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Novel approaches to the packaging technologies in meat products

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Abstract

Packaging is essential for preserving food safety and quality, and innovations in active packaging, especially antimicrobial packaging, enable the active suppression or elimination of spoilage-causing bacteria, thereby extending the product's shelf life. This work aims to elucidate several packaging technologies for beef products. Active packaging methods incorporate functional elements such as antioxidants and antimicrobials to prevent oxidative deterioration and microbial proliferation. Time and temperature indicators, gas sensors, and pH-sensitive films exhibit smart packaging technologies that provide real-time monitoring of meat quality and freshness, delivering essential information throughout the supply chain. Furthermore, digital technology, encompassing biosensors and QR codes, enhances traceability and transparency. Recent breakthroughs in nanotechnology have enhanced the mechanical durability and insulating properties of packaging materials, while also imparting antibacterial activity. Despite the significant development the packaging industry has witnessed with modern technology, high costs remain a challenge.

Keywords: *packaging, food, meat preservation*

Introduction

Meat packaging is dynamic, and its innovation has been the topic of much recent review. These are valuable; however, their categorization of recent technology and inventions in terms of their functional pathways and within smart packaging definitions may limit their application as a troubleshooting tool for industry, retailers, and other stakeholders. We should note that smart packaging encompasses intelligent and active packages designed to provide a 'cost-effective barrier against hazardous contaminants that simultaneously contributes to the longevity of product quality and enhancement of consumer appeal' (Holman et al., 2017).

Consumers are familiar with packaging, as currently most products are covered in one or more packaging materials. Food packaging protects against degradation and contamination and frequently contains information about the food. Labels with different colors, marks or fonts, different forms or standard sizes, and other characteristics that enhance consumer appeal may all be used in retail packaging to support food marketing (Li et al., 2022). In this work, we aim to highlight some approaches to the packaging technologies in meat products.

Novel approaches to the packaging technologies in meat products

The traditional packaging of fresh meat is used to prevent contamination, increase product shelf life, and promote enzymatic activity that improves meat tenderness, reduces weight loss, and promotes the development of oxymyoglobin pigment (instead of metmyoglobin) for a bright red color (Panea et al., 2014). Due to technological developments and the growing demand from consumers and industry for meat products with longer shelf life, improved safety and health benefits, convenience, environmental friendliness, and reduced food waste, traditional packaging techniques are unable to deliver these benefits (Ahmed et al., 2018).

To effectively address those challenges, a new type of packaging, called intelligent packaging, has entered the market (Choi et al., 2014). Intelligent packaging is a novel packaging technique developed in recent years for a variety of food items, including meat and meat products. Intelligent packaging notifies consumers of the condition of food by monitoring certain attributes of the food inside the box or the surrounding environment (Panea et al., 2014). The paramount intelligent packaging tools are sensors and indicators. Intelligent packaging systems can identify and alert users to changes in product quality during storage. Sensors, detectors, and radio-frequency detecting systems are instruments used in intelligent packaging (Kerry et al., 2006). Smart packaging technologies have seen significant development in recent years, enhancing the dissemination of information encoded as barcodes or visual indicators. Smart packaging systems can monitor loss of freshness over time, temperature variations during storage under different climatic conditions, changes in the composition of gases within the package, and the product's distribution date (Luo et al., 2022).

Biopolymers are commonly employed in food packaging due to their edibility and safety for humans. Proteins, polysaccharides, and their derivatives are the most studied nanocomposite biomaterials for food packaging applications. Nanocomposites based on cellulose and starch may be utilized in packaging systems to provide an eco-friendly alternative and promote sustainability goals. Some examples of natural antioxidants for fatty foods include edible films and coatings based on cellulose derivatives, chitosan, alginate, galactomannans, or gelatin (Ruan et al., 2019).

Another important advance is the development of nanotechnology that has improved barrier qualities, mechanical strength, and antimicrobial efficiency of packaging materials, hence boosting protection against oxygen, moisture, and microbial contamination. Furthermore, there is an increasing focus on sustainable packaging options, including biodegradable and bio-based materials such as chitosan, starch, and protein-based films, which minimize environmental impact while retaining functional performance (McMillin, 2026).

Food packaging that utilizes nanotechnology offers several benefits over conventional materials by enhancing attributes such as thermal resistance, durability, flame retardancy, and effective substance delivery in biological systems, all in a cost-efficient and sustainable manner. As a result of recent advancements, nanocomposite materials are now easily available, especially for the food processing, preservation, and packaging sectors, including applications for fruits and vegetables to extend shelf life and retard ripening. They also contribute to extrusion and co-extrusion processes in beverage manufacturing facilities (Bumbudsanpharoke & Ko, 2015). The primary emphasis of enhanced packaging is on nanomaterials that exhibit superior strength, flexibility, stability, and barrier properties. Active nanomaterials, including oxygen-scavenging agents and antimicrobials, are fundamental to active packaging (Li, C. & Lin, 2013).

Conclusion

In conclusion, meat packing technologies are rapidly evolving from traditional methods to modern ones to ensure meat safety and quality. Active packaging controls microbial growth and oxidation to lengthen product shelf life, while smart packaging technologies monitor freshness and storage conditions in real time to improve supply chain decision-making. Smart technologies improve traceability and consumer confidence. Nanotechnology also improves package insulation and antibacterial action. Although advances have been made, production costs remain high. Future studies should focus on cost-effectiveness and material safety.

Declarations

Ethical Approval Certificate
No need

Author Contribution Statement
Wadah Elsheikh: writing the original draft. Ilknur Ucak: supervision, conceptualization, review, and editing.

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Conflict of Interest
The authors declare no conflict of interest.

References

Ahmed, I., Lin, H., Zou, L., Li, Z., Brody, A L., Qazi, I. M., Lv, L., Pavase, T. R., Khan, M. U., Khan, S., & Sun, L. (2018). An overview of smart packaging technologies for monitoring safety and quality of meat and meat products. *Packaging Technology and Science*, 31, 449–471.

Bumbudsanpharoke, N., & Ko, S. (2015). Nano‐food packaging: an overview of market, migration research, and safety regulations. *Journal of food science*, *80*(5), R910-R923.

Choi, D. Y., Jung, S. W., Lee, D. S., & Lee, S. J. (2014). Fabrication and characteristics of microbial time temperature indicators from bio-paste using screen printing method. *Packaging Technology and Science*, 27, 303–312.

Dave, D., & Ghaly, A. E. (2011). Meat spoilage mechanisms and preservation techniques: a critical review. *American Journal of Agricultural and Biological Sciences*, *6*(4), 486-510.

Kerry, J. P., O'Grady, M. N., & Hogan, S. A. (2006). Past, current and potential utilization of active and intelligent packaging systems for meat and muscle based products: a review. *Meat Science*, 74, 113–130.

Li, C. & Lin, J. (2013). Applications and Future Trends. In Microwave Noncontact Motion Sensing and Analysis (eds C. Li and J. Lin). https://doi.org/10.1002/9781118742556.ch5

Li, X., Zhang, R., Hassan, M. M., Cheng, Z., Mills, J., Hou, C., ... & Hicks, T. M. (2022). Active packaging for the extended shelf-life of meat: perspectives from consumption habits, market requirements and packaging practices in China and New Zealand. *Foods*, *11*(18), 2903. https://doi.org/10.3390/foods11182903

Luo, X., Zaitoon, A., & Lim, L. (2022). A review on colorimetric indicators for monitoring product freshness in intelligent food packaging: Indicator dyes, preparation methods, and applications. *Comprehensive Reviews in Food Science and Food Safety*, 21, 2489–2519.

McMillin, K. W. (2026). New technologies in processed meat packaging. *Animal Frontiers*, *16*(1), 36-42. https://doi.org/10.1093/af/vfaf049

Panea, B., Ripoll, G., González, J., Fernández-Cuello, Á., & Albertí, P. (2014). Effect of nanocomposite packaging containing different proportions of ZnO and Ag on chicken breast meat quality. *Journal of Food Engineering*, 123, 104–112.

Realini, C. E., & Marcos, B. (2014). Active and intelligent packaging systems for a modern society. *Meat science*, *98*(3), 404-419.

Ruan, C., Zhang, Y., Wang, J., Sun, Y., Gao, X., Xiong, G., & Liang, J. (2019). Preparation and antioxidant activity of sodium alginate and carboxymethyl cellulose edible films with epigallocatechin gallate. *International journal of biological macromolecules*, *134*, 1038-1044.

Zhang, H., Hortal, M., Dobon, A., Bermudez, J. M., & Lara-Lledo, M. (2015). The effect of active packaging on minimizing food losses: Life cycle assessment (LCA) of essential oil component-enabled packaging for fresh beef. *Packaging Technology and Science*, *28*(9), 761-774. https://doi.org/10.1002/pts.2135