harmful UV and visible light, ensuring protection for 6 to 12 months against outdoor conditions [3].

Concerning tree nuts storage, diverse authors studied and compared different packaging materials to preserve quality and extend shelf life of these products. In this sense, Henriquez, et al. [4] analyzed the oxidative stability of pine nuts stored in three different pouches (LDPE, HDPE and a metallized multilayer film). The authors conclude that the metallized film is the best packaging material to store pine nuts at 20°C, which allows an extension of 440 and 100 days in their shelf life, compared with LDPE and HDPE films, respectively. Han, et al. [5] studied proteins quality of shelled walnuts using three different packages (PE, PE/PA with vacuum and PET/aluminum foil/PE with vacuum) during 6 months storage. Results show that PET/aluminum/PE with vacuum packaging can prevent the oxidation of walnut proteins, extend their shelf life, and minimize the nutritional loss. Moreover, Mexis, et al. [6] evaluated the performance of two multilayer packaging (PET/LDPE and LDPE/EVOH/LDPE) in the preservation of ground almond kernels during 12 months at 4 and 20°C with N_2 atmosphere or an O_2 absorber, in dark or exposed to fluorescence light. They found that regardless of the temperature and lightening condition, almonds packed in LDPE/EVOH/LDPE with an O_2 absorber had a low peroxide value during all the period, which means that the almond kernels can be classified as fresh.

However, despite the outstanding performance of multilayer films in preserving the quality of grains and nuts during storage, their use presents significant challenges related to recyclability and environmental sustainability. The chemical incompatibility between the different layers and the use of adhesives complicates traditional recycling processes, making these films difficult to recycle using conventional methods. This issue led to the exploration of alternative solutions such as delamination for separate recycling of each component, dissolution-reprecipitation techniques, and compatibilization methods. Despite these efforts, such alternatives are cost-effective, leading to the frequent disposal of these films through landfilling or incineration [7].

A promising alternative to address the recyclability challenge are multilayer films using the same polymer matrix (mono-material) incorporating different particles or additives to enhance gasses and light barrier properties, as silo bag. Moreover, other studies showed that the addition of thin coatings of Al_2O_3 and SiO_2 can significantly improve the barrier performance of PE or PP films, offering a more environmentally friendly option for food packaging due to the possibility of recycling these films by reprocessing [8].

Conclusion

Preservation of grains and nuts presents significant challenges that can be effectively addressed by using multilayer films. These films offer outstanding protection and therefore, they can extend shelf life and maintain nutritional quality of rich-fat products. Advanced technologies allow the combination of different materials; however, the inclusion of materials chemically incompatible in the multilayer configuration pose significant recyclability drawbacks. Ongoing developments are focused on creating more sustainable alternatives, such as mono-material multilayer films with additives and fillers. This alternative could offer a balance between performance and recyclability, contributing to more sustainable food packaging solutions.

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Conflict of Interest

The authors declare no conflicts of interest.

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