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Short communication

Sustainable pharmaceutical primary packaging: Innovative strategies and future perspectives

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Introduction

Pharmaceutical packaging is categorized into primary (direct contact with the product), secondary (protective and informational) and tertiary packaging (for storage and transportation).

Primary packaging plays a critical role in ensuring the quality, safety, and efficacy of pharmaceutical products. In addition to providing physical protection, primary packaging systems preserve product stability, prevent leakage and contamination, protect against light exposure and enable proper product identification and information delivery. During the 1950s plastic and aluminum materials became widely adopted in the industry due to their lightweight structure, durability, flexibility and cost-effective manufacturing properties. Since then, the use of plastic packaging has continuously increased, with the global pharmaceutical plastic packaging market expected to reach a value of 107.63 billion US$ by 2034. These environmental and regulatory challenges have accelerated the need for innovative and sustainable pharmaceutical packaging solutions. (Jackman et al., 2025)

Sustainable primary packaging in the pharmaceutical industry

Sustainability challenges

Despite their advantages conventional petroleum-based plastic materials present major environmental concerns, mainly because their production requires extensive consumption of fossil fuels. On the other hand, even though aluminum is considered infinitely recyclable, recycling in pharmaceutical applications remains limited due to complex multilayer structures commonly used in blister packaging, which requires energy-intensive separation process prior to recycling. In addition, pharmaceutical primary packaging generates significant amounts of packaging waste due to extensive use of single-use plastic materials and multilayer packaging systems with limited recyclability. In the last decade the total mass of packaging waste generated in the European Union increased by approximately 20%. Forecasts show that by 2030 packaging waste in the European Union could increase by 19%, while plastic waste may rise as much as 46%, highlighting the need for greener solutions. (European Parliament and Council, 2025; Jackman et al., 2025)

Regulatory requirements

The European Union has established packaging waste reduction targets aimed at achieving long-term prevention of packaging waste generation. The regulation sets a target of reducing packaging waste per capita of 5% by 2030, 10% by 2035 and 15% by 2040 to ensure continuous progress in waste prevention and implementation of circular economy principles. Regulation (EU) 2025/40 on packaging and packaging waste (PPWR) states that all

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packaging placed on the market should be recyclable by 2030. By the same year contact-sensitive plastic made from materials other than polyethylene terephthalate (PET) should contain at least 10% recycled content, while PET based contact sensitive packaging should contain at least 30% recycled material. Furthermore, Regulation (EU) 2025/40 requires manufacturers and importers to design packaging systems in a way that minimizes packaging weight and volume while still ensuring adequate functionality, product protection and safety. (European Parliament and Council, 2025)

Innovative strategies for sustainable primary packaging

In recent years, the pharmaceutical industry has increasingly focused on the development of innovative and sustainable packaging solutions. Current approaches include the use of recyclable mono-material packaging systems, biodegradable and bio-based polymers, lightweight packaging designs aimed at reducing environmental impact. One of the most important strategies is the transition from complex multilayer packaging toward recyclable mono-material packaging. Conventional primary packaging systems such as: multilayer sachets, blister packs and strip packaging often combine plastic polymers with aluminum layers to achieve optimal barrier protection. However, they complicate the recycling process. That is why the industry is increasingly exploring mono-material polyethylene (PE) and polypropylene (PP) or plant-based systems with enhanced barrier properties. Also, biopolymers derived from natural sources are considered promising alternatives because they can degrade into non-hazardous byproducts such as water, carbon dioxide and biomass which in the end reduces dependence on fossil fuels.

Growing attention is also placed on starch-based materials, polylactic acid (PLA), cellulose-based materials and algae-derived polymers.

However, despite significant progress in sustainable material development, implementation within pharmaceutical packaging systems remains challenging. Biodegradable and compostable materials often exhibit limitations related to barrier properties, thermal resistance, mechanical stability and compatibility with the product compared to conventional petroleum-based plastics. Furthermore, pharmaceutical primary packaging materials must comply with the strict regulatory and GMP requirements associated with product stability, patient safety and packaging integrity. (Ibrahim et al., 2022; Jackman et al., 2025)

Conclusion

Sustainable primary packaging has become an increasingly important focus within the pharmaceutical industry due to growing environmental concerns and stricter regulatory requirements. Current strategies are focused on improving recyclability and reducing packaging waste. Although biodegradable and bio-based materials show significant potential, they still present limitations related to barrier properties, stability and compatibility. That is why, conventional primary packaging materials will still be in use in the near future, at least until innovative solutions meet all the GMP requirements.

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