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Review Paper

Beyond recyclability: a holistic framework for sustainable meat packaging, balancing circularity, shelf life and consumer acceptance

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ABSTRACT

The intersection of material science (bio-based solutions), functionality (active and smart packaging) and systemic approaches (circular supply chains) is given to indicate sustainable meat packaging. This packaging should be regarded as a process balancing environmental goals with practical constraints (cost, performance) and consumer willingness to pay for sustainable packaging.

1. Introduction

This short review emphasizes a multi-dimensional approach (environmental, technical, and social) to sustainability in meat packaging, addressing gaps in current research that often focuses narrowly on recyclability or material substitution without integrating consumer behaviour or systemic trade-offs between sustainability, shelf life and cost (*Spada et al*., 2024; *Saini et al*., 2025). Current packaging relies on non-recyclable, multi-layered plastics, but sustainability is a driving force for meat packaging, including the development of packaging based on green materials in order to minimize environmental impact (*McMillin,* 2017*; Baskar et al.,* 2023*; Tandon et al.,* 2025).

The research objective was to evaluate emerging sustainable materials and technologies and propose a holistic framework integrating circular design, supply chain efficiency, and consumer perception to advance sustainable meat packaging.

2. Current challenges in meat packaging sustainability

Replacing commonly used plastic films derived from fossil fuel-based feedstock in the meat packaging sector is a complex challenge due to the exceptional properties of these films, such as high barrier performance, mechanical strength, and thermal resistance (*Caccialanza et al.,* 2023). However, growing environmental concerns, regulatory pressures, and consumer demand for sustainable packaging are driving the search for alternatives (*Ibrahim et al.,* 2022). Another challenge is the infrastructural gap embodied in the lack of composting/recycling facilities for bio based materials (e.g., only 2% of

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the U.S. population has curbside composting) (*Cruz Foam,* 2024). There is also consumer misalignment in, e.g., their willingness to pay for sustainable packaging (82% of consumers) compared to low recycling rates (21% of recyclable materials collected) (*Harris,* 2023). The mismatch between eco-conscious claims, actual recycling behaviour, and premium pricing of sustainable options limits their adoption and scalability (*Donkor et al.,* 2023).

3. Emerging sustainable solutions

Recent advancements in sustainable meat packaging focus on reducing environmental impact while maintaining food safety and shelf life. Biodegradable materials like polylactic acid (PLA), polyhydroxyalkanoates (PHA), polybutylene adipate terephthalate (PBAT), and chitosan- and starch-based films are replacing conventional plastics, offering compostability and antimicrobial properties (*Saini et al.,* 2023). Circular economy approaches for mono-material designs, such as recyclable polypropylene (PP) and amorphous *polyethylene terephthalate* (APET) trays, simplify recycling processes (*Fellegara et al.,* 2023), while active packaging, incorporating oxygen scavengers and moisture absorbers, extends product freshness (*Cenci-Goga et al.,* 2020). Additionally, smart labels with pH-sensitive indicators provide real-time spoilage alerts, helping to minimize food waste (*Nat,* 2024).

4. A proposed framework for sustainable meat packaging

The reviewed literature shows the main directions that define the framework for the development and application of sustainable packaging in the meat industry, namely: circular packaging design, integration of supply chains, consumer engagement, arising pressure from regulatory bodies. The main goal of circular design is to prioritize mono-materials and compostable/biobased options where feasible (*Ibrahim et al.,* 2022). The integration of supply chains implies centralized processing near markets to reduce transport emissions and shelf life loss (*Harris,* 2023). Consumer engagement is achieved by companies that practice transparent and clear product labelling to gain consumer trust and loyalty (*Spada et al., 2024*). Here, we should also mention the definition of metrics that evaluate the success of this process: cost savings, reduction in material use, increased shelf life, and improved recycling rates (*Morashi et al.,* 2022).

The sustainable meat packaging market is projected to reach US$12.4 billion by 2035, with a compound annual growth rate of 4.1% (*FMI, 2025*). The sustainable packaging market will grow from $276 billion in 2023 to $558 billion by 2034 (Figure 1) (*Statista,* 2025). That is more than doubling in just over a decade.

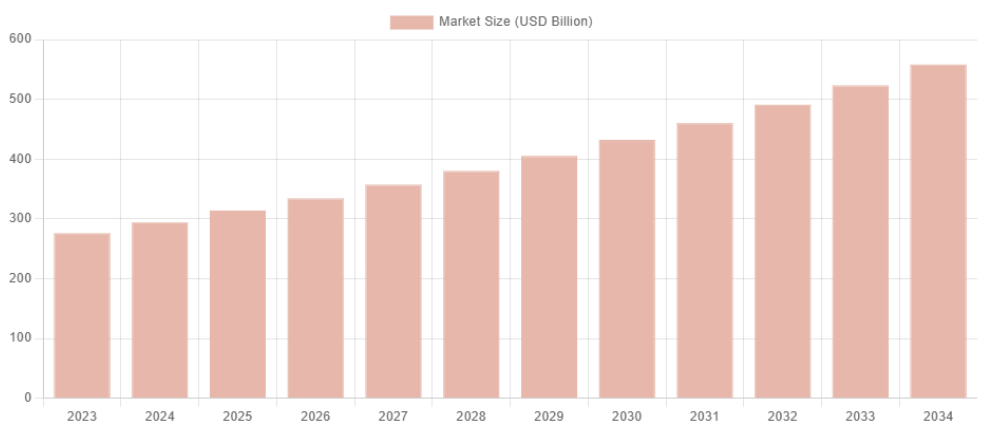

Figure 1. Global sustainable packaging market size projections (2023-2034)

https://stampedwithlovexoxo.com/blogs/love-letters/sustainable-packaging-statistics?srsltid=AfmBOoqQaBPseGssODgJZkFQFhkpNQ-shuTW9whVHaNSjbc9_epnD7-k

5. Conclusion

The meat industry is undergoing a transformative shift toward sustainable packaging, driven by environmental concerns, regulatory pressures, and consumer demand for eco-friendly solutions. Replacing widely adopted materials in the meat packaging sector is possible, but will take time. In the short term, hybrid materials and recycled materials will dominate as transitional solutions. Over the next 10–20 years, advances in biodegradable polymers, active

packaging, and circular economy models are expected to enable the widespread adoption of sustainable alternatives. The timeline will depend on technological progress, cost reductions, regulatory support, and consumer acceptance. While complete replacement may not happen immediately, the industry is moving steadily toward more sustainable packaging solutions.

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