Universidade de Lisboa

Faculdade de Farmácia

The upcycling life cycle for cosmetic products

Ana Maria Sobral Gonçalves Tojinha da Silva

Monografia orientada pela Professora Doutora Joana Marques Marto, Professora Auxiliar da Faculdade de Farmácia da Universidade de Lisboa e coorientada pela Doutora Ana Margarida Martins, Investigadora da Faculdade de Farmácia da Universidade de Lisboa.

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Trabalho Final de Mestrado Integrado em Ciências Farmacêuticas apresentado à Universidade de Lisboa através da Faculdade de Farmácia

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Resumo

Os cosméticos desempenham um papel importante no quotidiano das pessoas, com expressão nos cuidados pessoais e higiene e na satisfação de necessidades estéticas e culturais. Contribuem para o incremento da imagem e autoconfiança, impulsionando a sensação de bem-estar dos consumidores.

Nos últimos anos, tem havido um interesse crescente no desenvolvimento sustentável da indústria cosmética, partilhado por empresas de produção, laboratórios de investigação e desenvolvimento (I&D) e consumidores. Este interesse é alimentado pela crescente consciencialização dos consumidores para a importância de produtos amigos do ambiente, ao procurarem ativamente alternativas sustentáveis que contribuam para um estilo de vida mais saudável.

Os desafios da sustentabilidade estão presentes em todas as fases do ciclo de vida de um produto cosmético. Obter uma compreensão abrangente de cada fase é essencial para desenvolver estratégias que promovam ativamente a sustentabilidade no setor. O *upcycling* tem vindo a ganhar popularidade na indústria cosmética, permitindo reutilizar subprodutos e minimizar o desperdício. Com o aumento da perceção dos consumidores em relação ao impacto ambiental e às origens dos produtos cosméticos, o *upcycling* emergiu como uma tendência proeminente. Uma das principais preocupações neste processo é garantir o fornecimento sustentável de ingredientes, com foco na gestão de resíduos e subprodutos gerados pelas indústrias agroalimentares. Estes subprodutos contêm frequentemente compostos bioativos valiosos que podem ser utilizados na indústria cosmética. O desenvolvimento de estratégias para valorizar estes compostos é vital para reduzir resíduos e maximizar recursos.

Outras abordagens de sustentabilidade são exploradas nas fases subsequentes, incluindo estratégias para otimizar a produção, valorizar os resíduos de plástico, reduzir a pegada de carbono da indústria através de práticas inovadoras, como a captura de dióxido de carbono para a produção de combustível durante a fase de distribuição, e educar os consumidores sobre hábitos de consumo sustentáveis.

Esta tese explora o conceito de sustentabilidade, em particular o papel do *upcycling*, na indústria cosmética no sentido da prossecução e alcance de objetivos ambientais, focando-se nas abordagens implementadas pelas empresas ao longo de todas as fases do ciclo de vida de um produto cosmético, bem como na adoção de novas estratégias que possam contribuir para melhorar o desempenho do setor.

Palavras-chave: Indústria Cosmética; Sustentabilidade; *Upcycling*; Economia circular.

Abstract

Cosmetics play an important role in people's everyday lives, serving practical purposes for personal care and hygiene and fulfilling aesthetic and cultural needs. They contribute to consumers' image, self-confidence, and well-being.

In recent years, manufacturing companies, scientific research and development (R&D) laboratories, and consumers have shared a growing interest in sustainable development within the cosmetics industry. This interest is fueled by the consumers increasing awareness of the importance of environmentally friendly products, as they actively seek sustainable alternatives that contribute to a healthier lifestyle.

Sustainability challenges are present throughout every phase of a cosmetic product's life cycle. Gaining a comprehensive understanding of each phase is essential for developing strategies that actively promote sustainability within the sector. Upcycling has been gaining popularity in the cosmetic industry to reuse by-products and minimise waste. With increased consumer awareness about the environmental impact and the origins of cosmetic products, upcycling has emerged as a prominent trend. One of the primary concerns in this process is sustainable ingredient sourcing, which focuses on managing waste and by-products generated by the agro-food industries. These by-products often contain valuable bioactive compounds that can be utilised in the cosmetics industry. Developing strategies for recovering and valorising these compounds is vital for reducing waste and maximising the use of resources.

Other sustainability approaches are explored in the subsequent phases, including strategies to optimise production, valorise post-consumer plastic waste, reduce the industry's carbon footprint through innovative practices, such as carbon dioxide capture for fuel production during distribution, and educate consumers on sustainable consumption habits.

This thesis explores the concept of sustainability, particularly the role of upcycling in the cosmetics industry in achieving environmental goals, focusing on the approaches implemented by companies in all the phases of a cosmetic product lifecycle and on new strategies that contribute to improving the sector's performance.

Keywords: Cosmetic Industry; Sustainability; Upcycling; Circular economy.

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Por último, às minha amigas, pela compreensão e motivação em todos os momentos.

Abbreviations

CES – Consumer Electronics Show

EU – European Union

GLAM – Green Last Mile

GMP – good manufacturing practices

GP – grape pomace

GS – grape seed

OMWW – olive mill wastewater

OP – olive pomace

PA – poly(amide)

PE – poly(ethylene)

PET – poly(ethylene terephthalate)

PIF – product information file

PP – poly(propylene)

PS – poly(styrene)

PVC – poly(vinyl chloride)

R&D – research and development

SCG – spent coffee grounds

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1 Introduction

Cosmetics and the cosmetics industry play a significant role in our society. According to a research study presented by Cosmetics Europe in 2022, 72% of European consumers indicated that cosmetics and personal care products were either important or very important in their everyday lives. Furthermore, 71% reported that cosmetics and personal care items improved their quality of life (1). According to Regulation (EC) No. 1223/2009 of the European Commission, a cosmetic product is "any substance or mixture intended to be placed in contact with the external parts of the human body (epidermis, hair system, nails, lips and external genital organs) or with the teeth and the mucous membranes of the oral cavity with a view exclusively or mainly to cleaning them, perfuming them, changing their appearance, protecting them, keeping them in good condition or correcting body odours" (2).

In recent years, the cosmetics industry has been increasingly concerned about the sustainability of its products. According to a study by the Personal Care Products Council, 68% of customers feel that product sustainability is crucial when making a purchase, and 66% are willing to pay more for products that have beneficial environmental and social impacts (3). With the increased consumer awareness of social and environmental problems, there is more pressure than ever to shift towards more sustainable production and consumption patterns (4).

Each phase of a cosmetic product's life cycle impacts its sustainability, from the design to the post-consumer phase. Understanding each phase is crucial to developing and implementing strategies that contribute to improving the sector's sustainability (5).

The cosmetics industry is shifting towards longer-lasting, more effective, and environmentally friendly products. Upcycling is an emerging trend, a great strategy for addressing sustainability in industrial processes, contributing to a circular economy. Upcycling, also known as creative reuse, is the practice of repurposing waste resources into new products or materials that are of higher quality and positively influence the environment. The primary goal of this method is to decrease waste production and reduce environmental impact. Many byproducts of the fruit and vegetable processing industries that are typically discarded contain high levels of bioactive compounds, such as vitamins, minerals, and phenolic compounds that can be incorporated as cosmetic ingredients (6).

A circular economy reduces waste by reusing, repairing, refurbishing, and recycling existing materials and products. By maximising their value while in use and recycling them at the end of their useful life cycle, it intends to maintain materials and products in use for as long as feasible. Therefore, it is an essential strategy to conserve the environment and resources and lessen the need for virgin materials while achieving sustainable growth (7,8).

The cosmetics industry may make several efforts in this area, not only by selecting sustainable ingredients for formulations, but also by paying closer attention to manufacturing processes and decreasing water consumption (7,8).

2 Objectives

This thesis aims to analyse the main sustainability aspects to be considered along the life cycle of a cosmetic product, from the design and supply of raw materials, throughout the manufacturing process, packaging, and distribution, to the use and post-use phases. Furthermore, it will explore the initiatives that have already been implemented, or that can still be implemented by the cosmetics industry throughout the product's life cycle to achieve a more circular economy.

3 Materials and Methods

The elaboration of this thesis was based on the analysis and interpretation of several scientific articles, as well as several pages on the Internet, such as European Commission (available at: https://ec.europa.eu/info/index_en), Cosmetics Europe (available at: https://cosmeticseurope.eu), Cosmetics Design Europe (available at: https://www.cosmeticsdesign-europe.com), Cosmetics Design North America available at: https://www.cosmeticsdesign.com), Cosmetic&Toiletries (available at: https://www.cosmeticsandtoiletries.com), among other brands' websites.

Considering the timeliness of the topic, most of the bibliography used spans from 2018 to the present. However, some bibliography predates this timeframe.

Keywords such as cosmetic products, cosmetic ingredients, production, packaging, sustainability, product life cycle, circular economy, and upcycling were employed for this research.

4 Cosmetic products

Cosmetics have been used for thousands of years. Cosmetic products are part of our daily lives in a way that we hardly notice. From the toothpaste we use many times a day to the soap we use to wash our hands, all these products are cosmetics and are part of an enormous industry. Nowadays, most consumers use cosmetics and personal care items daily to contribute to their well-being and health and boost their self-esteem (9). According to Cosmetics Europe, there are seven categories of cosmetics and personal care products - oral care, skin care, sun care, hair care, decorative cosmetics, body care and perfumes (9) (Figure 1).

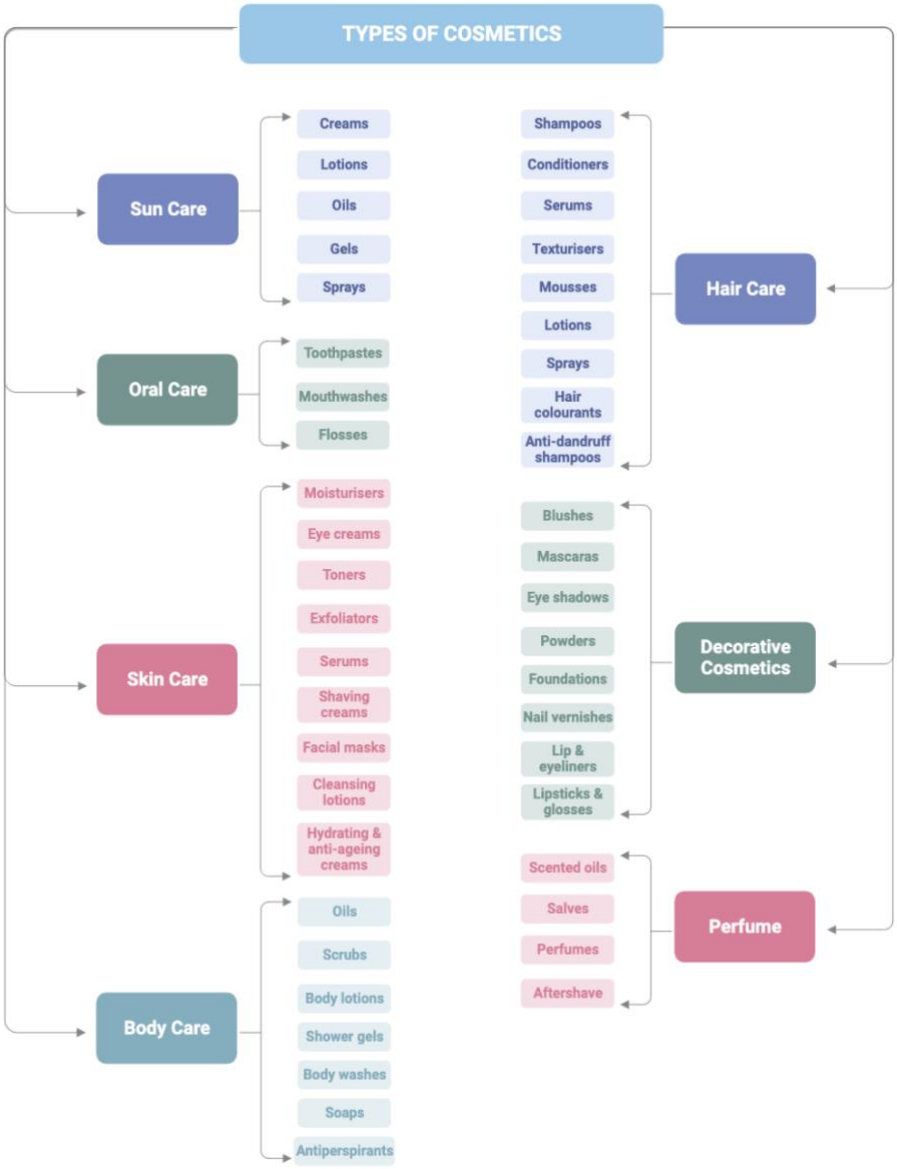

Figure 1. Types of cosmetics. Adapted from (9).

The results of the European Consumer Perception study published by Cosmetics Europe in 2022 showed that the average European consumer uses more than seven different cosmetic products per day and about thirteen per week, including several of the categories shown in Figure 1. In addition, the study also revealed that, on average, women use nine cosmetic items every day and fifteen every week. Furthermore, the male perception of the importance of different types of cosmetics – from skin care, sun care, and body care to perfume and makeup – grew by an average of 5.5% compared to 2017 (1).

4.1 Cosmetic Regulatory Framework

The primary legislation governing cosmetics sold in the European Union (EU) is Regulation (EC) No. 1223/2009, which permits the free circulation of safe cosmetics and protects consumers' public health (2).

The introduction of a cosmetic product on the market follows a well-established circuit and involves providing information to the competent authorities about identification, quality, safety, and claims. Concerning safety, requirements include a safety report demonstrating the safety assessment (2).

To ensure that all the obligations established in the regulation are fulfilled, it was necessary to define a responsible person, who is accountable for monitoring the product's entire life cycle and ensuring that the process complies with good manufacturing practices (GMP) and that the cosmetics placed on the market are safe (2).

The product information file (PIF) consists of a dossier with technical information about each cosmetic product. It contains the product description, its safety report, manufacturing method and GMP compliance, proof of the alleged effects of the product and data obtained on animal tests (2).

The PIF is mandatory for all products marketed in the EU, being drawn up and kept up to date by the responsible person. Whenever requested, the PIF must be immediately available to the Member State's competent authority where the file is located. The responsible person must keep the PIF for a period of ten years, counting from the date on which the last batch was placed on the market (2).

4.2 Cosmetic Claims

Cosmetic product claims are marketing tools companies use to distinguish their products from competitors and are often linked to their performance.

Regulation (EC) No 655/2013 on the common criteria for the justification of claims was created to encourage a common approach to claims across the EU, to provide end users with a high level of protection against misleading claims and to provide competent Member States authorities with a legal basis for market control decisions (10). Six equally important Common Criteria were defined:

(1) Legal compliance: Cosmetic products cannot claim that the product has been authorised or approved by the competent authorities or that it has a beneficial action when it only results in compliance with the very minimum legal criteria (10).

(2) Truthfulness: Claims of the presence of ingredients are only valid if they exist in the formulation. Similarly, an ingredient must not be present if the label states it is not. When a product is made with a certain ingredient, but the final product does not have the same properties as that ingredient, these properties cannot be claimed. Claims must distinguish expressions of opinion from verified claims and must always consider the target audience's ability to understand (10).

(3) Evidential support: Claims concerning cosmetic products, expressed or implied, must be based on adequate and verifiable evidence. The substantiation of the evidence for the claims must consider state-of-the-art practices. Whenever studies are used as evidence, they must be relevant to the product and the alleged benefit. They must comply with methodologies (valid, reliable, and reproducible) that are well-designed, well-conducted, and that respect ethical considerations (10).

(4) Honesty: Product performance presentations must not exceed available supporting evidence (e.g., electronically manipulated images). If the claims are linked to specific conditions of use (e.g., the use of two products in combination), this fact must be clearly stated (10).

(5) Fairness: Claims relating to cosmetic products must be objective, not denigrating competitors or legally used ingredients (10).

(6) Informed decision-making: The consumer should be able to make an informed choice of a product. For this, the marketing claims must ponder the ability of

the target public to understand them, being clear, understandable, precise, and relevant (10).

4.3 Statistical Data

In 2022, the European cosmetics industry was valued at €80 billion, making Europe the leading global market for cosmetic products in the world, alongside the United States (€80 billion), followed by China (€70 billion) (11) (Figure 2).

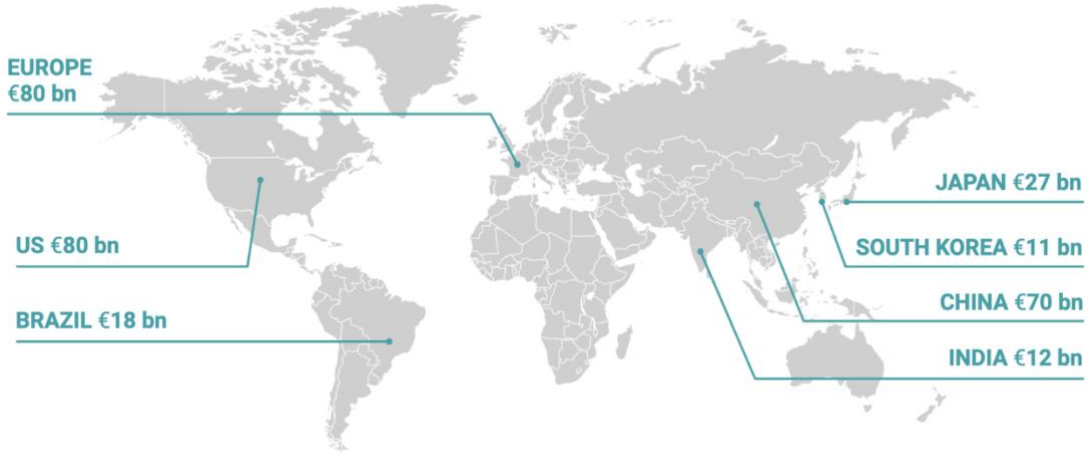

Figure 2. Global market for cosmetic products. Adapted from (11).

Within Europe, Germany is the country with the largest market for cosmetic products, with an estimated value of €14.3 billion in 2022, followed by France with €12.9 billion, the UK with €10.5 billion, Spain with €9.3 billion and Poland with €4.5 billion (11) (Figure 3).

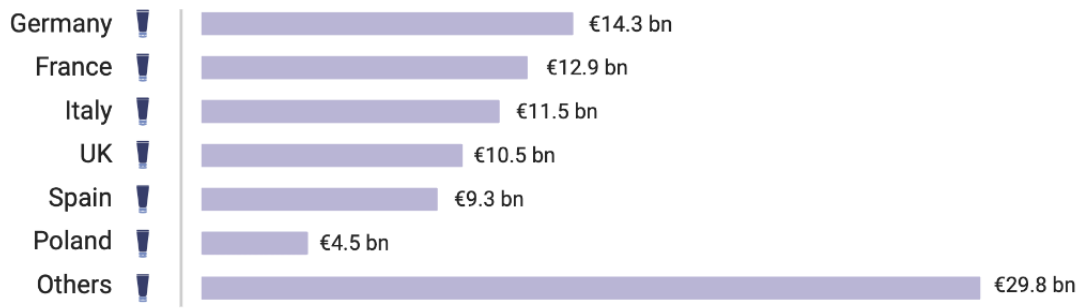

Figure 3. European market for cosmetic products. Adapted from (11).

The most significant product categories in the European market are skin care (€25.6 billion) and toiletries (€21.5 billion), followed by hair-care products (€15.7 billion), fragrances/perfumes (€14.0 billion), and decorative cosmetics (€11.5 billion) (11).

The cosmetics and personal care industry is one of the most innovative and research-intensive sectors, with companies investing heavily in research and development to create new and innovative products. This industry is driven by scientific advancements and consumer demand for new and improved products (12).

Leading companies in the cosmetics industry dedicate a significant part of their annual revenue to research and development (R&D), typically amounting to around 5% of their turnover within Europe, with the estimated total expenditure on R&D in Europe reaching €2.35 billion in 2017. Such R&D investments not only fuel innovation and product advancement but also foster industry growth and enhance competitiveness (12).

Innovation plays a vital role in the cosmetics industry, being a dynamic process. Developing a new product can require more than five years of dedicated research and formulation. However, the innovation journey does not stop there. Each year, approximately a quarter of cosmetic products on the market undergo improvements or are entirely new, reflecting a continued commitment to innovation and improvement (12).

Patent activity is an essential indicator of innovation in the industry. In 2009, 10% of all patents awarded in the EU were for cosmetic products, highlighting the industry's significant contribution to innovation. Patenting new formulations, ingredients, and technologies is a way for companies to protect their innovations and stay competitive in the market (12).

Around 30,040 scientists from diverse fields such as physics, microbiology, biology, toxicology, physiology, rheology, nanoscience, analytical chemistry, and genetics are employed in the European cosmetics and personal care industry. This industry places a strong emphasis on research, evident by the existence of at least 77 dedicated scientific innovation facilities in Europe focused on cosmetics and personal care research in 2018 (12) (Figure 4).

Figure 4. Number and location of scientific innovation facilities in Europe conducting research in the field of cosmetics. Adapted from (12).

With thousands of companies, the cosmetics industry is a significant economic sector in Europe, with over 3,6 million employees, including people employed directly, indirectly and through induced effects (11).

5 Sustainability in the cosmetics industry

5.1 Sustainability

The concept of sustainability is not new, but, due to its complexity, it can be quite ambiguous. Although there are multiple definitions and interpretations of sustainability, the Brundtland Commission's definition, originally introduced in the 1987 report "Our Common Future," is the most widely accepted. This report defines sustainable development as the "development that is able to meet the current needs of the population without compromising future generations to meet their own needs" (13).

The Commission's report emphasises three sustainability dimensions (13):

(a) Environmental dimension: requires the preservation of the natural capital without the degradation of source and sink functions of the environment.

(b) Social dimension: requires that the cohesion of society and its ability to work towards common goals be maintained.

(c) Economic dimension: implies financial viability, while development moves towards social and environmental sustainability.

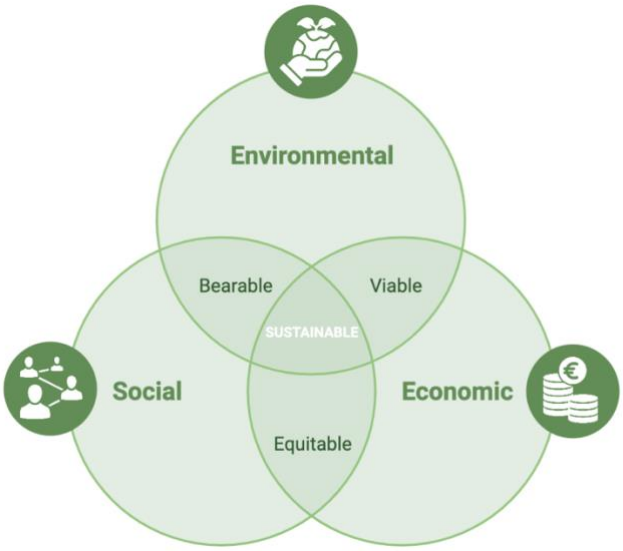

Figure 5. Dimensions of sustainability. Adapted from (4).

The document titled "Agenda 21", published in 1992, states that the primary causes of environmental degradation are production and consumption patterns. Therefore, it proposed implementing a new development model to replace conventional production and consumption standards with sustainable ones (14).

Nowadays, the media frequently emphasises the significance of sustainability, seeking to raise customer awareness about environmental and social issues and encouraging the purchase of sustainable products. As a result, cosmetic companies are consistently striving to enhance the sustainability of their practices and products (4).

5.2 Sustainable Cosmetics

The ambiguous use of some terminologies referring to cosmetics is likely to cause misunderstanding, making it difficult to differentiate between the meanings of terms like “green”,” natural”, “organic”, and “sustainable” cosmetics. Therefore, it is crucial to emphasise the distinction between these concepts (4).

Terms like “green”, “natural”, and “organic” solely apply to the product’s ingredients’ origin and type of agricultural practices. For example, green cosmetics use natural and biological plant-based ingredients rather than synthetic chemicals such as parabens, phthalates, and sodium lauryl sulfate, among others. Thus, these categories do not always imply that the products are “sustainable” (4). On the other hand, the term “sustainable” refers to a product designed with the environment in mind throughout its entire life cycle, from manufacture and distribution through waste disposal. Although the term “sustainable” does not have a universally accepted meaning when referring to cosmetics, these products have environmentally preferable characteristics and ethical, social, and economic responsibilities (4).

6 Upcycling during the cosmetic product life cycle

To promote sustainability within the cosmetics industry, it is necessary to adapt and innovate towards the development of more sustainable products and processes. This should be done while prioritising consumer safety and complying with relevant legislation (4).

To address sustainability in cosmetics products, all the life cycle phases must be considered. This includes the design and sourcing of raw materials, manufacturing, packaging, distribution, consumer use, and post-consumer use phases (Figure 6). By focusing on each phase, we can better understand the fundamental factors for promoting sustainability (4).

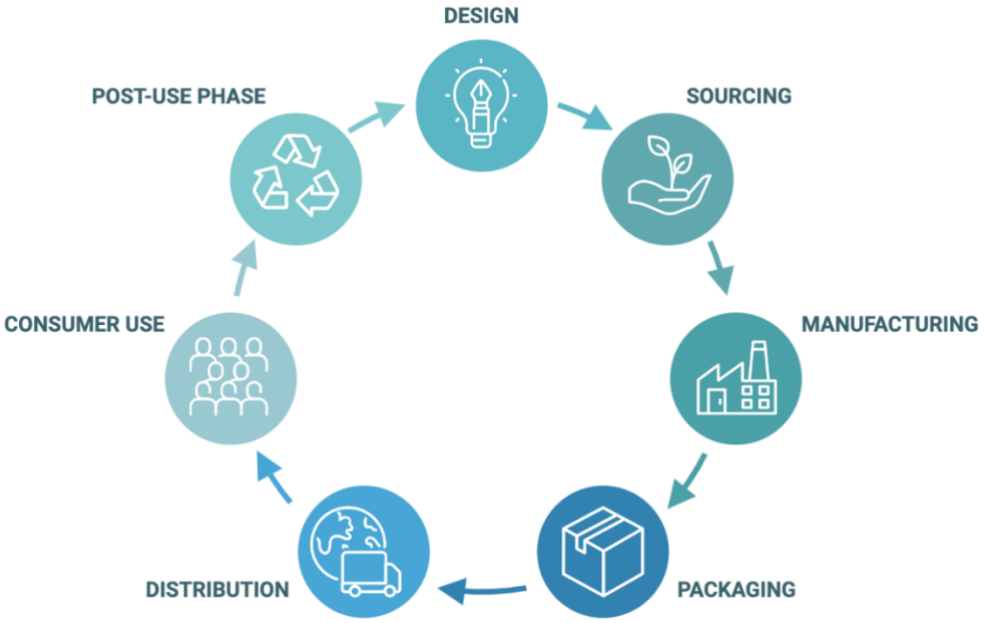

Figure 6. Cosmetic product life cycle. Adapted from (4).

6.1 Design

The sustainability of a cosmetic product is affected by each phase of its life cycle. However, among all the phases included in a cosmetic product's life cycle, design deserves special attention since the actions taken during this stage will impact all subsequent phases, greatly contributing to the product's sustainability profile (15).

A recent study revealed that sustainability is most affected by the design and raw material selection phases, each having a 16% impact. Meanwhile, the production, packing, and post-use phases had a 14% impact each, while the distribution and consumer use phases had a 13% impact. These findings underscore the significance of prioritising sustainability from the design phase, although the exact proportion may differ depending on the product type (16).

6.2 Sourcing

Many cosmetic companies are adopting a new strategy to use sustainable and natural ingredients instead of synthetic ones. This pursuit of sustainable ingredients demands that supplier companies continually expand their range of products and explore valuable ingredients from various sources, including residuals or waste from industrial production, especially the agro-food industry (17).

The agro-food industry has significantly contributed to the increase in industrial residues over the past few decades. According to the Zero Waste Beauty Report of 2022-2023 by The Upcycled Beauty Company, 1.3 billion tonnes, or one-third of the total amount of food produced worldwide, is wasted (18). This includes both waste that is rejected because it is not regarded aesthetically beautiful enough for supermarkets and waste produced during the food processing procedures. The discarded by-products include seeds, stems, leaves, and skins, which account from 3% to as high as 60% of the total plant food. Finding the most efficient and environmentally friendly extraction techniques to obtain high yields without affecting the stability of the extract and its components is the primary challenge when using these by-products (19,20).

A wide variety of food waste, particularly fruit, vegetable, and grain waste, can potentially be used to generate sustainable cosmetic components. Coffee, olives and grape industry by-products are examples of food waste that has been used over the last years in cosmetic products (Table 1). Due to their widespread consumption, these components' waste has a harmful impact on the environment and the economy. The potential for recycling this waste could lessen this impact and optimise the cosmetic ingredients' sustainability (19).

The ongoing disposal of valuable nutrients like proteins, antioxidants, and dietary fibres into the environment is not a sustainable practice within the food industry's sustainability framework and economy. With the global population expanding, it is

essential to explore alternative solutions to prevent the depletion of our food sources (21).

Table 1. Ingredient upcycling as an approach for developing more sustainable cosmetic products (22–34)**.**

Source	Company	Upcycled ingredient	Properties	Applications
Spent coffee grounds	UpCircle Beauty	Coffee oil	Hydrates, nourishes and repairs the skin barrier	Face and body care
	Givaudan and Kaffe Bueno	Koffee'Up™ (coffee oil)	Addresses early signs of ageing, improves skin hydration, and strengthens the skin barrier against external aggressors	Face care
Coffee bean silverskin	Mibelle Biochemistry	SLVR'Coffee™	Increases skin hydration and protects the skin from stressors	Active ingredient for skin care cosmetics
Coffee cherry	Sanam and Flora Reserve	Naox® Derma	Antioxidant, anti-inflammatory and anti-ageing properties	Active ingredient for skin care products
Byproducts of olive oil industry	Circumference	Extracts of olive leaves	Skin regenerative effects	Facial cleansing products
Grape pomace	Caudalie	Resveratrol	Anti-aging, anti-wrinkle and firming properties	Face care
Distilled patchouli leaves from the fragrance industry	Givaudan	Patchoul'Up™	Restores scalp microbiome and decreases dry flakes while regulating sebum production	Hair care

Bilberry seed	Givaudan	Omegablue®	Hydration, skin barrier restorations	Face and body care
	Pai Skincare	Billberry seed extract	Strengthens the skin barrier and soothes the skin	Face care
Downgraded avocados	Laboratoires Expanscience	Number 6 (avocado polyphenols concentrate)	Reduces dark circles and depuffs under-eye bags	Solid bar for eye contour
Damaged or misshapen bananas (yellow, pink and green bananas)	Kadalys	Yellow banana bioactive	Addresses early signs of ageing, by offering lifting, firming, and regenerating properties	Face, body and hair care
		Pink banana bioactive	Boosts the skin's radiance and promotes a more unified complexion	
		Green banana bioactive	Purifying and balancing proprieties, improves skin texture	
Plum kernel	Le Prunier	Plum oil	Plumps, hydrates, and brightens the skin	Face, body and hair care

6.2.1 Coffee industry byproducts

Coffee is a highly popular beverage globally and holds significant commercial value. The consumption of coffee worldwide reached nearly 10 million tonnes in 2020/2021, experiencing an annual increase of approximately 1% since 2017 (35). Each year, around 9 million tonnes of ground coffee are brewed, resulting in approximately 18 million tonnes of wet spent coffee grounds (SCG) (36). Unfortunately, most of this waste is disposed of in landfills, posing environmental risks as it generates methane and other greenhouse gases during the composting process (37).

Only around 30% of the mass of a coffee bean (*Coffea arabica*) can be converted into the beverage we consume; as a result, a larger portion becomes used coffee grounds, which are primarily discarded as trash. SCG reuse has drawn much attention, particularly in recent years. Over the last few years, technologies have been developed to modify this approach and turn SCG into value-added materials (38).

Certain companies in the cosmetics sector have begun to embrace the concept of upcycling by developing ingredients derived from coffee by-products. UpCircle Beauty, a London-based company, uses upcycled SCG in most of its products, which it obtains from local London cafés. They offer a variety of coffee-based products, including face and body scrubs (22). The French company Givaudan, and Kaffe Bueno, a Danish start-up company, collaborated to develop a coffee oil from discarded SCG, named Koffee'Up™ (23).

Coffee silverskin is a by-product of roasting coffee that results from the detachment of a thin, silver-coloured protective layer that surrounds the beans. Numerous studies have suggested that coffee silverskin contains various antioxidant compounds like chlorogenic acids (1-6%), caffeine (0.80-1.25%), and melanoidins (17-23%). These bioactive compounds have numerous beneficial effects on the skin, specifically can increasing hydration levels, help prevent skin ageing, as well as possessing soothing and antimicrobial properties (39). SLVR'Coffee™, developed by Mibelle Biochemistry, is the first upcycled ingredient based on coffee silverskin. Studies have demonstrated that this ingredient enhances skin resistance by boosting the skin barrier's functionality, reducing TEWL (transepidermal water loss), and increasing skin hydration (24).

In addition to SCG and coffee silverskin, the coffee industry also discards approximately 60% of the coffee cherry (coffee fruit) after removing the seeds (coffee

beans). However, the coffee fruit is a rich source of antioxidants, thus, there is interest in its upcycling. Sanam's, a Colombian company, and Flora Reserve recognised this and produced a pulp extract called Naox® Derma. This extract has been shown to possess anti-ageing, anti-inflammatory, and antioxidant properties that are excellent for cosmetic products (25).

6.2.2 Olive oil industry byproducts

Olive oil production is one of the most significant industries in most Mediterranean countries, with a significant economic impact. Olive tree (*Olea europaea* L.) is a traditional plant whose fruits are used for olive oil production, especially in Mediterranean countries. However, the several by-products derived from olive oil extraction can become a major environmental issue (40). These by-products are mostly leaves, olive pomace (OP), olive stones and olive mill wastewater (OMWW). As the demand for olive oil increases, there is a push to find sustainable uses for its byproducts, especially since some are non-biodegradable (41). These materials are a source of natural compounds, including antioxidants, fatty acids, and minerals that can be used as ingredients in the cosmetics industry. Olive leaves are particularly abundant in antioxidants, such as flavones, flavonols, flavan-3-ols, substituted phenols and secoiridoids (40).

Circumference, a beauty brand launched in 2018, partnered with the company Brightland Olive Oil for their Waste-Not Sourcing Initiative to upcycle organic olive oil by-products into skin care products. An example is their regenerative gel cleanser, whose key bioactive ingredient is an olive extract derived from upcycled olive leaves (22).

6.2.3 Grape industry byproducts

The grape industry and related ones (such as wine) also generate numerous by-products that other industries can use. Grapes are one of the world's most valuable crops, with an annual production exceeding 60 thousand tonnes. Approximately 80% of grapes are used for producing wine, creating substantial amounts of organic and inorganic residues, residual water, and greenhouse gases, whereas 20% of processed grapes remain as pomace (42). Grape pomace (GP) is an important solid waste generated from pressing and fermentation processes in wine industries. GP may be separated into two

fractions: seedless pomace, which is made up of pulp, skin, and stem, and grapeseed (GS). GP represents approximately 20% of the original weight of the grape (43). Pomace is a great source of phenolic compounds like phenolic acids and flavonoids. (43).

Caudalie's resveratrol is an example of a phenolic compound that is upcycled from winemaking and that can be an alternative to conventional antioxidant ingredients, having anti-ageing, anti-wrinkle and firming properties (26).

6.2.4 Others

Patchouli (*Pogostemon cablin*) is a sought-after ingredient in the world of perfumery because of its distinct woody and earthy aroma, with hints of tobacco and camphor.

Patchoul'Up™, a 100% upcycled active ingredient, has been introduced by Givaudan to help normalise the scalp microbiome, rebalance sebum production, and eliminate dry flakes. The ingredient is responsibly sourced from Indonesia and is created using green fractionation from distilled patchouli leaves that have already been used to extract essential oils for the fragrance industry (27).

Givaudan has also introduced Omegablue®, an ingredient that is derived from upcycled bilberry seeds. Although bilberries are traditionally used by the food industry for their juice and sugar, they are also a valuable source of anthocyanidins extracted from the pulp and fruit skin for the supplement and pharmaceutical industries. Additionally, the small seeds of the berries contain up to 20% of linoleic acid (omega-6) and α-linolenic acid (omega-3) in an ideal ratio, which are recognised for their ability to enhance hydration and improve skin barrier function (28). Pai Skincare, a company founded in 2007, also utilises upcycled bilberry extract, which is derived from seeds discarded by the juicing industry (29).

Laboratoires Expanscience has developed a new active ingredient for the eye contour using by-products from the avocado fruit. Number 6, their 6th ingredient upcycled from avocados, is sourced from avocados deemed unsuitable for the food industry. It is an aqueous active ingredient (a concentrated polyphenol extract) extracted from avocados sourced from Latin America (Peru). Number 6 is used in concentrations of 1 to 3% in products for the eye contour. Studies showed that Number 6 acts, on the one hand, on the microcirculation in the fragile eye contour area and regulates pigmentation to reduce

dark circles. On the other hand, it also reduces the fatty deposits at the origin of the eyebags (30,31).

Another example of upcycling comes from the French company Kadalys, founded in 2012. Kadalys takes misshapen or unsightly bananas that are usually discarded and creates bioactive ingredients for use in skin care products. The company works with banana growers in Guadeloupe and Martinique to ensure quality and safety through traceability, sustainable and fair-trade agricultural practices. Kadalys' bioactives are oily extracts obtained from the peel and pulp of green, yellow, and pink bananas using a patented extraction method. These bioactives are upcycled ingredients that have many benefits and can be used in cosmetic products to nourish the skin and hair. The brand's focus on sustainability has earned it recognition from the industry, including the 2021 Sustainable Beauty Awards (32,33).

Le Prunier is a luxurious skincare brand run by three sisters who are committed to creating sustainable beauty. Their family-owned California plum farm, established in 1916, is the foundation of their brand. They discovered the skin benefits of their organically grown fruit and began producing Plum Beauty Oil from the plum kernels, a waste byproduct of the farm, to eliminate waste and use sustainable plum-based ingredients. Plum oil is rich in vitamins and antioxidants, which plump, hydrate, and brighten the skin. This oil is suitable for use on the face, hands, body, and hair (34).

6.3 Manufacturing process

Cosmetic product manufacturing is an essential part of their life cycle. It is crucial for the cosmetics industry to reduce their manufacturing impact to a greater extent, to respect the planet and comply with the commitment to address the environmental pillar of sustainable development (5).

When setting goals, cosmetic companies should prioritise reducing their carbon and water footprints by minimising water and energy consumption and reducing waste (5). Despite significant progress, there is still potential for companies to decrease the environmental impact of the cosmetics industry (5).

6.3.1 Waterloop factories

Water is essential for all Earth's living beings. Bearing in mind the risk of water scarcity in some regions of the planet due to population and economic growth, the management

of this resource becomes a challenge to be addressed by companies when planning their operations (44).

Water plays a vital role in the cosmetics industry, being used for washing processes, cooling, and, to a great extent, incorporation into products. In fact, among all the raw materials, water is the most used in the formulation and production of cosmetics (44).

Acknowledging the significance of efficiently managing this valuable (yet finite) resource, numerous cosmetics companies have begun to assess and track the quantity of water used throughout the manufacturing process (44).

To prepare for potential water scarcity risks and reduce water consumption within the cosmetics industry, companies can implement circular water management practices. These transform the linear use of water, which leads to increasing contamination and wastewater, into a circular system where water is recirculated and continually reused. At the plant level, circular water management should follow the 5Rs approach: reduce, reuse, recycle, restore, and recover (45) (Figure 7).

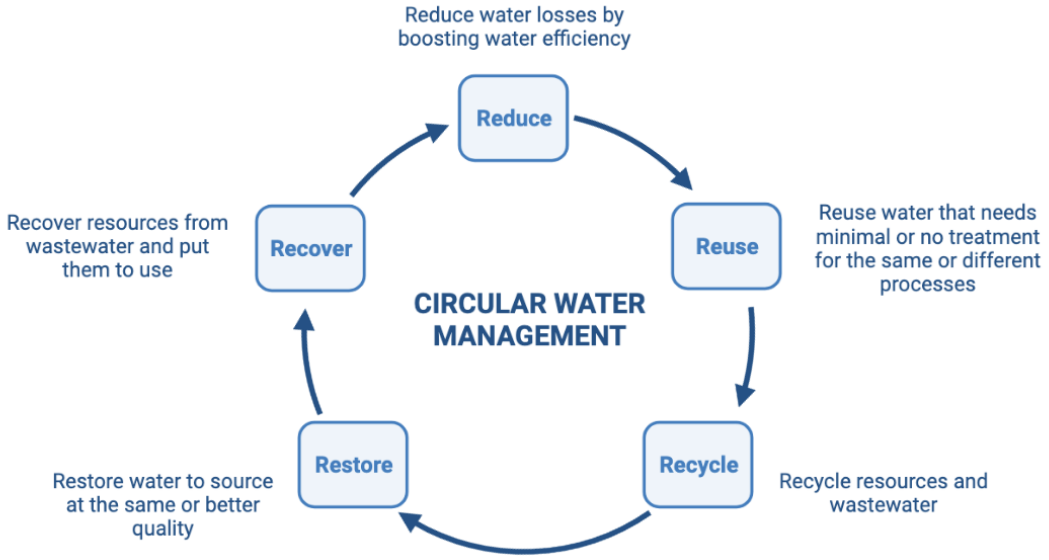

Figure 7. Circular water management. Adapted from (45).

L'Oréal, one of the largest cosmetics companies in the world, has been making strides towards sustainability. Their "waterloop factories" are part of their sustainability initiative, which aims to reduce the company's environmental impact while increasing efficiency and productivity. These factories are specifically designed to reuse and recycle water, making them one of the most sustainable industrial facilities in the world (46,47).

The “waterloop factory” concept was adopted for the first time in 2017 by the L’Oréal Burgos factory in Spain. The "waterloop" standard is achieved in a factory when all the water required for industrial processes like equipment cleaning, steam production, and utilities is obtained from water retreated, recycled, and reused in a loop on site. This approach eliminates the need for public or municipal water supply, except for human consumption or product ingredient purposes, and has obvious financial benefits (46,47).
The L’Oréal Progress Report 2019 states that wastewater recycling in “waterloop factories” is achieved through a combination of ultrafiltration/reverse osmosis (membrane filtration) and evapoconcentration (distillation), ensuring a biological and physicochemical treatment of used water (effluent water) to obtain clean water (raw water). The system implemented in these factories allows for an average of 200 m^3 of water to be reused daily, totalling 60 million litres per year. This is equivalent to the yearly water consumption of 600 families (46).
L’Oréal currently has six "waterloop factories” and plans to implement this approach in all its 39 factories by 2030, with a focus on regions with water scarcity or inadequate supply infrastructure (47).
Overall, L’Oréal’s “waterloop factories” are a great example of how companies can prioritise sustainability in their business operations.

6.4 Packaging

Packaging plays an important role in promoting economic, environmental, and social sustainability by safeguarding products from damage or spoilage, facilitating efficient business operations, and ensuring that consumers can enjoy the full benefits of the product. Ultimately, the primary objective of packaging is to deliver the product to the end user in pristine condition. Furthermore, for some products, the packaging is also crucial in making them look appealing and desirable to consumers (5). Thus, sustainable packaging is an important consideration for designers, who must balance consumer appeal with environmental responsibility when creating designs that are both attractive for consumers and eco-friendly (5).
The Packaging and Packaging Waste Directive is the main regulation governing packaging in the EU. This Directive was first introduced in 1994 and sets out common standards for packaging aimed at facilitating trade and reducing the environmental impact (48).

Plastics play a crucial role in many aspects of our daily lives, but unfortunately, their improper disposal and handling have led to serious pollution problems worldwide. The plastic waste crisis is one of the most pressing environmental challenges of our time, and it is crucial that we find ways to repurpose post-consumer plastic waste and transition to a more circular economy (49).

Plastics are extensively used in packaging due to their desirable characteristics like transparency, softness, heat sealability, and impressive strength-to-weight ratio. Therefore, even cosmetic products are packaged using plastics, either as rigid or flexible packaging (50).

Petrochemical-derived plastics like poly(ethylene terephthalate) (PET), poly(vinyl chloride) (PVC), poly(ethylene) (PE), poly(propylene) (PP), poly(styrene) (PS), and poly(amide) (PA) are widely used in the packaging of cosmetics, due to their abundance, affordability and excellent mechanical properties. Moreover, these plastics act as effective barriers to oxygen, carbon dioxide, anhydride, and aroma compounds (50).

While some advances have been made in PET recycling and degradation technology, most of these solutions focus on using the resulting monomers to create more PET or other second-generation materials. It is critical to keep investigating ways to make the most of this abundant resource and reduce our reliance on single-use plastics (49).

A recent study (49) reported an innovative technique that uses engineered *Escherichia coli* to convert terephthalic acid, a monomer derived from PET, into vanillin (Figure 8). This small molecule has a wide range of applications in the cosmetics and food industries.

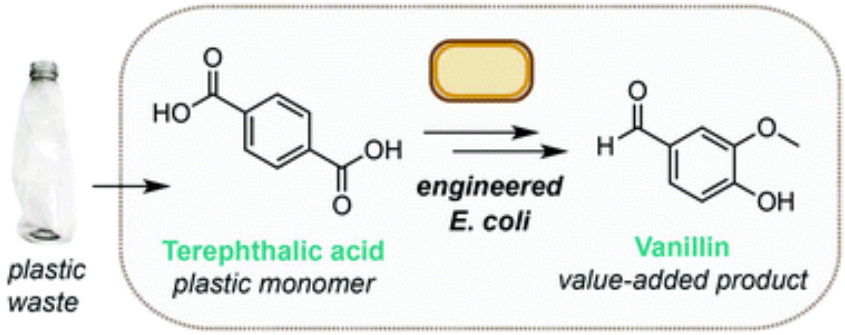

Figure 8. PET upcycling into the value-added compound vanillin. Adapted from (49).

This method of vanillin production from waste PET has several advantages, including the use of a low-cost and abundant raw material, the reduction of environmental pollution by converting waste into a valuable product, and the potential to meet the increasing demand for vanillin in the cosmetic industry. The study discusses the potential of this process to be scaled up for industrial use. The microbial synthesis of vanillin from PET waste could be a viable solution for reducing PET waste and producing a valuable product. However, certain challenges still need to be addressed before this method can be fully optimised for industrial-scale production, in particular, the low yield of vanillin. Therefore, optimal conditions for maximising vanillin production from waste PET must be further evaluated.

Despite the challenges, the microbial production of vanillin from waste PET is an exciting field of study that can potentially transform the production of this valuable compound. Utilising affordable and abundant raw materials like PET could offer a sustainable and eco-friendly source of vanillin, decreasing dependence on natural resources and promoting the circular economy.

6.5 Distribution

One more determining factor of cosmetic product sustainability is the transportation of ingredients, materials, packaging, and final products. In the distribution phase, the main factor at stake is the combustion of fossil fuels that releases carbon dioxide (CO_2), a greenhouse gas that contributes to global warming (4,5).

To minimise emissions associated with cosmetics transportation, the industry is adapting its distribution practices. Companies are shifting from road to rail and from air to sea and introducing hybrid or electric vehicles. Some have also consolidated their distribution networks to reduce distances between centres and retailers, while others use mega-warehouses to reduce unnecessary journeys. Using larger container trucks and compact products has also helped reduce the number of journeys required. These products, which are smaller in size and volume than conventional products, require less packaging and enable more units to be transported simultaneously, which results in reduced greenhouse gas emissions during distribution (15).

In 2019, L’Oréal launched the Green Last Mile (GLAM) programme to reduce its environmental impact in urban areas. This initiative was implemented in selected regions based on the delivery volume. In Brussels, L’Oréal teamed up with Proximus,

a Belgian telecom company, to deliver telecom products, such as smartphones, accessories, and routers and hair salon products, using electric bicycles. The collaboration aims to minimise carbon dioxide emissions and enhance the customer experience by offering fast and eco-friendly delivery options (51,52).

With the help of a second partner, this programme was launched in May 2020 through three divisions: L'Oréal Professional Products, Active Cosmetics, and Consumer Products, in Anvers and Brussels, increasing the number of deliveries using electric bicycles, particularly to pharmacies. Between November 2019 and October 2020, they were able to make about 2,500 deliveries in more than 270 places of sale due to this innovative project (51).

The transportation sector poses a significant challenge in reducing CO_2 emissions as part of the energy transition. While electric vehicles show promise as a sustainable alternative to fossil fuels, the limited storage capacity of their batteries can pose a challenge. An alternative is switching to bio-based fuels, which are promising and sustainable alternatives. However, producing biofuels requires a significant amount of land that may compete with food production (53).

A recent study has explored how a circular economy approach can be applied to fossil fuels, particularly in relation to reducing carbon dioxide emissions. This approach involves capturing CO_2 emissions, rather than simply releasing them into the atmosphere (53).

First, the vehicle's exhaust gases are cooled, and the water is separated from the gases. Then, through a process called "temperature swing adsorption", CO_2 is separated from nitrogen, oxygen and other gases with an adsorbent material. When the adsorbent material becomes saturated with CO_2, it is heated to extract the CO_2 and convert it from the gaseous state to the liquid. Carbon dioxide in liquid form is thus stored in a storage tank and can then be delivered and transformed into fuel at service stations using renewable electricity (53).

6.6 Consumer use

The environmental impact of cosmetic products is significantly influenced by their use phase, which varies greatly across different categories of products. The use phase particularly contributes to the sustainable impact of rinse-off or wash-off cosmetic products such as shampoos, conditioners, soaps, and hand washes. This is because the

amount of water used to rinse off the product, the energy consumed to heat the water, and the discharge of the products down the drain can have a negative impact on the environment. Therefore, it is important to consider the use phase of these products when assessing their overall sustainability impact (15).

For instance, research suggests that approximately 90% of the total CO_2 emissions across the lifecycle of a shampoo come from the heating and use of tap water. This highlights the need to be mindful of the amount of water and energy used during the use phase of cosmetic products (15).

Educating consumers on how to use cleansing products in a more energy-efficient way can help reduce the environmental impact of these products. Many companies feature campaigns on their websites that provide suggestions and tips for reducing household water use, such as encouraging consumers to: reduce shower duration (which saves water and reduces the energy required to heat it); decrease product usage to the necessary amount, as excessive use not only leads to an increase in water consumption but increase the amount of product that needs to be produced, packaged, and transported; turn off the water while shampooing, conditioning, lathering soap, or brushing teeth; install water-efficient showerheads (15).

However, there is always a waste of water when using these types of products. Thus, consumers should also repurpose and upcycle the leftover water that contains these types of products. One feasible approach involves collecting the water in a container and utilising it to water plants or gardens. Alternatively, this water can be employed to clean floors or other surfaces, serving as a practical and eco-friendly solution.

The cosmetics industry can also avoid wasting water by developing 2-in-1 formulas, like 2-in-1-shampoo + conditioner, or formulas that do not need to be rinsed or require less water for use (54,55).

Head & Shoulders has introduced a 2-in-1 shampoo + conditioner that helps save water and is more sustainable for the environment. This product combines shampoo and conditioner in one bottle, reducing the need for an additional rinse step and therefore saving water. By using the 2-in-1 formula, consumers can save up to 30% more water each time they shower. Additionally, the 2-in-1 product is designed to be more effective, meaning that consumers can achieve the same results with less product, reducing waste and packaging. This not only saves water, but also reduces the amount of plastic waste generated by packaging two separate products (54).

Love Beauty Planet, a new environmentally conscious beauty brand, has developed a unique fast-rinse conditioner that significantly reduces shower time. Their fast-rinse technology quickly breaks down the conditioner into many smaller molecules, making rinsing easier, helping save both time and water (55).

To reduce water consumption and save energy, L'Oréal recently launched its latest innovation, the Water Saver, at the Consumer Electronics Show (CES) 2021. The device aims to help salons reduce water consumption during hair washes without compromising the quality of the wash. This innovative system directly blends specially formulated shampoos, conditioners and treatments from L'Oréal Professionnel and Kérastase into a micronised water stream, ensuring improved absorption and faster rinsing, reducing water usage by up to 80% (56).

L'Oréal is taking an active approach to reduce the carbon footprint of its products, and this device is one of its many initiatives to promote sustainable practices in the beauty industry. Although the L'Oréal Water Saver was launched for salons, an at-home version of the device is in the works (56).

6.7 Post-use phase

The post-use phase of a cosmetic product involves the proper management of the packaging waste to minimise its environmental impact (4).

Cosmetic companies play an important role in influencing consumers to adopt environmentally responsible disposal practices. They can achieve this by making choices in packaging types, weight, size, labelling, and even external initiatives that promote recycling and reuse (5).

Many cosmetics companies have implemented consumer incentives, like giving free products or vouchers for returning refillable or reusable packaging. This environmentally friendly approach to packaging not only saves on raw materials but also allows for cost savings to be passed on to the consumer (5).

It is very important to unravel how consumers use and dispose of the product packaging and to educate them to be more sustainable and make a difference through responsible consumption (5).

Lush, a popular cosmetics company, has introduced a new initiative called "Bring It Back" to encourage consumers to recycle their packaging. The aim of this initiative is to reduce the amount of waste that ends up in landfills and to promote sustainability

(57). To participate in the "Bring It Back" programme, consumers need to bring their empty Lush product packaging to a Lush store. The packaging can be from any Lush product, including shampoo bottles, soap containers, and face mask pots. In return, customers receive €0.50 per pack to use for their purchases at Lush. Lush will then recycle or repurpose the packaging into new products (57).

Created in 1990, Back-to-M.A.C is a program created by M.A.C to encourage customers to return the main packaging of previously purchased cosmetics. By returning six empty containers, customers can receive a free lipstick of their choosing (58). Back-to-Mac is making an impact. More than 340,000 pounds of empty M.A.C containers were processed in the United States in 2022, the equivalent of 9,300,000 lipsticks (59).

Boti Recicla is a programme created by the Brazilian cosmetic company O Boticário that allows consumers to return empty cosmetic packaging to their stores. Boti Recicla was founded in 2006 and, in terms of collecting stations, is already Brazil's largest package return programme in the cosmetics sector. In addition to contributing by properly disposing of waste, exchanging three empty packages gives customers a R$15 discount on purchases over R$150. Boti Recicla accepts cosmetic packaging of any material, whether plastic, glass, or paper, and the collection points collect packaging from any cosmetics brand. (60).

Skincare company Murad has partnered with TerraCycle to introduce the Murad Recycling Program, enabling consumers to recycle their empty Murad products' packaging. To take part in the programme, consumers can register on the TerraCycle website and obtain a shipping label. They can then pack their empty Murad products and send them to TerraCycle for recycling. As a reward, participants earn points that can be redeemed for charitable donations (61).

Mustela, a French skincare brand specialising in baby and maternity products, has launched a new refillable packaging system in pharmacies across France. The brand has partnered with Jean Bouteille, a company specialising in eco-friendly packaging solutions, to create a refillable bottle for their best-selling cleansing milk. The refillable bottle, called "Reviens", is made of glass and features a pump dispenser, which can be reused multiple times. Consumers can purchase the bottle once and then return to the pharmacy to refill it with the cleansing milk. In 2021, this system was available in 21 pharmacies in France. This initiative not only reduces waste but also provides long-term cost savings for consumers (62).

7 Conclusions and Perspectives

Cosmetics play a significant role in people's daily lives, which is why it is crucial to develop more environmentally friendly products and reduce their impact on the planet. Sustainability has become a crucial aspect of the cosmetics industry in recent years, and cosmetic companies are increasingly focused on incorporating sustainable practices and products into their operations. While progress has been made in this area, there is still much work to be done to ensure that the industry is truly sustainable.

An approach to increase sustainability is upcycling, i.e., using by-products of the cosmetics or other industries and either reuse them (e.g., water during production) or transform them (or some of their components) into added value products (e.g., ingredients for cosmetics). When writing this monography, it became clear that upcycling is mainly involved in the ingredients sourcing phase. Thus, in the subsequent phases, other sustainability approaches are discussed in addition to upcycling.

The sustainability of cosmetics heavily relies on the choice of ingredients. Cosmetic companies should prioritise the use of sustainable alternatives and responsibly source their ingredients. This involves exploring the use of by-products from the agro-food industry and implementing efficient extraction methods to maximise the utilisation of food waste, allowing the transformation of previously unwanted food waste into valuable and essential ingredients for cosmetic products. Furthermore, partnerships between food producers and cosmetic companies are a highly effective strategy that enables the exchange of resources and knowledge, facilitating the identification of suitable by-products for upcycling and creating a more sustainable supply chain.

Optimising production processes and adopting circular water management in their facilities can also help to reduce the environmental impact of cosmetic production.

Regarding packaging, developing strategies to valorise post-consumer plastic is crucial to address the plastic waste crisis and promote a circular economy. A strategy to address post-consumer plastic waste is to shift the perspective from viewing it as waste to recognising its potential as a valuable resource for producing high-value materials that are relevant to various industries.

Adapting distribution practices and developing strategies to capture CO_2 and use it to produce fuel can also help to reduce the industry's carbon footprint.

Finally, inspiring and educating consumers to use and dispose of products in a sustainable manner is crucial to promoting sustainable consumption habits.

By taking these steps, cosmetic companies can reduce their environmental impact, potentially achieve long-term cost savings, and create a more resilient future. Additionally, consumers can benefit from safe and effective products with better sustainability profiles and adopt more sustainable consumption practices.

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