cosmetics

Review

Cosmetic Packaging: European Regulatory Aspects and Sustainability

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Abstract: This review aims to provide a comprehensive overview of various aspects related to cosmetic product packaging, highlighting both advancements and challenges in the field. Initially, it offers a general description of the main materials used in cosmetic containers, including plastic, glass, paper, and aluminum. This is followed by an analysis of the existing EU legislative frameworks that govern cosmetic packaging, encompassing chemical, food, and waste regulations. The paper also discusses recent EU regulatory proposals and guidelines from trade associations aimed at enhancing the sustainability of cosmetic packaging materials. Additionally, the role of recycled and bio-based packaging materials in promoting environmental sustainability is analyzed. Overall, this review aims to provide insights for experts in the field on how to balance safety, functionality, and environmental responsibility in cosmetic packaging.

Keywords: cosmetic packaging; EU legislation; guidelines; container materials; sustainability

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1. Introduction

Packaging plays a vital role in protecting and transporting goods, as well as facilitating the communication and use of industrial products such as foods, cosmetics, and pharmaceuticals. Packaging materials are typically classified into primary, secondary, and tertiary categories, each fulfilling specific yet interconnected roles within the logistics and distribution chain.

Understanding the composition and properties of packaging materials is essential to guaranteeing the efficient delivery and storage of goods. Typically, the decision-making process concerning packaging is complex, requiring input from various stakeholders, fulfillment of various functions, meeting diverse requirements, and careful consideration of various conditions [1]. For instance, when developing packaging for a cosmetic product, adherence to technical specifications such as product protection, compatibility with the product, and performance in the filling process is essential. However, the ultimate selection of packaging largely relies on the manufacturer's discretion and the desired brand image.

The most important types of materials employed to produce packaging are glass, paper, metal and overall plastics [2]. In the last few years, however, the surge in global consumption patterns has intensified the environmental footprint of packaging waste, with significant repercussions on ecosystems and human health, underscoring the urgent need for sustainable innovations in packaging materials. Alternatives such as paper, Paper bamboo or innovative materials such as bioplastics have started to be proposed as an innovative approach to packaging, aligning with the growing demand for green and sustainable products. However, all these innovative sustainable materials must still ensure safety standards, and current regulations often lag behind these advancements.

Consequently, as a result, cosmetic and packaging manufacturers often have to refer to non-specific but related regulations, such as those in the food industry. Indeed, despite their specificity, food and cosmetic packaging share numerous similarities and analogous risks: both food and cosmetic products come into direct contact with the packaging materials, raising concerns about potential chemical migration and the safety of the end consumer.

Focusing on the European industry of packaging, despite the pressing need for uniform regulations, there is currently a significant variance in the regulatory strategy adopted by the Member States of the EU. This divergence presents substantial challenges, hindering the smooth operation of the internal market for packaging. For this purpose, Directive (EC) n.62/94 was enacted with the aim of standardizing national regulations concerning packaging materials and waste management, promoting reuse, recycling, and other methods of packaging waste recovery, thus fostering the transition towards a circular economy [3]. In alignment with the principles set by this EU Directive, a strategy was launched in January 2018, the EU Circular Economy Action Plan (CEAP), including a focus on plastics [4]. In particular, this strategy is designed to enhance the sustainability of plastics by promoting recycling, reducing the use of single-use plastics, and fostering innovation in plastic production and design. The importance of this focus lies in the fact that plastic is widely used throughout various industrial sectors, including cosmetics packaging, due to its versatility, cost-effectiveness, and durability. Nevertheless, despite its widespread utility, plastic poses significant environmental and health risks [5].

Plastic packaging can introduce contaminants or impurities into the cosmetic product, compromising its safety and efficacy. Meanwhile, consumers expect cosmetics to be safe for use, both in terms of efficacy and potential health risks.

In view of the premises, it is clear that regulatory bodies and industry stakeholders play a key role, not devoid of consistent challenges, in the transition to packaging sustainability. As a result of these challenges, the EU Commission has recently proposed a new regulation aimed at reducing the environmental impact of specific plastic products [6], and it is still working on providing a more detailed legislative framework. This review aims to provide an overview of the various aspects related to cosmetic product packaging, offering insights into potential advancements and challenges.

Initially, a general description of the main cosmetic container materials, such as plastic, glass, paper, and aluminum, will be given. Afterwards, a description of existing EU legislation frameworks governing the packaging of cosmetic products will be done, including chemical, food and waste regulations. The paper also discusses recent EU regulatory proposals as well as guidelines from trade associations for improving the sustainability of cosmetic packaging materials. Additionally, it will examine the role of recycled and bio-based packaging materials in promoting environmental sustainability, with a particular emphasis on the migration of substances from the container to the formulation.

2. Cosmetic Packaging

Cosmetic packaging is all about keeping the product safe against light and microbiological contamination, while also serving as a key element in marketing strategies. The type of container impacts both user convenience and consumer safety by affecting the accuracy of the delivered dose [7].

Primary packaging constitutes the immediate enclosure of the product, coming into direct contact with its contents. It serves as the first line of defense against external factors such as moisture, light, and air, which may compromise the product's stability and efficacy. Common materials used in primary packaging include glass, plastics, metals (mainly aluminum), and composite materials designed to meet specific product requirements. These materials must exhibit suitable barrier properties, inertness, and compatibility with the product to prevent contamination and maintain its quality throughout its shelf life. Primary cosmetic packaging comes in a variety of shapes and sizes, including attractive cylindrical tubes for lip gloss, compact square jars for creams, elegant pump bottles for lotions, and convenient stick sizes for deodorants and solid perfumes.

Secondary packaging encompasses the outer layer surrounding primary packaging, providing additional protection during handling, transportation, and storage. Its primary function is to enhance the structural integrity of the primary containers, safeguard against mechanical damage, and facilitate efficient handling and identification. Cardboard, corrugated board, paperboard, and various types of plastics are commonly employed in secondary packaging due to their durability, flexibility, and printability. Additionally, secondary packaging may incorporate features such as cushioning materials, seals, and labeling to further ensure product safety and compliance with regulatory standards. Secondary cosmetic packaging typically includes a range of sizes and shapes, such as rectangular boxes designed to snugly fit perfume bottles, square cartons for creams and serums, and cylindrical tubes for mascara, all crafted to enhance protection, display, and branding appeal.

Tertiary packaging involves the consolidation and containment of multiple units of primary or secondary packaging for bulk transportation and distribution. It serves as a protective barrier against external hazards such as moisture, temperature fluctuations, and physical impacts during transit. Tertiary packaging materials are typically robust and cost-effective, prioritizing efficiency and sustainability in supply chain logistics. Common materials include pallets, stretch wrap, shrink wrap, corrugated fiberboard containers, and reusable shipping containers, selected based on factors such as weight, volume, and mode of transportation [8]. Figure 1 illustrates the three primary types of cosmetic packaging.

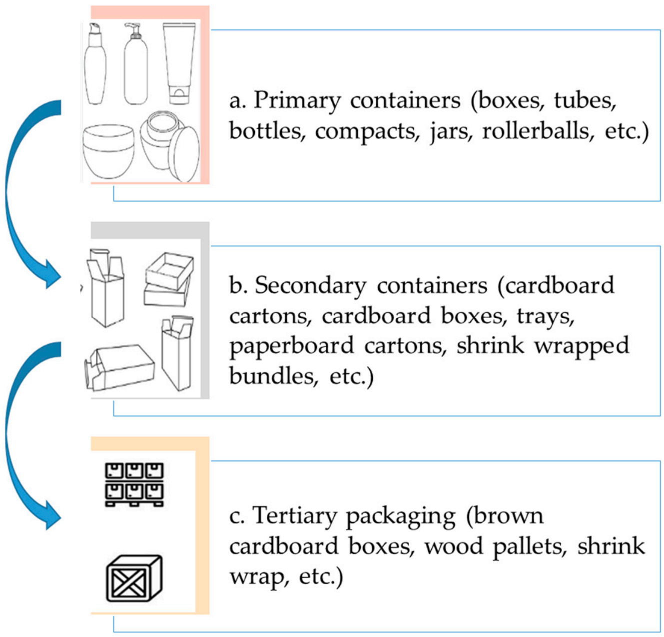

Figure 1. Types of cosmetic packaging: (**a**) primary packaging, which directly contains the product such as bottles, tubes, and jars; (**b**) secondary packaging, which includes the outer wrapping or box that encases the primary package for additional protection and branding; (**c**) tertiary packaging, used for bulk handling, storage, and distribution, typically including larger boxes and pallets.

Special attention must be given to the interactions between the content and packaging, commonly referred to as container–content interactions (CCI). CCI studies, prevalent in the food and pharmaceutical sectors, examine the potential migration of molecules from packaging to product, which can affect product quality, efficacy, and consumer safety. Hence, food product legislation plays a pivotal role in the cosmetic industry by aiding in container selection [9].

2.1. Glass

Glass, being an inert material, is the preferred choice for cosmetic packaging due to its zero migration properties, ensuring the integrity of the cosmetic formulation. Its transparency, color variety, decorative potential, impermeability, chemical integrity, design flexibility, heat stability, microwave compatibility, etc. further justify its extensive use in the food and beverage industry [10]. Moreover, its unique attributes position glass as an excellent material for pharmaceutical packaging [11]. In the European Pharmacopoeia, there is a chapter on glass containers for pharmaceutical use [12].

From a recycling standpoint, it is also an excellent material, as glass can be recycled indefinitely without losing its properties. Recycling glass saves energy and environmental resources. However, despite its advantages, glass packaging has several drawbacks, the first of which is its weight, which makes it heavier than plastic and cardboard, resulting in heavier transport, which causes more emissions of CO_2. Another inconvenience arises when transporting fragile glass bottles or jars, as they might be subjected to rough handling and could potentially shatter, leading to messy spills and the risk of injuries. Furthermore, glass packaging may not be ideal for products like face creams or lotions that are frequently used in the bathroom, where moisture and humidity can accumulate, leading to slippery surfaces and increasing the likelihood of accidents. In addition, glass containers are not suitable for items for babies or pets that need to be lightweight and safe from breakage, just as in the food industry.

2.2. Paper

Cosmetic companies are increasingly turning to paper as a material for cosmetic product packaging due to growing consumer demand for eco-friendly alternatives. Paper packaging is perceived as a green and low-impact solution because it is easily recyclable and biodegradable. However, while paper offers certain advantages, it also presents challenges and considerations that must be addressed.

Paper packaging aligns with consumers' desire for sustainable and environmentally friendly products. Brands that adopt paper packaging can enhance their image as environmentally responsible companies, potentially attracting environmentally conscious consumers. However, it is essential for companies to ensure that their paper packaging truly embodies sustainability principles, addressing issues such as recyclability, sourcing, and environmental impact throughout the entire lifecycle of the product. Indeed, while paper containers may seem eco-friendly, they often require a plastic film lining to ensure product integrity and prevent contamination. This plastic layer adds complexity to the recycling process and raises questions about the overall environmental impact of paper-based packaging solutions. Cosmetic companies must balance the need for product protection with their sustainability goals when choosing packaging materials.

Notably, recycling paper packaging involves significant water consumption and energy usage, particularly in the pulping process [13]. Moreover, the presence of plastic components complicates the recycling process, as separating the paper from the plastic can be technically challenging and economically unfeasible. Cosmetic companies need to invest in innovative recycling technologies and work collaboratively with waste management facilities to improve the recyclability of paper-based packaging. Moreover, to address concerns about deforestation and habitat destruction, cosmetic companies must ensure that the paper used for packaging comes from responsibly managed forests certified by organizations like the Programme for the Endorsement of Forest Certification (PEFC) or the Forest Stewardship Council (FSC). Sourcing paper from certified forests helps mitigate environmental impacts and supports sustainable forestry practices [14,15].

Overall paper packaging has inherent limitations compared to other materials like plastic and glass. It is not waterproof, which can pose challenges for products that are sensitive to moisture or require airtight sealing. Additionally, paper packaging is generally not reusable, unlike some plastic or glass containers that can be repurposed or refilled, leading to potential waste generation. However, ongoing research and innovation in paper packaging technology have recently expanded the possibilities for cosmetic companies. New advancements in barrier coatings and material engineering are improving the performance of paper-based packaging, making it more suitable for a wider range of cosmetic products while maintaining its sustainability credentials [16].

2.3. Aluminum

Aluminum is an excellent packing material, offering a formidable shield against air, light, temperature fluctuations, moisture, microorganisms, and odors. It remains neutral in taste, capable of housing volatile components and preserving aromas. Its lightweight nature facilitates ease of handling; indeed, approximately 11% of global aluminum production finds application in packaging, of which 75% is dedicated to food, 8% to cosmetics, 7% to pharmaceutical products, and 10% is allocated to various other industries [17]. In cosmetic packaging, aluminum tubes are ideal for creams and lotions, while aluminum bottles are commonly used for shampoos and conditioners.

Aluminum jars preserve thicker products like waxes, while aluminum cans offer lightweight protection for aerosol-based items. Aluminum compacts provide sleek packaging for powders and eyeshadows. Bottles with spray pumps maintain the quality of perfumes, while aluminum sachets offer convenience for single-use or sample-sized products. Aluminum foil packaging ensures stability by creating barriers against moisture, light, and air. These diverse options demonstrate aluminum versatility in meeting the packaging needs of the cosmetics industry. Notably, aluminum is highly recyclable, making it an environmentally friendly choice. Additionally, aluminum packaging helps extend the shelf life of cosmetic products by protecting them from external factors that can degrade their quality.

While aluminum packaging offers numerous benefits, it also carries drawbacks, particularly concerning its environmental and social impact. Mining for aluminum can result in deforestation, pollution, and human rights violations in countries like Malaysia and Guinea. The energy-intensive process of bauxite extraction damages local habitats and can lead to habitat loss, soil erosion, and water contamination. Additionally, waste generated during aluminum production poses bioaccumulation risks for aquatic life, affecting the broader ecosystem and potentially human health through the food chain. Moreover, the production processes and energy consumption associated with aluminum packaging contribute significantly to its "global-warming cost" compared to plastic alternatives [18]. Another drawback relies on the fact that aluminum, as a metal-based packaging material, is not entirely inert to food and cosmetic products; therefore, it requires the application of protective lacquers and coatings to prevent interaction between the container and the content, as well as the migration of metal components [19]. These coatings face challenges in maintaining integrity over long storage periods, meeting stringent regulatory requirements, and ensuring product visual appeal. Contamination can occur through extraction, interaction with substances, or delamination from the metallic substrate. Compounds such as alcohols and low-molecular-weight substances pose adhesion problems and may compromise product quality. Compliance with FDA regulations and European Parliament standards is essential, demanding coatings with chemical resistance, ductility, and adhesion properties. While liquid organic coatings currently dominate the market, the shift towards powder coatings is driven by environmental concerns and regulatory pressures. Powder coatings offer solvent-free application, shorter processing times, and potential cost savings, presenting a promising alternative for the future of cosmetic packaging [20].

Overall, innovations in barrier coatings and material engineering are elevating the capabilities of aluminum cosmetic packaging, ensuring its suitability for diverse product ranges while upholding its sustainability attributes.

2.4. Plastic

Plastics are ideal for packaging due to their lightweight, convenience, and affordability, as well as their many desirable properties, such as transparency, softness, heat seal ability, and a good strength-to-weight ratio. Even for cosmetic products, plastic is widely used for rigid and flexible packaging. Globally, over 30% of plastic production is used for disposable packaging [21].

In the packaging industry, petrochemical-based plastics such as polyethylene terephthalate (PET), polyvinyl chloride (PVC), polyethylene (PE), polypropylene (PP), polystyrene (PS), and polyamide (PA) have long dominated due to their abundance, affordability, reliable mechanical performance, and heat resistance. However, there is a growing interest in renewable alternatives like PLA, bio-PE, and bio-PET, reflecting a broader environmental consciousness. Yet, the cosmetics sector presents unique challenges demanding more than just eco-friendly or biodegradable materials. As in the food industry, packaging in the cosmetic industry must contend with product instability, requiring bioplastics with tailored functionalities [22,23].

More than 30 types of plastics are employed as packaging materials, often enhanced with additives to confer specific characteristics [7]. For instance, UV light protection additives are incorporated into transparent packaging to prevent product degradation through photoactivation processes. Dyes and pigments are included to enhance packaging aesthetics, while processing aids or antioxidants facilitate manufacturing processes and improve durability. Plasticizers can also be added to enhance flexibility. Recent research has explored the integration of nanoparticles, particularly nanocomposites of phyllosilicates, into plastic materials to bolster their barrier properties [24].

Additives, due to their lack of chemical bonding with the polymer, can potentially migrate from the container to its contents, posing a potential leachable. As a result, the potential release of plastic additives into cosmetic products during storage becomes significant especially if they can be dangerous for human health [25]. Additionally, elements like oxygen and water vapor can permeate packaging materials from the surroundings to the product.

Careful selection of packaging materials is crucial, taking into account their barrier properties against various compounds that may migrate either from the product to the packaging or vice versa. Such migrations can lead to alterations in product formulation, potentially impacting its efficacy. Furthermore, migration from product to container can affect the container's properties, compromising its strength and durability [9]. Moreover, the transfer of a compound from the container to its contents under normal usage conditions or extreme circumstances also includes Non-Intentionally Added Substances (NIAS) that have not been deliberately included for technical purposes and that can be potentially harmful. These substances may include impurities, degradation byproducts or environmental contaminants.

Given these premises and considering that cosmetic products are utilized daily by individuals of all age groups, careful monitoring of plastic additives in hygiene and beauty items must be carried out to ensure consumer welfare. According to Regulation (EC) n.1223/2009, toxicologists are responsible for evaluating packaging risks and potential contaminants in cosmetic products, which poses a significant challenge for the industry. However, it does not provide detailed guidance on the specific tests required for such evaluations. Therefore, appropriate strategies must be introduced to address these risks. This can be achieved by developing specific analytical tests and standard procedures that facilitate comprehensive toxicological assessments, thereby ensuring consumer safety.

It is evident how the legislation for materials in contact with food is of great assistance to the cosmetic sector, as it serves as a guide to protect consumer health even for cosmetic products that share similar chemical and physical characteristics with food. Similarly to food packaging, cosmetic packaging can also leach diverse contaminants based on content type, temperature, and duration of contact. Hence, tests for assessing material release properties and potential migration in cosmetic packaging are predominantly analytical and usually derive from standardized food packaging assessments. These tests aim to detect if plastic production additives, potentially harmful to human health, migrate into the product. A notable example is bisphenol A (BPA), a chemical compound primarily used in the manufacturing of various plastics that, being similar to 17β-estradiol, interacts with human estrogen receptors and, for this reason, has been banned in European cosmetic products and restricted in food items. Several methods for determining BPA in foodstuffs have been developed in the last 10–15 years [26] and can also be applied for monitoring the phenomenon of migration from cosmetic matrices. To assess the safety of contact materials by simulating real-world conditions and to predict the transfer of chemicals from the packaging into the product, both the food and cosmetic industries employ substitutes useful to mimic interactions with different types of products. Guided by regulations such as those set by the European Union, common simulants include water for aqueous environments, 3% acetic acid for acidic foods, 10% ethanol for alcoholic foods, and refined olive oil for fatty foods [27]. This approach is extended to cosmetic research, aiming to find substitutes that represent worst-case scenarios accurately while ensuring compliance with safety standards.

An illustrative example of a CCI study was conducted recently by P. Murat and colleagues. In this study, eleven potential cosmetic packaging materials (made up of PET, PE, PP and SAN) were evaluated using different simulating liquids. These types of packaging were put in contact with five simulants chosen to mimic cosmetics behavior to reinforce the safety evaluation of the cosmetic containers. Leachable was analyzed using a GC-MS method developed to screen for different phthalates. Some phthalates and BPA were detected in several samples, but only one contaminant, diisobutyl phthalate, was found to be above the set concentration threshold [9].

Other similar tests are reported in the literature aimed at checking levels of polycyclic aromatic hydrocarbons or heavy metals or carcinogenic, mutagenic, or toxic for reproduction (CMR) substances [25,28–30].

The plastics industry has historically prioritized production over recycling or reusing, leading to significant waste accumulation, particularly in packaging. Poor waste management contributes to millions of tons of plastic ending up in terrestrial and oceanic environments, with land-based sources being the primary contributors. Microplastic particles, formed through degradation, pose risks to marine life and can enter the food chain, potentially carrying harmful contaminants. Plastic pollution also has substantial economic costs, affecting industries like tourism, fishing, and shipping [31]. Even in recent years, there has been an increase in single-use plastics. However, the massive production of plastic packaging has led to environmental concerns, resulting in a shift to a circular economy of plastics that emphasizes reuse and recycling, a topic that will be discussed in more detail in Section 4 below.

3. Regulatory Aspects of Cosmetic Packaging in Europe

Regulation (EC) n.1223/2009 governs all aspects related to the composition, presentation, and requirements necessary for the production, sale, and import of cosmetic products. It consists of 40 articles and 8 annexes, including Annex I, which concerns the safety of cosmetic products and packaging [31]. Among all the articles, article 3 is one of the most important, stating that "*a cosmetic product made available on the market shall be safe for human health when used under normal or reasonably foreseeable conditions of use*". Article 10 indeed mandates that the Responsible Person ensure cosmetic products undergo a safety assessment in accordance with Annex I before being placed on the market. According to article 11, the Responsible Person must compile the Product Information File (PIF). The essential element of the PIF is the Cosmetic Product Safety Report (CPSR), which serves to demonstrate that a cosmetic product complies with Article 3 of the Regulation. Information on packaging, reported in the CPSR, is present in Annex I, part A, point 4 [31].

Packaging must not negatively impact the safety of the cosmetic formulation. It must also comply with the Packaging and Waste Directive and the requirements relating to EU legislation on chemical products [3,32–34].

Although there are no specific rules for the packaging of cosmetics, point 4 of Annex I, part A, requires the Safety Assessor (SA) to consider the potential impact of packaging on product safety. The SA must evaluate the potential migration of substances from the packaging to the formulation. However, since migration cannot always be avoided, Article 17 of Regulation (EC) n.1223/2009 allows for the unintentional presence of traces of a prohibited substance, provided Article 3 of the regulation and good manufacturing practices are observed [31]. The undefined concept of unintentional traces has posed challenges for manufacturers in drafting the CPSR, prompting the European Commission to publish guidelines on Annex I in 2013 [35].

In analyzing the regulatory aspects of packaging, it is necessary to also refer to EU regulations concerning the packaging of the substances and chemical mixtures used to create the finished product.

Regulation (EC) n.1272/2008 on the classification, labeling and packaging of substances and mixtures (CLP) applies to the raw materials that constitute cosmetic products, as these are considered chemicals. This regulation harmonizes the classification of substances and mixtures, as well as the rules related to labeling and packaging, to ensure a high level of protection for human health and the environment and the free circulation of the substances. The CLP Regulation requires cosmetics manufacturers to classify the substances in their products based on the hazard criteria established by the regulation itself, thereby guaranteeing consumer safety [32].

The fundamental elements of packaging containing chemical substances or mixtures, as specified in article 35 of the CLP, are resistance and robustness. In certain cases, the container must be equipped with a child-proof closure, and in others, it must bear a tactile danger warning [32]. These attributes ensure that the packaging provides a solid seal and does not loosen under the stresses encountered during handling. Additionally, the packaging must not attract children's attention or cause confusion among adults, as also reported in the Regulation 2023/988/UE on General Product Safety. Packaging, in fact, must not compromise the health and safety of the consumer; therefore, cosmetics must not be confused with food products due to their packaging [33].

Regulation (EC) n.1907/2006, concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), regulates the production, import and use of chemical substances, including cosmetic raw materials. Safety is of paramount importance as cosmetic products must be safe for use. REACH aims to enhance the protection of human health and the environment from the risks posed by chemical substances while also promoting the competitiveness of companies within the EU. Only substances registered in accordance with REACH are authorized for use in cosmetic products that can be marketed in the European Union [34].

Cosmetic products must also comply with Directive 75/324/EEC, which pertains to the harmonization of laws among Member States regarding aerosol dispensers. The person responsible for marketing cosmetic aerosol dispensers must affix the symbol 3″ (an inverted epsilon) to the dispensers, indicating that they meet the requirements of this Directive and its Annex [36].

3.1. Food Legislation as a Guide for Cosmetic Packaging

European legislation has established several regulations to define interaction and migration studies on packaging, depending on the type of product to be marketed. These include the European Pharmacopoeia [12] for medicinal products, Regulation (EC) n.745/2017 for medical devices [37], Regulation (EC) n.10/2011 [27] and Regulation (EC) n.213/2018 [38] for food and food contact packaging materials [8]. In contrast, the cosmetic sector lacks specific migration limits in its regulations. Consequently, as suggested in the guidelines on Annex I [35], cosmetic companies often rely on the food regulations regarding primary packaging namely on regulation EC n.1935/2004 and on regulation EU n.10/2011. Regulation (EC) n.1935/2004 concerns materials and articles intended to come into contact with food during production, processing, storage, preparation and serving to ensure their safety. For instance, primary packaging must not release or transfer its components into the food in a manner that could endanger the consumer's health or negatively impact the quality of the food itself [39].

Regulation (EU) n.10/2011 on food contact materials (FCMs) and materials and objects in contact with food addresses the specific safety of plastic materials and objects intended for food contact [27]. It includes a positive list of substances authorized for use in plastic materials and articles and imposes restrictions on migration limits (article 12), specifying the maximum allowed amount of migration. Many substances used in the production of FCMs have already undergone toxicological evaluation, primarily concerning ingestion. The scientific community agrees that ingestion poses a greater risk than skin contact. The regulation also includes the use of food simulants, substances that mimic the behavior and characteristics of certain classes of food. For cosmetic products, it is crucial to report the food simulants that have been used [27].

When compliance with food legislation cannot be guaranteed due to a non-permitted component or because it exceeds pre-established limits, this does not necessarily mean that the packaging is unsuitable for the cosmetic product in question. In such cases, the suitability assessment falls to the SA, who may use other standards, such as pharmaceutical ones, to verify whether the chosen packaging material is compatible with the cosmetic formulation. Indeed, cosmetic products often involve complex matrices that can differ significantly from food. Moreover, if manufacturers wish to use new and/or original containers, a more thorough evaluation of the materials and the container/formulation interaction is required. One critical aspect to investigate is microbiological safety, as plastics derived from waste are highly likely to be microbiologically contaminated. Recycled plastic must meet the same safety standards and composition requirements as virgin plastic and must comply with the migration limits and restrictions established by Regulation (EU) n.10/2011. Therefore, plastic waste must be decontaminated before reuse, using appropriate recycling technology to ensure that these materials meet safety standards [27].

Regulation (EU) n.1616/2022, concerning the marketing of materials and objects intended to come into contact with food products, includes specific provisions regarding the use of recycled plastic and new recycling technologies. Notably, plastic materials suitable for food contact can also be considered for cosmetic use. However, the use of recycled plastic materials is recommended only if strict safety requirements are met. This regulation specifies the recycling technologies appropriate for producing recycled plastic intended for food contact [39]. It also introduces a voluntary labeling system for food products packaged with recycled plastic, enabling consumers to easily identify such products and make informed choices [40].

Regulation (EU) n.1616/2022 is crucial given the priority of addressing environmental pollution from plastic, with the packaging sector being a major producer. Packaging is considered the main source of waste globally, often having a very short useful life, such as in the case of disposable plastic [41,42].

3.2. Guidelines from Industrial Associations

It must be noted that primary packaging is generally not produced by the cosmetic company itself but by external suppliers who are expert packaging manufacturers. Therefore, continuous interactions between the packaging industry and cosmetic companies is essential to ensure consumer safety.

To address regulatory gaps in cosmetic packaging, cosmetic industry associations have provided guidelines to manufacturers. In particular, in 2019, Cosmetic Europe published the Advisory Document on "Information Exchange on Cosmetic Packaging Materials Along the Value Chain in the Context of the EU Cosmetics Regulation (EC) n.1223/2009". This document aims to clarify and define the requirements of the regulation, enabling the SA to effectively carry out the safety report [25].

This advisory document proposes a methodology for the exchange of information between the cosmetics and packaging industries. There is no legal obligation for cosmetic manufacturers to use this information. According to this advisory document, all items and/or materials used to create the packaging must be accompanied by their general chemical composition. This allows the SA to evaluate the impact of the packaging on the safety of the cosmetic product.

It is essential to assess the characteristics of the packaging material, the interactions between the product and the packaging material, the barrier properties of the packaging material, and the migration of substances to and from the packaging material. These factors indicate potential dangers and allow the SA to estimate the associated risks. The SA must consider the composition of the material, including additives, technically unavoidable impurities, and possible migration from the packaging. Migration can also depend on storage conditions.

Cosmetics Europe has stated that it may be effective to refer to Regulation (EC) n.1935/2004. They note, "The materials developed for food packaging have often already been tested, and relevant information on stability and migration may be available. Consequently, further experiments may not be necessary. However, further evaluation may be required for new packaging" [25].

Indeed, it is mandatory for cosmetic packaging to comply with EU legislation on chemicals and packaging waste [3,32,34]. According to REACH, packaging companies must declare the presence of substances of very high concern (SVHC) by providing their identity if they are present in quantities equal to or greater than 0.1% w/w. They must also confirm that there are no heavy metals exceeding the limit of 100 ppm, as stipulated by the Packaging Waste Directive for the sum of the concentration levels of lead, cadmium, mercury, and hexavalent chromium. Additionally, packaging companies must provide appropriate documentation to the cosmetics company regarding banned substances or those subject to restrictions under Annex II and III of Regulation n.1223/2009, as well as substances classified as skin sensitizers.

To facilitate the preparation of the Product Information File (PIF), a packaging supplier is required to provide information on the packaging material, including the component name, type of material, and general chemical description [25]. Even in the case of migration, the cosmetics company can refer to tests already existing in the food sector, with specific limits set by EU or national legislation based on toxicity data for specific substances.

The rules for plastic materials used to create primary packaging in direct contact with food are established by Regulation (EU) n.1245/2020 of the Commission, which amends the 2011 regulation [43].

For materials such as paper, rubbers and printing ink, the rules for migration tests are established by national regulations or industry guidelines.

Migration tests can be performed on foods, food simulants, migration models, or estimated based on conservative assumptions or models. The SA must determine which method to use for migration testing and whether the results can be applied to the cosmetic formulation.

In the cosmetic field, certain chemical formulas, such as alkaline preparations used in hair care, cannot be represented by food simulants. When no appropriate simulants exist or if the migration evaluation with food-suitable simulants results in values exceeding the Overall Migration Limit and/or Specific Migration Limit, the "safe for food, safe for cosmetics" argument cannot be applied. In such cases, the packaging cannot be assessed as compliant with food contact regulations. Therefore, it is clear that a cosmetic container may not comply with food contact standards if it contains a substance not authorized for materials in contact with food or if the substance is used outside the restrictions established for such use. When cosmetics are not assigned to a food simulant, the cosmetics company relies on the opinion of an expert to assign an appropriate food simulator. The cosmetic industry can also refer to pharmaceutical standards as well as food and feed additives [43].

In general, because European legislation is still developing, member states have a certain degree of autonomy that allows for guidelines from industry associations. For example, in Italy in 2016, the Italian Packaging Institute presented the "Guidelines for the Definition of Packaging Characteristics as Part of the Safety Assessment of the Cosmetic

Product: Operational Suggestions for the Obligations Required by Regulation 1223/2009 on Packaging". These guidelines aim to provide SAs with the most suitable tools necessary for risk assessment and the compilation of the CPSR. The migration tests conducted with the alternative simulants proposed by the Cosmetic Packaging Commission take into account the actual conditions of use and packaging of the relevant cosmetic products [44].

More recently, Aliplast, a company specializing in the collection and recycling of plastic waste, in collaboration with Cosmetica Italia (the Italian Association of Cosmetic Companies), developed a white paper titled "Plastic Packaging in the Cosmetics Sector—Guide for More Circular Production". These guidelines provide recommendations for designing each type of plastic container (such as PET, PP, PE, etc.) to ensure maximum recyclability at the end of its life, in accordance with the standards set by RecyClass and SPICE. (Sustainable Packaging Initiative for Cosmetics), European initiatives by plastic recyclers and the cosmetics industry. This concise guide, intended for producers in the cosmetics industry, contains practical indications for designing easily recyclable cosmetic product packaging. The objective of the white paper and the partnership between Aliplast and Cosmetica Italia is to promote the development of aesthetically refined packaging that enhances the functionality of the product while being useful for waste elimination. While in the past, cosmetic product packaging struggled to balance aesthetic, commercial, and environmental considerations, today, the principles of a circular economy guide much of the innovation in the beauty sector [45].

The European Commission has adopted new EU Ecolabel criteria for cosmetics, providing consumers across the EU with reliable evidence of genuinely eco-friendly brands and supporting the transition to a clean, circular economy [46]. To assist consumers in properly disposing of cosmetic packaging, European legislation mandates that manufacturers include alphanumeric coding on the packaging. As chemical products, cosmetic packaging must also comply with the European recyclability requirements outlined in Decision (EC) No. 129/97 [47].

Given the complex legislative landscape, Table 1 has been created to provide a concise summary of all the different EU legislation frameworks governing cosmetic packaging.

Table 1. EU legislation frameworks regulating packaging of cosmetic products.

EU Legislative Framework	Regulation	Subject	[Ref]
COSMETICS	Regulation (EC) n.1223/2009	Regulation on Cosmetic Products - Annex I (Cosmetic Product Safety Report) - Annex II (Substances Prohibited) - Annex III (Restricted Substances)	[31]
	European Decision 25/11/2013	Decision on Guidelines on Annex I to Regulation (EC) n.1223/2009	[35]
	Industrial Guidelines	Cosmetic Europe (2019): Document on information exchange on cosmetic packaging materials along the value chain in the context of the EU cosmetics regulation EC n.1223/2009	[25]
		Italian Packaging Institute (2017): open work table of safety of cosmetic packaging	[44]
		Aliplast (2024): Cosmoprof 2024	[45]
	Regulation (EU) n.988/2023	General product safety	[33]
CHEMICALS	Regulation (EC) n.1907/2006	Regulation concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)	[34]
	Regulation (EC) n.1272/2008	Regulation on classification, labeling and packaging of substances and mixtures (CLP)	[32]
	Directive (EEC) n.324/1975	Aerosol dispensers	[36]

Table 1. *Cont.*

EU Legislative Framework	Regulation	Subject	[Ref]
FOOD	Regulation (EC) n.1935/2004	Regulation on materials and articles intended to come into contact with food	[39]
	Regulation (EU) n.10/2011	Regulation plastic materials and articles intended to come into contact with food (FCMs)	[27]
	Regulation (EU) n.1245/2020	Regulation on plastic materials and articles intended to come into contact with food	[43]
	Regulation (EU) n.1616/2022	Regulation on recycled plastic materials and articles intended to come into contact with foods	[40]
WASTE	Directive (EC) n.62/1994	Directive on packaging and packaging waste	[3]
	Proposal for a Regulation 2022	Proposal on packaging and packaging waste	[6]

4. Sustainable Cosmetic Packaging

In recent decades, the expansion of the cosmetics industry has led to the generation of a greater amount of waste at all stages of production and disposal. Consequently, the impact of the cosmetics industry on a sustainable environment is significant. Most cosmetic packaging is made of plastics and non-recyclable composites, which exacerbate the environmental impact. As these plastic materials degrade, they break down into microparticles known as microplastics. This issue is further compounded by the fact that in some types of products, microplastics can also originate from the ingredients themselves. The pervasive presence of microplastics in ecosystems poses potential harm to wildlife and human health, underscoring the urgent need for appropriate management of cosmetic waste [48].

For these reasons, there is a growing interest in sustainable cosmetic packaging solutions, such as biodegradable materials, recycled plastics, and minimalistic designs that reduce waste. For instance, some companies have pioneered the use of "naked" packaging, offering products like shampoo bars and solid lotions that require no packaging at all. Additionally, other brands utilize glass containers and recycled plastics for their products. Other practical examples are offered by circular shopping platforms that collaborate with important cosmetic brands to provide reusable packaging that consumers can return for cleaning and refilling. These initiatives not only help in reducing landfill waste but also conserve resources and promote a circular economy, reflecting a commitment to environmental responsibility and sustainability within the cosmetics industry. However, adopting circular economy principles requires several actions throughout the supply chain of cosmetic products, including reducing consumption, designing reusable and recyclable products, making production energy efficient, and improving recycling practices. The predominance of plastic in cosmetic packaging suggests that both bioplastics and plastic recycling can substantially contribute to sustainable packaging.

Currently, recycling faces challenges related to sorting and contamination, which impact the safety and cost of recycled materials. Advances in nanomaterial science offer promising solutions; rapid developments in recent decades suggest that nanoparticles could revolutionize packaging materials [49]. However, overcoming the economic barriers to recycled materials requires continued investment and legislative support. High costs are also attributed to the need for comprehensive management of environmental impacts, which involves considering the entire life cycle of products from sourcing to production. Educating consumers and businesses on life cycle thinking is also essential for promoting sustainable practices. Digitalization, a key component of the fourth industrial revolution, supports the transition towards a circular economy by digitizing the product life cycle through intelligent, interconnected web-based platforms. This approach enhances the productivity and efficiency of packaging from production to consumption, thus improving sustainability [50]. Moreover, the reuse and refill of packaging present viable alternatives to landfilling [22]. In the post-consumer phase, recycling, reusing, or refilling used packaging is preferable to landfill disposal. To create a circular economy, it is also necessary to reduce overall production, though this approach remains underutilized due to safety concerns [51]. Therefore, the adoption of circular economy principles involves a comprehensive strategy across the entire plastics supply chain, encompassing consumption reduction, product redesign, energy-efficient production, and improved recycling practices [52]. However, this approach is still underused due to safety uncertainties.

The EU Commission intends to ensure that by 2030 all packaging is reusable or recyclable in an economically sustainable way while substantially reducing waste production. In November 2022, the European Commission presented a proposal for a regulation amending Directive (EC) n.62/94 on Packaging and Packaging Waste, provided for by the "New Action Plan for the Circular Economy for a cleaner and more competitive Europe", presented in March 2020 [6]. This new regulation updates the regulatory framework respecting the rules relating to environmental protection and waste, reduces the use of virgin plastic, and develops a strategic framework for bio-based, biodegradable, and compostable plastic. This EU proposal aims to reduce packaging waste and encourage the reuse of packaging, through standardization of packaging formats and clear labeling of reusable packaging. It also aims to eliminate packaging, defined as "unnecessary", create mandatory return systems for plastic bottles and aluminum cans and mandate rates of recycled content that manufacturers will have to include in new plastic packaging.

An overview of the main aspects associated with the transition towards sustainable cosmetic packaging is shown in Figure 2.

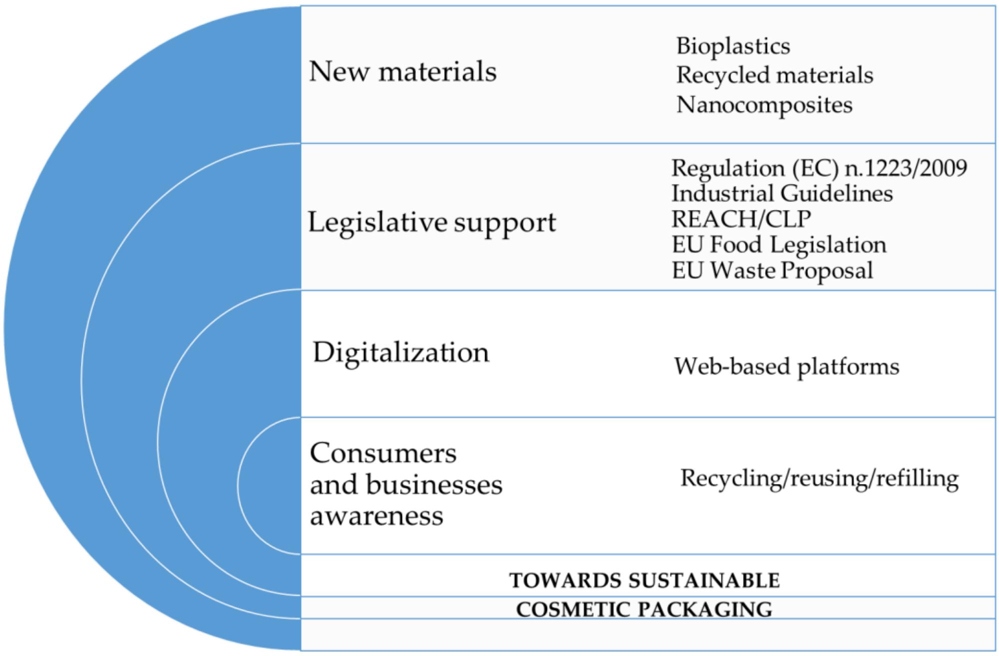

Figure 2. Key elements involved in the transition towards sustainable cosmetic packaging.

In the following two paragraphs, we explore sustainable packaging solutions, focusing particularly on the merits and challenges of bioplastics and recycled materials.

4.1. Bioplastics and Biopolymers

Bioplastics play a pivotal role in revolutionizing food and cosmetic packaging by offering sustainable alternatives to traditional plastics, thereby reducing environmental impact, and promoting the use of renewable materials. The term bioplastics covers a wide range of definitions and production techniques, including deriving monomers from renewable biomass, extracting polymers from biomass, biodegradability of the polymer, production via biological processes, or a combination of these factors. It is important to avoid labeling fossil-derived, degradable plastics as bioplastics.

Employing more precise terminology can improve comprehension. For example, bio-based durable PE is sourced from biomass but exhibits low biodegradability, whereas PBS is derived from fossil fuels yet is biodegradable. Furthermore, PHAs are both biodegradable and bio-based when cultivated from biomass-grown microorganisms. Additionally, PHAs are both biodegradable and bio-based when produced from biomass-grown microorganisms [53].

It is important to distinguish between biodegradation and composting, as compostability depends on specific microbial and chemical conditions. Additionally, it is crucial to understand that bio-based plastics are not inherently more environmentally friendly than fossil-based plastics. Sustainability depends on various factors throughout the product life cycle, such as how the raw materials are sourced, processed, and disposed of, which requires comprehensive life cycle assessments. Bioplastics are plastics made from natural materials, like plants, instead of fossil fuels. Bioplastics, derived from natural materials like plants, are perceived as environmentally superior but are often costlier due to a scarcity of resources and higher production energy. Farming for bioplastic plants can harm the environment, and disposal poses challenges due to inadequate recycling and composting infrastructure. In addition, competition with food sources is possible since some bioplastics use food crops, raising concerns about shortages.

In an ideal circular economy, plastics are sourced from renewable or recycled materials and produced in biorefineries able to convert biomass into valuable chemicals, categorized into first-generation (e.g., fermentable sugars from corn) and second-generation (non-edible biowastes) feedstocks [22]. However, a full transition from fossil-based to biomass plastics is presently improbable due to resource constraints, underscoring the necessity of decreasing consumption and enhancing recycling efforts.

Completely substituting global packaging plastics with bioplastics would demand significant agricultural resources, emphasizing the necessity for sustainable solutions that strike a balance between environmental impact and resource utilization. Moving towards a circular plastic economy entails utilizing renewable energy for both production and recycling processes. Advanced recycling methods transform plastic waste into valuable materials, utilizing biomass and pyrolysis oils as feedstocks. Future biorefineries strive to repurpose agricultural and food waste into resources, incorporating seaweed and plant-based monomers. Overcoming challenges involves enhancing conversion efficiency and refining processing techniques. Research focuses on improving pretreatment methods and developing robust microorganisms to streamline the transition towards renewable resources in biorefineries. Several methods have been explored for obtaining vinyl monomers, carboxylic acids, alcohols, amides, and rubbers from biomass [54]. Additionally, aliphatic polyesters, such as PLA, PBS, and PHAs, constitute a prominent category of bioplastics renowned for their degradability, rendering them suitable for various applications [55].

Despite their environmental benefits, challenges persist in scaling up bioplastic production and optimizing their properties for commercial viability. Nevertheless, ongoing research and advancements in biorefinery technologies hold promise for widespread adoption of bioplastics across various industries [16].

4.2. Recycled Packages: Strategies, Challenges and Future Directions

The ability to recycle a material depends on its inherent characteristics. Recycling can be categorized into four types based on the quality of the material produced (Figure 3). Primary recycling involves mechanically processing material into a product with identical properties to the original material. For instance, PET from used bottles can be used to manufacture new bottles. Secondary recycling yields a product with lower quality properties compared to the original material, such as producing synthetic fibers from PET bottles. Tertiary recycling, also referred to as chemical recycling, entails using the material to generate chemicals; for example, degrading PET into monomeric units for the production of virgin PET. Quaternary recycling involves utilizing waste material for energy production through incineration [56].

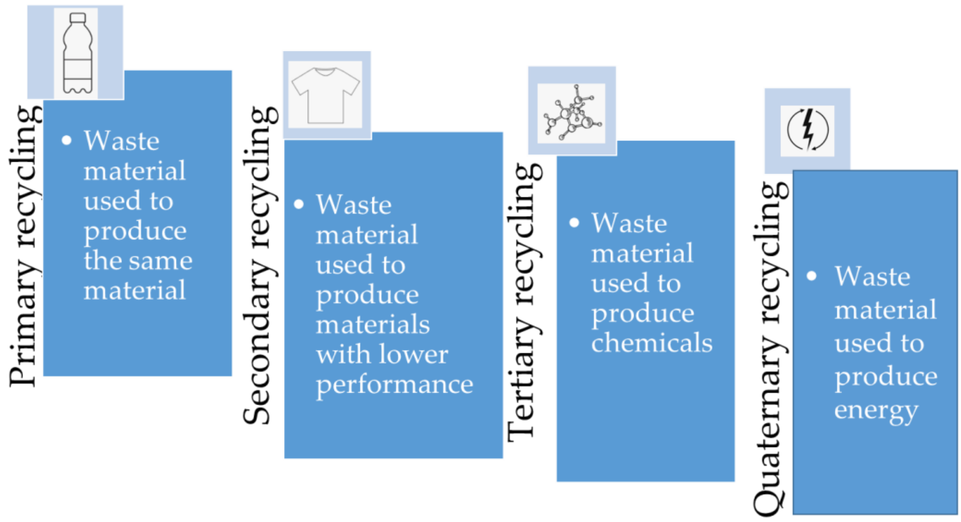

Figure 3. Recycling categories.

Metal and glass containers are permanently recyclable since their properties remain unchanged throughout the recycling process [22]. Materials like thermoplastics, paper, and paperboard undergo chemical alterations during recycling, potentially constraining their recyclability. For instance, recycled PET progressively experiences a reduction in some mechanical properties with each recycling cycle [13]. Nevertheless, recycling remains a crucial strategy for alleviating environmental degradation by lessening the need for new materials. The effectiveness of recycled plastic depends heavily on the quality and purity of the recycled compounds, which often change, affecting their usability. To meet functional requirements, recycled materials are frequently combined with new ones. However, recycling encounters significant challenges, including inefficient waste management systems, low recycling rates, and the presence of multiple components in recycled materials, all of which compromise their safety and usability. Another layer of complexity is added by the migration of chemicals from packaging to contents. This process involves diffusion through packaging materials and subsequent transfer to the product, influenced by factors such as initial concentration, size, solubility, and environmental conditions. In the realm of food safety, stringent regulations are in place, with specific limits established to safeguard consumers. These regulations aid scientists in studying the properties of cosmetic packaging in correlation with the behavior of the product it contains, which must possess similar characteristics to food. Current regulations governing recycled plastics in food contact materials are under review to ensure equal safety standards for both recycled and new materials. Compliance with these limits is verified using food or regulated food simulants. These simulated foods mimic real ones and possess different properties, such as being hydrophilic (water-attracting) or lipophilic (fat-attracting). Researchers test a variety of foods, including those with low fat content and high fat content. They have discovered that foods with higher fat content tend to allow certain substances, such as small particles and oily matter, to migrate into them more readily. Additionally, lighter molecules migrate faster, particularly under conditions of heat and prolonged storage. Paper and cardboard packaging generally facilitate greater substance migration into food compared to plastics like PE and PP, possibly due to their higher porosity. Among plastics, PET and PA exhibit lower rates of substance migration because they offer better barriers. However, even within the same type of plastic, molecules may migrate differently depending on the shape of the packaging. For instance, PET trays allow more migration of smaller particles compared to PET bottles, likely due to differences in shape. Thinner packaging also tends to facilitate faster migration. In October 2020, the European Commission unveiled a chemicals strategy aimed at enhancing the safety of recycled materials and products. This involves eliminating harmful substances, including endocrine disruptors, from everyday items like food packaging [57]. Two primary methods are commonly utilized to analyze the contents of food packaging: targeted and non-targeted approaches. In targeted analysis, scientists specifically search for predetermined substances, while in non-targeted analysis, they seek substances that were not previously anticipated, such as non-intentionally added substances (NIAS). NIAS occurrences are more common when recycled materials are utilized, as various components may become mixed during recycling processes or undergo degradation during recycling.

Recently, Van Velzen and colleagues investigated the contents of PET bottles made from different types of PET, including some newly produced and some recycled [58]. They combined recycled PET pellets with new ones in various proportions to manufacture the bottles. The analysis involved examining the composition of both pellets and bottle pieces for metals and chemicals. Antimony, cobalt, and chlorine were detected in the pellets, while chemicals like acetaldehyde and benzene were found in the bottles, primarily originating from PET heating during bottle production. Furthermore, certain chemicals inherent to PET manufacturing were identified. Interestingly, bottles made from new PET exhibited similar chemical levels, suggesting minimal impact from recycled PET. Another study by Horodytska and colleagues explored the composition of recycled pellets from plastic bags and cleaning product containers [59]. The analysis unveiled a diverse array of chemicals, derived from plastic additives and other contaminants. Moreover, contact between certain foods and packaging materials resulted in chemical breakdown and alteration over time [60]. As with recycled food packaging, since packaging plays a crucial role in the preservation of cosmetics, evaluating the quality of recycled cosmetic packaging is of paramount importance. This assessment entails identifying and measuring the materials as well as any unintended substances that may originate from production or recycling processes.

5. Conclusions

With the rise in environmental consciousness among consumers, the cosmetic industry is increasingly seeking more sustainable packaging options, such as bioplastics or recycled materials. This shift towards eco-friendly packaging highlights that sustainable solutions not only reduce waste but also enhance brand trust and loyalty. Nonetheless, this transition poses challenges in terms of material availability, safety and cost-effectiveness. Additionally, standardized labeling and certification for sustainable packaging are essential to ensure transparency and consumer safety.

Packaging safety for cosmetics is concisely outlined in Regulation (EC) n.1223/2009. Currently, to choose the appropriate packaging, regulations on chemical substances, food regulations, and industrial guidelines assist cosmetic and packaging companies with regulatory aspects. The EU Commission is also working on proposed regulations for the recycling and reuse of packaging to promote sustainability while maintaining competitiveness and innovation.

Therefore, the transition of the cosmetics industry to sustainable packaging practices and safety standards requires close collaboration among regulatory bodies, trade associations, and companies. To achieve this goal, it is crucial to establish rigorous standards and certification processes.

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Abbreviation

BPA	Bisphenol A
CCI	Container-Content Interactions
CEAP	Circular Economy Action Plan
CLP	Classification, Labeling and Packaging
CMRCPSR	Carcinogenic, Mutagenic, or toxic for ReproductionCosmetic Product Safety Report
FCMs	Food Contact Materials
FDA	Food and Drug Administration
FSC	Forest Stewardship Council
NIAS	Non-Intentionally Added Substances
PA	Polyamide
PBS	Polybutylene succinate
PE	Polyethylene
PEFC	Programme for the Endorsement of Forest Certification
PET	Polyethylene terephthalate
PHAs	Polyhydroxyalkanoates
PIF	Product Information File
PLA	Polylactic acid
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl chloride
REACH	Registration, Evaluation, Authorisation and restriction of Chemicals
SA	Safety Assessor
SAN	Styrene acrylonitrile copolymer
SVHC	Substances of Very High Concern

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