

SUSTAINABILITY TRENDS IN PACKAGING INDUSTRY AND PACKAGING MATERIALS

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Abstract: The primary function of packaging is to protect the product. Beyond this, packaging must also provide all necessary information to the consumer. Additionally, it simplifies the transportation of finished goods. However, with advancements in technology, limited resources, and a growing population, packaging has taken on new responsibilities. Primarily, it refers to product protection, but it also addresses environmental concerns by promoting sustainability. This paper discusses development trends in packaging and the packaging industry, with special emphasis on innovations in the field of active and smart packaging. It also examines the issue of packaging waste.

Key words: sustainability, packaging materials, active packaging, smart packaging, pollution prevention,

1. INTRODUCTION

Packaging plays a crucial role in the product supply chain. Its influence is essential for preserving product quality. Specifically, packaging protects products during transportation and handling from potential physical damage as well as environmental factors such as light, oxygen, moisture, and microorganisms. It also prevents various biological, microbiological, and chemical changes, ensuring the quality and safety of products throughout the entire process, from production to consumption [1], [2]. Active packaging is designed to actively respond to environmental changes and the condition of the product. Smart packaging, on the other hand, includes sensor technologies. Sustainability continues to be an increasingly significant concern for the packaging value chain. The major trends expected to transform the packaging industry in the future include active packaging and smart packaging, which are among the most innovative solutions reshaping the field. The major trends expected to transform the packaging industry in the future include [3]-[6]:

- Eco-friendly packaging - biodegradability, recyclability of packaging materials, lightweight packaging, packaging waste minimization, edible materials for packaging, etc., and sustainability,
- E-commerce - innovative packaging solutions for tracking and monitoring products during transit (radio frequency identification - RFID and two-dimensional-barcode or QR codes),
- Direct-to-consumer (D2C) - specially designed to reduce shipping costs, and custom packaging solutions (a wide range of customized products to meet the most diverse needs of customers),
- Digitalization - connected packaging (QR codes, contactless communication and augmented reality), automation, and Internet of Things (IoT) in packaging,
- Creative, simple, humorous designs and fonts,
- Personalized packaging (limited edition packaging, customizable designs, and packaging with unique messages or themes),
- Interactive and active packaging,
- Smart packaging - combination of active, intelligent, and modified atmosphere packaging techniques,
- Circular packaging - circular packaging solutions incorporate the principles of the circular economy and integrate seamlessly into sustainability efforts,
- Sustainable labeling - using eco-friendly labels and ink, or opting for no label at all to minimize waste.

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In the following section of this paper, we will provide a more detailed analysis of some of the key development trends in packaging materials and packaging industry, which we believe are the most significant. These trends address environmental impact, protection, and pollution prevention. Leading global brands are increasingly focusing on environmental responsibility and sustainability. Products designed for reuse, packaged in sustainable, recyclable, and reusable materials, reflect a commitment to a more sustainable future.

2. PACKAGING WASTE AND SUSTAINABILITY

We live in a time of rapid technological development (industry 5 and industry 6), but also of increasing environmental awareness, which poses big and difficult tasks for the packaging industry in terms of the direction of its development. For example, in 2022, the European Union (EU) generated an estimated 186.5 kg of packaging waste per inhabitant [7], while in Serbia in the same year, according to the data of the Serbian Environmental Protection Agency (SEPA), 60 kg of this waste was generated per inhabitant [8]. Based on the data presented, 3 times less packaging waste per inhabitant was generated in our country in the observed year compared to the EU. This amount is smaller even in comparison with Bulgaria, as a member of the EU, which generates the least amount of packaging waste per inhabitant (78.8 kg per inhabitant [7]). Figure 1 graphically presents the amount of packaging placed on the market of the Republic of Serbia by year in the period from 2018 to 2022.

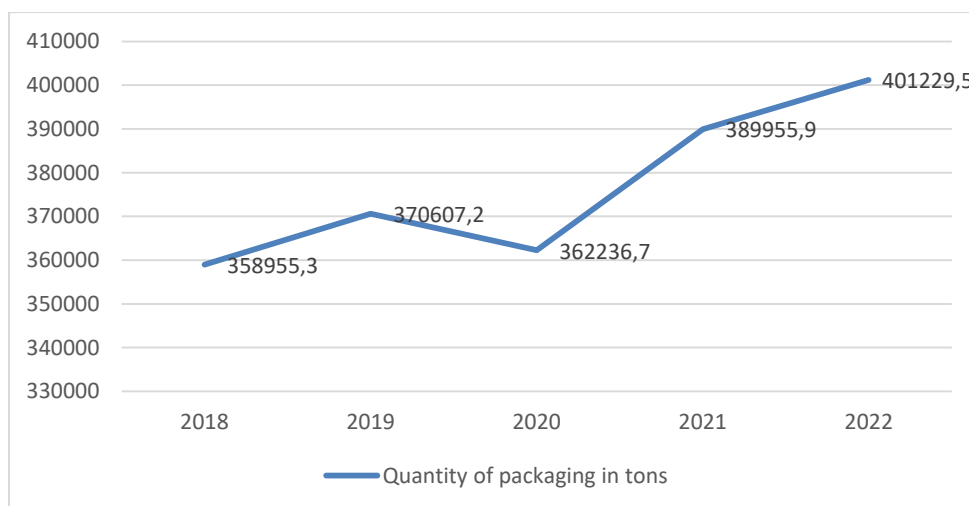


Figure 1 – The amount of packaging placed on the market of the Republic of Serbia by year in the period from 2018 to 2022, [8]

From the graph shown in Figure 1, we can see an increase of about 12% in the amount of packaging, in 5 years. Practically, this is equivalent to the amount of generated packaging waste. However, part of the packaging waste is reused (56.65%), while another part is recycled, both of which are essential pollution prevention measures. Data on the quantities of general packaging waste is often incomplete and not precise enough, according to the SEPA report [8]. Unfortunately, recycling and reuse of packaging waste are not sufficiently developed, meaning a large portion of usable and recyclable packaging waste ends up in landfills.

2.1 Eco-friendly packaging

Eco-friendly packaging is introduced to support the sustainable development of the consumer firm [9], and it aims to reduce or completely eliminate the impact on the environment (zero emissions, zero waste, cleaner production, prevention of pollution). These materials can be sourced from renewable resources or agro-industrial waste. In addition, these materials can be biodegradable or compostable. It is important to emphasize that these materials are expected to influence the reduction of energy

consumption and, as already pointed out, the reduction of the amount of packaging waste. In the total generated packaging waste, both in the EU and in our country, the largest percentage belongs to paper and cardboard, followed by plastic [7], [8]. A sustainable approach that helps reduce plastic packaging pollution is to replace conventional plastics with biodegradable materials. Biodegradable packaging, in addition to reducing packaging waste, offers numerous advantages such as: sustainability, pollution prevention, carbon neutrality and reducing the use of fossil fuels [10]. Figure 2 schematically presents the categorization of biodegradable packaging materials. Several classes of biopolymers can be broadly categorized into synthetic biopolymers produced by chemical synthesis and natural or bio-based biopolymers derived from biological sources [11].

In addition to biodegradable packaging materials, eco-friendly packaging materials also include: recyclable and reusable packaging (which enhance the lifecycle of packaging materials); minimalist packaging (a trend toward minimalism that reduces excess packaging and encourages the use of fewer resources); and lightweight packaging (which reduces the weight of packaging, leading to a reduction in transport costs and carbon emissions). Lighter packaging also contributes to lower waste generation; edible packaging (companies are exploring the use of edible materials for packaging, especially in the food industry, to reduce waste and create more innovative product experiences. These materials are an integral part of the products and are consumed with the products, so they are also inherently biodegradable in composting and other biological recycling and could include ingredients like rice, seaweed, or starch. Currently, the new regulation governing sustainability dimensions of packaging is expanding on multiple fronts. The above refers primarily to the concept of recycling and the use of recycled packaging materials, as well as sustainable packaging on a global level. Thanks to the growing awareness of environmental issues, such as plastic pollution, resource scarcity, and climate change, the demand for sustainable packaging solutions has increased, as already emphasized in this paper [12]. The integration of AI in packaging design reduces material usage and optimizes the entire packaging lifecycle. As a result, pollution is prevented, thus minimizing its environmental footprint.

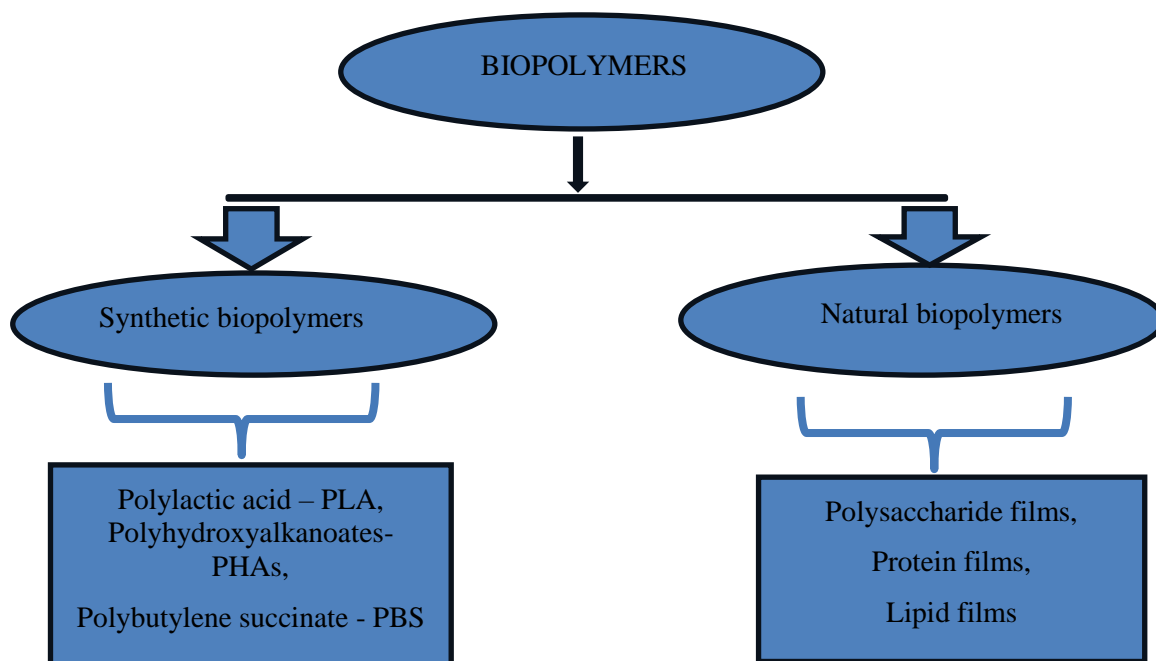


Figure 2– Schematic representation of biodegradable materials categorization for packaging food products, [11]

The circular economy model addresses the problem of single-use packaging by promoting reusable packaging in a specific way, which can drastically reduce packaging waste generation and

resource consumption. In October 2021, PepsiCo pioneered compostable snack bags made from plant-based materials [12]. In addition to the example of PepsiCo, Table 1 shows examples of other companies that occupy leading positions at the international level in the production of sustainable packaging materials [13]. More precisely, in order not to spread this article too much, we will present only the top 3 companies in this domain. The most important sustainable packaging materials of these companies were also presented.

Table 1 – Top 3 sustainable packaging companies in the world and their packaging products

Company Name	HQ Location	Products
Solutum	Israel	Vivomer: This bio-based material is compostable, and it is designed to fully break down in soil and marine environments, leaving no microplastics behind. Biodegradable Polybags: These bags are compatible with various disposal methods (composting, incineration, landfill, and recycling).
Stora Enso	Finland	Corrugated packaging: Made from renewable materials, these products are designed to protect goods while being recyclable. Paperboard materials: Lightweight, low-carbon packaging that meets the demands of modern consumers while ensuring high performance and sustainability.
Nohbo	USA	Shampoo and Conditioner Drops - single-use, water-soluble drops, providing a convenient and eco-friendly alternative to traditional shampoo bottles, eliminating plastic waste.

The movement toward sustainable packaging will include both improving current bio-based packaging, and development of new bio-based materials [14]. It is obvious that the future of the packaging industry is oriented towards such materials, especially when considering the enormous accumulation of plastic waste, the recycling rate of which, despite all efforts, remains relatively low, at about 9% [3].

2.2. Our experiences with packaging at Beohemija

During 2024, we cooperated with the company Beohemija as part of the Project "Valorization of powdered by-products from the production of perlite". The project was supported and financed by the Provincial Secretariat for Higher Education and Scientific Research, The goal of the project was the development of new, i.e. new abrasive liquid agents whose recipe traditional abrasive components are replaced with waste, powdered perlite from the Termika Zrenjanin factory. In addition to the above, it was also emphasized finding solutions for innovative, environmentally friendly packaging, which the Beohemija company accepted.

Beohemija applies new, energy-efficient technical and technological knowledge, uses biodegradable raw materials, recyclable packaging materials and follow all trends in the field of ecology [15]. In addition, the company is working intensively on adapting the Proposal for a Packaging and Packaging Waste Regulation [16]. As part of the project, work on harmonizing primary and secondary packaging with the goals of the updated Directive on packaging and packaging waste (Directive (EU) 2018/852 [17]) was intensified. The measures applied include:

- Monitoring and controlling the final product packaging process,
- Recycling packaging waste, and
- Producing and utilizing packaging made from recyclable materials.

Currently, the focus is on designing innovative packaging with significantly reduced weight (lightweight packaging), an increased percentage of recycled materials, and refill options. Particularly noteworthy are the new refill packaging solutions, which fall into the eco-friendly category.

3. CONCLUSION

With a steadfast commitment to innovation and a willingness to embrace change, the future of packaging holds boundless potential for those ready to seize it. These trends reflect a growing emphasis on innovation, consumer engagement, and environmental responsibility within the packaging industry. In summary, the future of the packaging industry lies in improving and increasing its sustainability. Simply put, the development direction of the packaging industry is to enhance its sustainability through the use of eco-friendly materials, recycling, reuse, and the reduction of packaging waste.

Considering the growing focus on environmental responsibility, sustainability, and innovation, the packaging industry faces both significant challenges and opportunities. By developing new, eco-friendly materials, improving recycling processes, and encouraging the use of reusable packaging, the industry can substantially reduce its negative environmental impact. The application of technologies such as artificial intelligence and smart packaging can further optimize the packaging lifecycle, reducing resource consumption and increasing efficiency.

In the future, sustainability will not just be a trend but a core value upon which companies in the packaging industry will build their competitiveness. Given the rapid pace of technological development and growing consumer awareness of environmental protection, the packaging industry is expected to become a key player in reducing global pollution and creating sustainable business models. This transformation process requires the collective effort of all stakeholders: manufacturers, legislators, consumers, and researchers, to achieve the goal of sustainable solutions that meet market needs while preserving natural resources for future generations.

To make real progress, it is crucial for the packaging industry to continue exploring and implementing innovations, including biodegradable materials, recyclable and reusable options, as well as smart packaging that can provide better consumer experiences while simultaneously reducing environmental footprints.

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