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COMPOSITE PACKAGING AND THE ROLE OF ECO-DESIGN IN THEIR RECYCLING

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ABSTRACT

The beginning of composite packaging was laid in 1930, when ordinary paper rubbed with paraffin was used for packaging liquid and other "wet" products. According to the modern understanding of "composite packaging", it is made of different materials that cannot be separated manually and none of them represents more than 95% of the weight of the package. Since composite packaging consists of many different materials, it cannot be recycled directly without being separated, which creates several difficulties and often leads to landfilling or incineration. In this regard, to improve the possibility of implementing a circular economy for composite packaging waste, innovative solutions are required for the separation and recovery of recyclable materials, but above all innovations in their design and eco-design, which would facilitate their subsequent treatment and recycling.

Key words: composite packaging, eco-design, circular economy, recovery

INTRODUCTION

Due to their resistance, lightness and durability, composite packaging is increasingly taking up a larger share of packaging in a number of industries. Different types of composite packaging are used in various industrial sectors – food, pharmaceutical, electrical appliance manufacturing, transportation, etc. Composite materials are classified according to their composition, that is, base material and additional material. The base material from which the packaging is made binds the denser material in its structure. That is why the base material is called the matrix or binding material, and the denser material is present in the form of sheets, fragments, particles, fibers or whiskers of another natural or synthetic material.

Research over the last two decades presents composites as an alternative to many standard materials, after it has been proven that they have a significant enhancement in the structural and mechanical properties of fiber-reinforced materials. Although composite materials manage to enhance the resistance of materials, at this stage there is a high concern about the accumulation of waste in the environment. This concern has led to the development of environmentally friendly materials linked to cleaner production processes and easier recycling of composite packaging. The Commission's (Eurostat) statistics on packaging waste show that large quantities of primary raw materials (primary materials) are used for packaging. 40% of plastics and 50% of paper used in the Union are used for packaging, and packaging accounts for 36% of municipal solid waste. (Regulation (EU) 2025/40)

The high and constantly increasing amounts of packaging generated, as well as the low levels of reuse and collection, and the low recycling, represent significant obstacles to achieving a low-carbon circular economy. The EU has therefore adopted a regulation to establish rules that cover the entire life cycle of packaging and reduce the adverse impact of packaging and packaging waste on the environment and human health. (Regulation (EU) 2025/40)

AIM

The aim of this study is to examine the design of existing composite packaging and the possibility of recovery and recycling of the materials, depending on their composition and regulatory requirements in Europe.

RESULTS AND CONCLUSION

Types of composite packaging and their potential for use

In general, composite packaging can be divided based on the number of layers and materials from which each of them is made. The most common composite packaging is of several types – plastic multilayer packaging, flexible plastic packaging and composite packaging containing paper and plastic. Composite packaging comes in many different forms and its use is increasing (Table 1). This is largely due to the many cost and efficiency benefits that can be achieved in the supply chain.

Table 1: Types and uses of composite packaging

Type of composite packaging material	Examples of packaging usage	Typical packaging composition (from outside to inside)
Poly-laminated cardboard (liquid cardboard)	Milk cartons and coffee cups	PE / ink / cardboard / PE Cardboard makes up about 85% of the weight of the composite material.
Multi-laminated cardboard	Durable (storage-resistant) milk carton	PE / ink / cardboard / PE / aluminum foil Cardboard makes up about 75% of the weight of the package, and aluminum – about 5%.
OPET/PE foils	Yellow cheese packaging	OPET / ink / LDPE
OPET/AI/PE foils	Pet food, baby food, coffee and other powdered food products	OPET / ink / aluminum foil / PE
OPP foils – metallized	Yogurt caps	Ink / paper / aluminum metallization / OPET / varnish
OPP foils – hot sealing	Cooked packaged foods	PE-PP copolymer / PP / PE-PP copolymer
OPP foils – metallized	Chip packaging, packaging foils, labels	OPP copolymer / OPP / OPP copolymer / ink / aluminum metallization / PE-PP copolymer / OPP / PE-PP copolymer
OPP/PVDC foils	Biscuit packaging	PVDC / ink / OPP / PVDC
Aluminum and paper packaging	butter packaging	Aluminum foil/wax/paper
Multi-layer bottles	Sauce bottles.	PET / EVOH / PET print – OPET / aluminum foil / PE

Abbreviations used: LDPE (low density polyethylene), PP (polypropylene), OPP – polypropylene foil, produced by a multilayer extrusion process, is called coextrusion oriented polypropylene foil, HDPE (high density polyethylene), PET (polyethylene terephthalate), OPET- (biaxially oriented polyethylene terephthalate) PVC (polyvinyl chloride), PS (polystyrene), PA (polyamide); PE – polyethylene; EVOH (ethylene vinyl alcohol), PVDC (polyvinyl dichloride)

All functions of composite packaging and its widespread use create a serious problem and raise the question of how to separate all these materials in order to reuse them. Today, there are several options for treating this type of composite packaging, but they still cannot solve the complete problem of recycling the materials, and rely mainly on raw material or energy recovery. An option for the recovery of composite packaging containing paper, plastic and aluminum foil is, for example, obtaining high-quality composite packaging boards for the furniture industry. Composite packaging containing paper, plastic and aluminum most often consists of about 21% PE, 4% aluminum and about 75% paper. The cardboard layer must provide stability, the PE layers provide protection against moisture on the outside and the outside of the package, while the aluminum acts as a gas barrier (Markwardt 2017). When these composite packaging is heated, the polyethylene turns into a kind of glue. The pulp of ground composite packaging is pressed and recognized boards are obtained, which are used in the furniture industry or in construction. The resulting product is sufficiently resistant to water and moisture to be used in garden furniture. (Packaging Manufacturers Association, Turkey).

There are other widespread composite packaging, such as toothpaste tubes, which are made of aluminum coated with polyethylene. Most often, technologies for treating toothpaste tubes include their use in cement kilns. Aluminum oxide is part of the cement, and polyethylene is used as fuel. In this way, the raw material and energy potential of packaging waste is utilized. A frequently used method of treating composite packaging waste is to incinerate it without separating the materials in it, using the energy released during combustion, but losing the raw material capacity of the materials (Adefeso 2012, https://www.repack.bg/kniga2/kniga2.php.). Incineration takes place under a special regime and it is necessary to burn only previously separated waste, for which it is clear what materials it is composed of.

The structure of the composite material makes it difficult to separate the different materials. This creates a number of problems. First, there is an increased cost and energy cost of recycling the materials compared to creating virgin materials. (Oliveux *et al.*, 2015). Second, the materials are always of lower quality, which decreases due to recycling and wear and tear throughout their life (Yang *et al.*, 2012). Third, because the material is of lower quality, it has fewer application options and is more difficult to use compared to virgin materials.

Although the recycling of composite packaging is hampered precisely by the need to separate the types of materials, there are some examples in this regard, such as the technology used by the Turkish Packaging Manufacturers' Association.

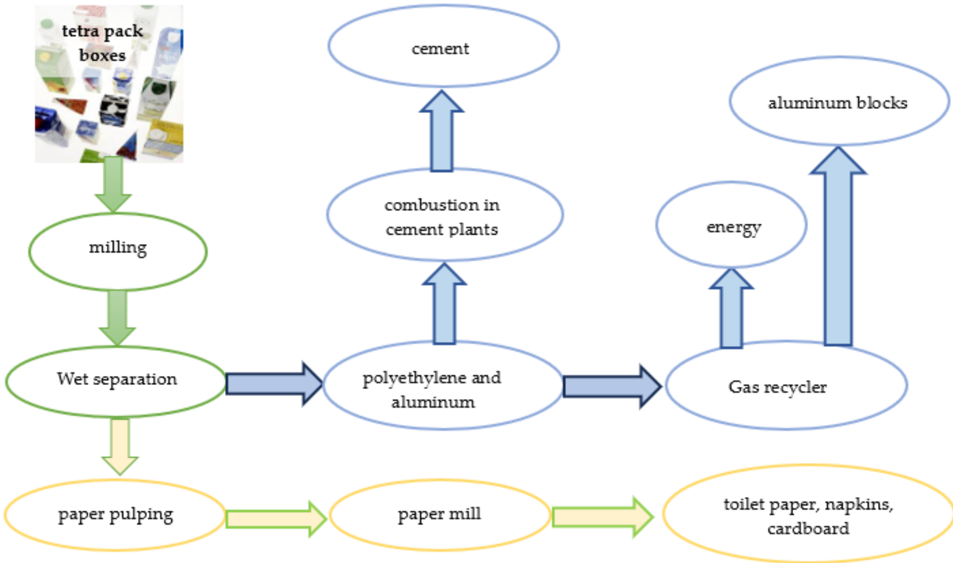

Figure 1: The technology that the Turkish Packaging Manufacturers Association applies in recycling composite packaging (Packaging Manufacturers' Association, Turkey http://ambalaj.org.tr/en/environment-recycling-of-composite-packaging.html)

The long and strong fibers of the cardboard box after separation can be processed into corrugated cardboard and toilet paper, and the rest of the aluminum and polyethylene are used as a fuel substitute in the cement industry, but this requires a lot of work and energy consumption. Other companies rely on micro-emulsion technology, by treating the composite packaging with a microemulsion, then washing the material, restoring the microemulsion and sorting the individual fractions obtained. In this way, the installation carries out the entire separation process, which is achieved by stirring at a temperature of 40° C – until the individual fractions are obtained. (https://www.saperatec.de/en/technology.html). In recent years, there has been a lot of work on recycling and finding an application for the resulting aluminum and polyethylene (PolyAl*) residue, but a technology for large-scale recycling has not yet been developed. (Axjo Group, Regulation (EU) 2025/40, Packaging Manufacturers' Association, Turkey).

Successful recycling and use of composite materials requires incentives, infrastructure, good recycling techniques and viable markets for the recycled materials (Tarverdi, 2009). According to (Cherrington *et al.* 2012), there are three main motives that determine the promotion of recycling of composite materials – environmental impact, legislation and economic opportunities.

Key considerations when designing composite packaging

The high and constantly increasing amounts of packaging generated, as well as the low levels of reuse and collection, and the low recycling, represent significant obstacles to achieving a low-carbon circular economy. The EU therefore adopted Regulation (EU) 2025/40 to establish rules covering the entire life cycle of packaging and reducing the adverse impact of packaging and packaging waste on the environment and human health.

According to the new European requirements included in the regulation, all packaging placed on the market must be recyclable, that is, designed with the possibility of recycling the materials, which allows for the use of the obtained secondary raw materials, which are of sufficient quality compared to the initial material, or the so-called high-quality recycling. Another condition for the recyclability of packaging is the possibility, when it becomes waste, to be collected separately, sorted and recycled on a large scale. In this regard, the European Union's provisions are that all packaging should be designed, manufactured and placed on the market in such a way as to allow its reuse as many times as possible or its high-quality recycling. Europe, revised and supplemented Directive 2009/125/EC, which introduced the concept of ecodesign, now taking into account the environmental impact of materials, resources and end-of-life scenarios and the objectives for reducing the impact of the product on the environment (Regulation (EU) 2024/1781). In other words, the product design is carried out in accordance with environmental protection conditions.

These European Union requirements for packaging placed on the market pose new challenges for manufacturers and importers of packaging and packaged goods.

The European-wide recycling targets for the individual materials used to produce packaging did not include composite packaging, which until recently was counted as the predominant material from which it was made. Due to the difficulties in its treatment, a large part of it is not recycled. With the changes in European legislation, composite packaging is counted more as a material contained in the packaging, with possible derogations for materials that represent less than 5% of the total mass of the packaging unit. (Regulation (EU) 2025/40).

The majority of the composite packaging produced can be classified as category 3 and category 13 according to table 1 of Annex 2 of the Regulation (EU) 2025/40

Table 2: Extract from indicative list of packaging materials, types and categories referred to in Article 6 of the Regulation (EU) 2025/40

Category No	Predominant packaging material	Packaging type	Format (illustrative and non-exhaustive)	Colour / Optical transmittance
…….	…….	…….	…….	…….
3	Paper/cardboard	Composite packaging of which the majority is paper/cardboard	Liquid packaging board, and paper cups (i.e. laminated with polyolefin and with or without aluminium), trays, plates and cups, metallised or plastic laminated paper/cardboard, paper/cardboard with plastic liners/ windows	–
…….	…….	…….	…….	…….
13	Plastic	PP – flexible	Films, including multilayer and multi-material packaging	Natural / coloured
…….	…….	…….	…….	…….

The Regulation sets out recyclability classes, also based on design-for-recycling criteria. Design-for-recycling criteria ensure the circularity of the use of the resulting secondary raw materials, which are of sufficient quality to replace primary raw materials.

Table 3: Recyclability performance grades, according to table 3 of the Regulation (EU) 2025/40

2030		2035			2038		
Recyclability performance grade	**Design for recycling (DfR) Assessment of recyclability per unit, in terms of weighting**	**Recyclability performance grade (for DfR)**	**Design for recycling (DfR) Assessment of recyclability per unit, in terms of weighting**	**Recyclability performance grade (for recycled-at-scale assessment)**	**Recyclability performance grade**	**Design for recycling (DfR) Assessment of recyclability per unit, in terms of weighting**	**Recyclability performance grade (for recycled-at-scale assessment)**
Grade A	higher or equal to 95 %	Grade A	higher or equal to 95 %	Grade A RaS	Grade A	higher or equal to 95 %	Grade A RaS
Grade B	higher or equal to 80 %	Grade B	higher or equal to 80 %	Grade B RaS	Grade B	higher or equal to 80 %	Grade B RaS
Grade C	higher or equal to 70 %	Grade C	higher or equal to 70 %	Grade C RaS	Grade C CANNOT BE PLACED ON THE MARKET	higher or equal to 70 %	Grade C RaS
TECHNICALLY NON-RECYCLABLE	lower than 70 %	TECHNICALLY NON-RECYCLABLE	lower than 70 %	NOT RECYCLED AT SCALE	TECHNICALLY NON-RECYCLABLE	lower than 70 %	NOT RECYCLED AT SCALE

The design criteria for recycling, according to the Regulation, also consider additives to the base material that may interfere with the sorting process and contamination of secondary raw materials, as well as how firmly attached components and layers can be separated and this may affect the recyclability of the packaging. In addition, from 2035 a new factor is added to assess the recyclability of packaging, namely the large-scale recycling assessment.

In this regard, it is essential to rethink the production and options for subsequent treatment of composite packaging, through the prism of the ecodesign concept, to ensure the integration of environmental aspects into the product design, in order to improve the environmental performance of the product throughout its life cycle and the possibility of utilizing waste products.

The hierarchy of preferred packaging design changes is towards avoidance or minimization, followed by reuse, recycling, recovery (energy) and finally disposal. At the same time, embedded in the resource design hierarchy are the requirements to maintain or improve the functionality of the packaging system (fitness for purpose) and to minimize product losses.

Specifically, the key design aspects that need to be considered to minimize the environmental impact of composite packaging are:

- Be as light as possible to minimize material consumption;
- Minimizing production resources (e.g. energy and water);
- Search for inks that generate minimal emissions of volatile organic compounds (VOCs);
- Using recycled materials if possible;
- Source sustainable raw materials (e.g. fibers) from responsible suppliers;
- Design for efficient packaging recycling, even if recovery options are currently limited. For composite materials, this may include reducing the number of layers of material or even moving to single-component packaging. Minimizing the use of resin additives and carefully considering the use of caps, seals, inks, dyes and label
- Design for easy polymer separation during processing.

To address this issue, there has been a trend in recent years towards avoiding multilayer packaging due to the more environmentally friendly image of monomaterial packaging. For example, the RecycleReady technology from DOW® (Midland, MI, USA) allows the replacement of heterogeneous multilayer packaging, e.g. containing PET and PE, with an all-polyolefin packaging containing a barrier adhesive (Corey 2016). Based on a combination of its own bimodal PE technology and processing technology, Borealis has developed a full PE laminate as an alternative to multilayer structures. In general, however, the replacement of multilayer packaging systems should only be undertaken if product protection can be equally guaranteed.

CONCLUSION

Different types of composite packaging are used in various industrial sectors – in the food, pharmaceutical, electrical appliance manufacturing, transport, etc., as the widespread distribution of composite packaging and the difficulties in their subsequent treatment require a specific approach and clearly defined rules for their management.

With the changes to the European legislation in the field of packaging waste – Regulation (EU) 2025/40, the EU skillfully combines the main motives that determine the stimulation of recycling of composite materials – environmental impact, legislation and economic opportunities.

Most of the efforts are still directed at technologies for separation, thermal treatment, etc. of the resulting waste, and not at improving the eco-design of composite packaging.

Eco-design, in turn, implies taking into account all possible environmental impacts of a given product at the earliest stage of its design, with the aim of improving its energy and raw material efficiency throughout its life cycle. The main goal of the eco-design of composite packaging is for it to be designed and created in such a way that the waste generated from it can subsequently be easily processed, separated in separation plants and recycled or utilized.

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