

Review

Agro-Industrial Side Streams in Cosmetics: From Raw Materials to Scale-Up and Life Cycle Assessment Within a Circular Economy Framework

Malvina Hoxha ¹, Visar Malaj ², Maria Manconi ^{3,*} and Maria Letizia Manca ³

¹ Department of the Chemical-Toxicological and Pharmacologic Evaluation of Drugs, Faculty of Pharmacy, Catholic University Our Lady of Good Counsel, 1005 Tirana, Albania; m.hoxha@unizkm.al

² Department of Economics, University of Tirana, 1005 Tirana, Albania; visarmalaj@feut.edu.al

³ Department of Life and Environmental Sciences, University of Cagliari, University Campus of Monserrato, 09042 Cagliari, Italy; mlmanca@unica.it

* Correspondence: manconi@unica.it; Tel.: +39-0706758582

Abstract

The cosmetic industry represents a major sector of the global economy and is expected to significantly grow in the coming years. To enhance consumer acceptance and address increasing sustainability concerns, cosmetic companies are actively seeking innovative solutions to mitigate their environmental, economic, and social impacts. In accordance with this, several scientific studies focus on the development, scale-up, and life cycle assessment of sustainable cosmetic products, especially those derived from side streams in accordance with circular economy principles. Various reviews have addressed this topic; however, they typically cover one or two of these dimensions, providing only a partial perspective. In particular, existing studies mainly analyze the types of side streams used and the resulting products, often lacking a comprehensive framework that can effectively support the translation of these approaches into industrial-scale production. The aim of the present review is to address this gap by providing a comprehensive analysis of the maturity level of development, scale-up processes, and life cycle assessment of cosmetic products based on agro-industrial side streams. This analysis is intended to support companies in the transition towards more sustainable practices by reducing carbon footprint and limiting the intensive extraction of virgin raw materials. The different approaches and methodologies proposed for the development and scale-up of sustainable cosmetic products from agro-industrial side streams are also analyzed, considering whether life cycle assessment has been performed. Furthermore, the most suitable business models will be selected as innovative and sustainable value chains capable of generating economic benefits, fostering local development, and enhancing resource efficiency and supply security.

Keywords: agri-food side streams; extracts; life cycle assessment; circular economy; sustainability



Academic Editor: Enzo Berardesca

Received: 1 April 2026

Revised: 20 April 2026

Accepted: 28 April 2026

Published: 2 May 2026

Copyright: © 2026 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article distributed under the terms and conditions of the [Creative Commons Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

1. Introduction

The cosmetic industry represents one of the largest and most rapidly expanding sectors in the global economy. The global cosmetics market was valued at approximately USD 500 billion in 2017 and has continued to grow at a compound annual growth rate of approximately 4–7%, with projections exceeding USD 800 billion by 2030 [1]. The principal product categories encompassed within the cosmetics market include skincare, haircare,

color cosmetics (make-up), fragrances, toiletries and deodorants, and oral care products, with skincare consistently representing the leading segment [2]. The market is dominated by multinational corporations; however, the European cosmetic landscape is characterized by a substantial presence of Small and Medium Enterprises (SMEs), which constitute more than two-thirds of all cosmetic manufacturers, numbering over 4000 across the European Union [1]. Europe alone accounts for a market valued at over €66 billion, making it the largest consumer market for cosmetic products globally. The sustained growth of the cosmetics market can be attributed to a confluence of socioeconomic, technological, and cultural factors. Rising consumer income and evolving lifestyles constitute primary demand drivers, particularly in emerging economies where increasing discretionary spending and urbanization have expanded the consumer base for beauty and personal care products [3]. The proliferation of social media platforms, including Instagram, TikTok, and YouTube, has fundamentally reshaped consumer engagement with cosmetic brands, as influencer marketing, user-generated content, and algorithm-driven product recommendations have become powerful determinants of purchasing behavior [4]. Indeed, products promoted by beauty influencers now account for approximately 25% of the turnover of cosmetic online retailers [4]. Furthermore, the aging global population, particularly in Western markets, has stimulated demand for anti-aging and cosmeceutical products, a segment that has experienced rapid growth over the past decade. Demographic variables such as age, gender, educational attainment, and occupation have also been shown to significantly influence purchasing behavior, particularly in the organic cosmetics segment. Additionally, shifts in consumer preferences toward ingredient safety and environmental sustainability of products represent one of the most significant contemporary trends in the industry.

Unfortunately, this continued expansion inevitably entails an increase in environmental pressure across all phases of the cosmetic product life cycle, encompassing raw material sourcing, manufacturing, packaging, distribution, consumer use, and post-consumer disposal [5]. Indeed, environmental concerns associated with the cosmetics sector include unsustainable resource consumption, greenhouse gas emissions from manufacturing processes, extensive generation of non-recyclable plastic waste, with nearly 70% of cosmetic plastic packaging currently being non-recyclable, and the release of potentially harmful substances into aquatic ecosystems. In response to these challenges, cosmetic companies are increasingly directing their efforts towards identifying and implementing strategies for environmental impact reduction. In particular, regarding the raw material sourcing phase, considerable attention is being devoted to the substitution of conventional ingredients with more environmentally sustainable alternatives, including the valorization of agro-industrial side streams and the adoption of green chemistry principles and bio-based and naturally derived ingredients [5]. Side streams are usually considered as wastes or residues without any added value, but nowadays they have gained renewed attention as rich sources of bioactive and technologically relevant compounds and have now gained significant importance due to their circular sustainability and green credentials, which can diminish the footprint of producer industries [6].

Despite the increasing number of studies on agro-industrial side streams for cosmetic applications, the available literature remains highly fragmented. Most contributions focus on the extraction and characterization of bioactive compounds, while only a limited number address scalability, regulatory feasibility, or environmental assessment in an integrated manner.

In particular, there is a lack of studies that simultaneously evaluate technological maturity, industrial feasibility, and sustainability performance through standardized approaches such as life cycle assessment (LCA) and life cycle cost analysis (LCCA) of the resulting products. This fragmentation limits the translation of laboratory-scale findings into in-

dustrial applications and reduces the practical relevance of current research. Accordingly, Machado et al. emphasize the need to consider not only the biological properties but also the regulations and the economic and social impacts of incorporating by-products into cosmetics [7].

Therefore, a comprehensive and integrative analysis that combines these dimensions is needed to support the development of sustainable cosmetic value chains based on agro-industrial side streams.

Indeed, the effective scaling up of cosmetics from side streams may play an essential role in advancing the sustainability and environmental footprint of these industries, thanks to the reduction in new feedstocks, waste production, energy requirements, and the consequent cost of final products. From a marketing and communication perspective, the use of side streams in cosmetics can enhance the perceived sustainability of products and position them as attractive, natural choices for consumers, potentially increasing long-term profitability [7].

2. Types of Agro-Industrial Side Streams Used in Cosmetic Product Development

Agro-industrial side streams represent a rich and sustainable reservoir of bioactive compounds increasingly exploited for cosmetic formulations. However, their level of development and applicability vary significantly depending on the source, processing chain, and degree of technological advancement.

To overcome the descriptive nature of existing literature, the side streams reported in this review are discussed using a comparative framework based on four key dimensions: (i) technological maturity level (TRL), (ii) scalability potential, (iii) availability and economic relevance, and (iv) level of validation (in vitro, in vivo, clinical).

Among the most extensively studied systems, wine- and olive-derived side streams, particularly grape pomace, seeds, and olive residues, exhibit the highest technological maturity. These by-products are rich in polyphenols, vitamin E, and fatty acids, and have been incorporated into a wide range of formulations with demonstrated antioxidant, anti-aging, and photoprotective properties (Table 1) [8,9].

In the case of wine-derived residues, extracts containing ellagic acid have been successfully employed as exfoliating phytoactive agents [10], while more recent studies have explored the development of dextran–grape pomace conjugates with enhanced anti-aging properties [11].

In addition, advanced formulation strategies have been reported, including nano-delivery systems based on liposomes and nanoparticles, which improve the stability and biological efficacy of the bioactive compounds. For example, Castangia et al. developed a green synthesis approach for silver nanoparticles using grape pomace extract, subsequently stabilized in liposomes [12]. This system combined the antioxidant activity of grape polyphenols with the antimicrobial properties of silver, showing effectiveness against pathogens such as *Staphylococcus aureus* and *Pseudomonas aeruginosa*, as well as protective effects on fibroblasts and keratinocytes under oxidative stress conditions.

Similarly, olive oil industry side streams, such as pomace, mill wastewater, and leaves, represent a well-established source of functional compounds, including hydroxytyrosol, oleuropein, tyrosol, squalene, and phytosterols, which are associated with strong antioxidant and photoprotective properties [13,14]. Extracts obtained from olive pomace have demonstrated significant radical scavenging activity and the ability to support skin barrier function [15]. In particular, these extracts showed strong in vitro antioxidant activity, effectively scavenging ABTS and DPPH radicals and providing protection in the β -carotene/linoleic acid system. Moreover, formulations maintained their reducing capac-

ity over 90 days and exhibited pronounced antiglycation effects. Notably, their antioxidant performance exceeded that of tocopheryl acetate, both in pure form and when incorporated into cosmetic formulations, highlighting their potential as natural active ingredients. Given the central role of oxidative stress in compromising skin barrier function, such properties suggest a potential indirect contribution to skin barrier homeostasis through the mitigation of oxidative damage to structural components.

Further supporting their advanced development stage, Nunes et al. formulated oil-in-water creams containing different olive-derived extracts, demonstrating antioxidant, anti-enzymatic (collagenase and elastase inhibition), and photoprotective effects, together with confirmed *in vivo* safety [16]. In addition, Buzzi et al. developed products based on extracts from olive leaves and mill wastewater rich in hydroxytyrosol, which were successfully evaluated in a placebo-controlled clinical study [17]. Outstandingly, the above-mentioned studies based on both wine and olive side streams report advanced formulation strategies, including nano-delivery systems and validation *in vitro* and *in vivo*, indicating relatively high TRLs and potential for industrial translation. In addition, comprehensive reviews have highlighted the broad cosmetic potential of these materials, including antioxidant, photoprotective, anti-hyperpigmentation, and skin-regenerating effects [9].

Likewise, high-volume residues from the brewing and coffee industries, such as spent grain (accounting for approximately 85% of total brewing waste, ~39 million tons/year worldwide), spent hops, surplus yeast, and spent coffee grounds, silverskin, pulp, and husks, represent highly available and economically advantageous resources, with strong scalability potential due to their global production and low cost. From a technological maturity perspective, these side streams can be considered at an intermediate TRL. Several studies report the successful incorporation of these materials into cosmetic formulations, including masks, creams, and delivery systems, demonstrating antioxidant, regenerative, and photoprotective properties [18]. In particular, Klosowski et al. developed cosmetic face masks containing spent grain extracts (5–10%) showing anti-aging activity, with optimal performance observed at 5% concentration [19]. Similarly, Bucci et al. enhanced the technological functionality of brewing residues by extracting ferulic acid and encapsulating it into ultradeformable liposomes, improving its topical delivery and skin regenerative effects [20]. Lima et al. further demonstrated the potential of spent hop extracts as natural photoprotective adjuvants in sunscreen formulations, highlighting their content in α -acids and prenylated flavonoids and their ability to enhance *in vitro* UV absorption [21].

Coffee-derived side streams show comparable trends. Grigolon et al. developed an active ingredient from coffee silverskin (SLVR'Coffee™), capable of upregulating genes involved in oxidative stress defense in keratinocytes, indicating a clear bio-functional potential at the cellular level [22]. In addition, Rodrigues et al. formulated a hand cream containing 2.5% coffee silverskin extract, demonstrating biocompatibility with human fibroblasts and keratinocytes and *in vivo* anti-aging efficacy [23]. Spent coffee grounds have also been successfully valorized into exfoliating formulations, further supporting their versatility in cosmetic applications [24]. Despite these promising results, the level of validation remains predominantly limited to *in vitro* and short-term *in vivo* studies, with only a few examples of more advanced formulation testing.

These limitations currently hinder their transition toward higher TRLs and large-scale cosmetic production.

Fruit-derived side streams (e.g., tomato, apple, banana, and citrus) represent a heterogeneous group characterized by good availability and promising bioactive profiles. However, their level of technological maturity (TRL) and validation varies considerably depending on the specific source.

Among these, tomato and apple residues can be considered the most advanced systems in terms of technological development. Tomato processing generates large volumes of side streams, including peels, seeds, and fibers, which are rich in carotenoids, particularly lycopene, polyphenols, and unsaturated fatty acids [25]. From a validation perspective, these materials have been incorporated into functional cosmetic formulations, such as creams enriched with tomato pomace oil, which demonstrated the ability to modulate the skin microbiome in human volunteers, indicating early-stage *in vivo* validation [26]. In addition, the high lycopene content of tomato skins (up to 734 µg/g dry weight) further supports their photoprotective and antioxidant potential, reinforcing their applicability in cosmeceutical formulations [27].

Similarly, apple pomace, representing 25–40% of processed apple mass, is a highly abundant and economically relevant by-product, rich in polyphenols, pectin, and vitamins [28]. In terms of technological maturity, apple-derived side streams show relatively advanced development, supported by both formulation studies and clinical validation. For instance, Di Lorenzo et al. demonstrated the anti-aging efficacy of a cream containing apple oleolite in a placebo-controlled clinical study on human volunteers, indicating a higher TRL compared to most other fruit-derived residues [29]. Additional studies report the development of hydrogels and emulsions incorporating apple extracts, with demonstrated antioxidant and photoprotective activities [29–31].

Citrus-derived side streams, particularly from orange and lemon processing, also represent highly available and economically relevant residues, although their technological maturity is more heterogeneous. Orange peels have been successfully valorized into cosmetic formulations with relatively advanced validation levels. For example, extracts incorporated into whitening creams demonstrated a measurable reduction in skin melanin content in human volunteers, indicating clinical-level validation. Additional studies report the development of stable oil-in-water emulsions with antioxidant activity and sun protection factors above 15. Furthermore, the incorporation of orange peel extracts into lipid nanocarriers has enabled the formulation of topical emulsions with demonstrated *in vivo* anti-aging effects, including improvements in skin hydration, elasticity, and transepidermal water loss [32]. At the molecular level, nanoparticle-based formulations have also been shown to downregulate matrix metalloproteinase-1 (MMP1) expression in UV-induced photoaging models, supporting their functional efficacy [33].

In contrast, lemon-derived side streams remain at a lower TRL, with limited studies mainly focused on preliminary formulation development. Available works report the preparation of eco-friendly creams based on lemon seed oil with antimicrobial and antioxidant properties comparable to commercial products, as well as nanoemulsions capable of controlled release and prolonged antioxidant activity [34,35]. However, these studies are largely restricted to *in vitro* or early-stage evaluations, lacking clinical validation and long-term performance data.

Similarly, banana-derived side streams, although widely available and economically attractive, remain at a lower TRL. Current studies are mainly limited to preliminary formulation development and *in vitro* or basic *in vivo* evaluations. For example, banana peel extracts have been incorporated into microemulgels, emulsions, and body lotions, showing antioxidant activity, acceptable physicochemical properties, and absence of skin irritation [36,37]. However, these studies generally lack advanced validation, long-term stability assessment, and clinical evidence.

Overall, while fruit-derived side streams offer strong scalability potential due to their high availability and low cost, their technological maturity and level of validation remain uneven. Apple and tomato residues stand out as the most promising candidates for industrial translation, while orange side streams show intermediate-to-advanced development

with emerging clinical evidence. In contrast, banana and lemon residues are still at an early stage of development. This heterogeneity highlights the need for standardized methodologies and more advanced validation studies to support their progression toward higher TRLs and large-scale cosmetic applications.

In contrast, several side streams, including pomegranate, mango, saffron, onion, argan, coconut, date palm, almond, and artichoke, remain at an early stage of technological development, generally corresponding to low-to-intermediate TRLs. Despite their often-high availability and potential economic relevance, these materials are primarily investigated for their bioactive composition and in vitro properties, with limited evidence of fully developed cosmetic formulations or large-scale validation. Pomegranate-derived side streams, mainly consisting of peels (approximately 50% of the fruit weight), are rich in bioactive compounds such as punicalagin, ellagic acid, anthocyanins, and flavonoids [38]. From a validation perspective, studies report strong antioxidant, antibacterial, and photoprotective activities, including high radical scavenging capacity and significant sun protection factor values. However, despite these promising properties, their technological maturity remains low, as no fully developed cosmetic formulations or clinical validations have been reported to date.

Mango-derived side streams represent a more advanced case within this group, showing intermediate TRLs. Peels and seed kernels are rich in mangiferin, gallotannins, and fatty acids [39] and have been successfully incorporated into a variety of formulations, including shampoos, gels, emulsions, and lipid nanocarriers [40,41]. Some studies report enhanced skin permeation and in vivo anti-aging effects, indicating early-stage clinical relevance [42,43]. Nevertheless, most applications remain limited to small-scale formulations, and industrial scalability is still constrained by the lack of standardized processing methods [44].

Onion side streams, particularly outer skins and peels, are widely available and economically relevant, with high quercetin content [45]. Their TRL can be considered intermediate, as several studies report the development of stable cosmetic formulations, including creams and emulsions with antioxidant and photoprotective properties comparable to synthetic UV filters [45]. However, validation remains limited to short-term stability and in vitro or preliminary in vivo testing.

Argan (*Argania spinosa* L.)-derived side streams (press-cake, pulp, and shells) are produced in significant quantities and show potential for cosmetic applications [46]. However, their technological maturity remains relatively low, as most studies focus on bioactivity or formulation components rather than finished cosmetic products. Some advances include the development of nanoemulgels and emulsions using extracts as natural emulsifiers, as well as biodegradable films with antioxidant and regenerative properties [47–49]. Guillaume and Charrouf provided a comprehensive review of the dermocosmetic applications of argan side streams, highlighting that argan fruit pulp and press-cake contain saponins, peptides, and proteins with potential cosmetic properties, and reporting several patents related to cosmetic formulations derived from these materials [46]. Nevertheless, validation is largely restricted to in vitro studies, with limited evidence of clinical application.

Coconut (*Cocos nucifera* L.) and date palm (*Phoenix dactylifera* L.) are highly abundant and economically attractive but remain at an early TRL. Reported applications include basic formulations such as creams, scrubs, and soaps, with demonstrated antioxidant, moisturizing, and anti-aging effects [50,51]. In the case of date palm, some in vivo studies on human volunteers indicate potential functional benefits, suggesting a slightly higher level of validation compared to other early-stage residues [52,53]. However, these studies remain limited in scope and scale.

Saffron (*Crocus sativus* L.) -derived side streams, particularly petals and tepals, represent a promising but still emerging area of research. Although recent studies have demonstrated the feasibility of incorporating these extracts into emulsions and hydrogels with good stability and sensory properties, their technological maturity remains low, with limited validation beyond laboratory-scale formulation [54,55].

Similarly, almond (*Prunus dulcis* Mill.) and artichoke (*Cynara cardunculus* L. var. *scolymus*) side streams show isolated examples of cosmetic application, including UV-protective formulations and clinical evaluation of anti-aging creams [56,57]. However, these cases remain sporadic, and the overall level of technological development is still limited. Overall, despite the wide availability and promising bioactive profiles of these side streams, their technological maturity and level of validation remain heterogeneous and generally lower than those observed for wine-, olive-, or certain fruit-derived residues. The main limitations include the lack of standardized extraction processes, limited scalability, and insufficient clinical validation. Addressing these challenges will be essential to enable their progression toward higher TRLs and broader industrial applications.

From a comparative perspective, clear differences emerge across side streams, as seen in Table 2. Grape and olive residues can be considered the most mature systems, with higher TRLs, broader formulation diversity, and some degree of process optimization. Conversely, emerging side streams often lack clinical validation, standardized extraction protocols, and long-term stability data.

In terms of scalability and economic relevance, residues generated in large volumes, such as brewer's spent grain, coffee by-products, and fruit pomace, offer significant advantages for industrial exploitation. Nevertheless, their practical application is constrained by compositional variability, seasonal dependence, and regulatory challenges.

Moreover, the level of validation remains a critical limitation across the literature. While numerous studies demonstrate promising in vitro and short-term in vivo results, robust clinical trials and long-term safety assessments are still scarce.

Overall, although a wide range of agro-industrial side streams can be valorized as sources of functional molecules for cosmetic applications [58–60], a clear gap persists between experimental potential and industrial implementation. Bridging this gap will require not only technological optimization but also standardized methodologies, comprehensive validation, and integration of environmental and economic assessments.

Table 1. Main agro-industrial side streams, bioactive compounds, and cosmetic applications.

Side Stream Source	Main By-Product	Key Bioactive Compounds	Cosmetic Application	Formulation Developed	References
 Almond	Shells, skins	Flavonoids	UV protection, scrubs	✓ Limited	[56]
 Apple	Pomace	Polyphenols, pectin	Anti-aging, SPF	✓	[28–30]
 Argan	Press-cake, shell	Proteins, saponins	Emulsifiers, films	✓	[47,48]
 Artichoke	Leaves, heads	Polyphenols	Anti-aging	✓ Limited	[57]
 Banana	Peels	Antioxidants	SPF, anti-aging	✓	[36,37]

Table 1. Cont.

Side Stream Source	Main By-Product	Key Bioactive Compounds	Cosmetic Application	Formulation Developed	References
 Citrus	Peels	Flavonoids	Whitening, anti-aging	✓	[32,61]
 Coconut	Husk, shell, pulp	Various	Scrubs, creams	✓ Few	[50,51]
 Coffee	Silverskin, grounds	Caffeine, chlorogenic acids	Anti-aging, exfoliation	✓	[18,23]
 Date palm	Seeds	Oils, polyphenols	Moisturizing, anti-aging	✓ Limited	[52,53]
 Grape	Pomace, seeds	Polyphenols, ellagic acid	Anti-aging, antioxidant	✓	[9–12]
 Mango	Peels, kernels	Mangiferin, gallotannins	Anti-aging, anti-acne	✓	[39–41]
 Olive	Pomace, wastewater	Hydroxytyrosol, oleuropein	Photoprotection, anti-aging	✓	[13–16]
 Onion	Peels	Quercetin	UV protection	✓	[45,62]
 Pomegranate	Peels	Punicalagin, flavonoids	Antioxidant, SPF	✗	[38,63]
 Saffron	Petals	Polyphenols	Emulsions, hydrogels	✓	[55]
 Tomato	Peels, seeds	Lycopene, fatty acids	Photoprotection, microbiome balance	✓	[26,27]

Table 2. Comparative framework of agro-industrial side streams.

Side Stream	TRL	Scalability	Availability Economic Relevance	Validation Level
Almond	Low	Medium	Medium	In vitro + limited in vivo
Apple	Medium–High	High	High	In vitro + clinical
Argan	Low–Medium	Medium	Medium	In vitro
Artichoke	Low	Medium	Medium	In vitro + limited clinical
Banana	Low	High	High	In vitro
Citrus	Medium	High	High	In vitro + in vivo
Coconut	Low	High	High	In vitro
Coffee	Medium	High	High	In vitro + limited in vivo

Table 2. Cont.

Side Stream	TRL	Scalability	Availability Economic Relevance	Validation Level
Date palm	Low	High	High	In vitro + limited in vivo
Grape	High	High	High	In vitro + in vivo + clinical
Mango	Medium	Medium	Medium	In vitro + in vivo
Olive	High	High	High	In vitro + in vivo + clinical
Onion	Medium	High	High	In vitro
Pomegranate	Low	Medium	Medium	In vitro
Saffron	Low	Low	Low	In vitro
Tomato	Medium	High	High	In vitro + in vivo

3. Scale-Up Challenges

The main studies report the development of cosmetic products using agro-industrial side streams, but the methodologies required for the industrial production remain a critical bottleneck. Important barriers consistently limit the industrial-scale adoption, and they include the following: (i) the variability of the composition of biomasses depending on cultivar, season, processing method, and storage; (ii) the lack of standardized methods to treat biomasses or to separate the functional extracts; (iii) the low bioavailability and sensitivity of some key functional molecules contained in the biomasses; and (iv) the need to identify all components and to confirm their safety. Beyond these limits, the integration of agro-industrial side streams into stable, cosmetologically appealing formulations also remains challenging. Unfortunately, industrial scale-up of finished cosmetic products from agro-industrial side streams is scarcely documented in scientific literature. While most studies concentrate on extraction, biological characterization, and potential cosmeceutical applications at the laboratory scale, they largely overlook the translation to pilot- or industrial-scale manufacturing of finished formulations; see Table 3. One of the few studies explicitly addressing the transfer from laboratory to industrial scale is that of Verdon et al., who reported the complete scale-up of an extract derived from apple side streams, from laboratory process optimization to industrial manufacturing trials, demonstrating robustness, reproducibility, and a higher yield compared to the original raw material [59]. Cárdenas-Toro et al. proposed the design of a sunscreen (SPF 50+) containing grape seed oil and grape skin extract from wine industry residues. They reported material balance calculations for a pilot production of 100 kg, although this remained at the design stage [60,64]. Krzywostań et al. [65,66] in their review highlighted the gap between functional molecule recovery and actual cosmetic manufacturing optimization. In summary, whilst the scientific rationale for employing agro-industrial side streams as cosmetic ingredients is well established, the transition from bench-scale characterization to industrial-scale finished product manufacturing is documented in only a handful of cases, and formal reports of scale-up trials with full process validation remain exceedingly rare.

Table 3. Overview of scale-up and sustainability assessment in side-stream-based cosmetics.

Side Stream	Scale-Up Level	LCA Performed	Key Findings	Limitations	Reference
Apple pomace	✓ Industrial	✗	Full scale-up, high yield	No LCA	[59]
Algae	✗ Lab	✓	Lower environmental impact	Not agro side streams	[67]
Grape waste	✓ Pilot design	✗	Process design (100 kg)	Not validated	[60]
Strawberry waste	✗ Lab	✓ Partial	CO ₂ extract LCA	Only the extraction stage	[66]
Various	✗ Lab	✓	Extraction comparison	No formulation	[7]
Packaging	✓ Industrial	✓	Impact reduction (29%)	Not ingredients	[68]

4. Life Cycle Assessment

While the valorization of agro-industrial side streams for cosmetic applications is a rapidly growing field, the current literature predominantly emphasizes laboratory-scale extraction and in vitro characterization of functional compounds, with limited attention given to process scale-up and life cycle assessment (LCA) [7,69]. To date, no studies have reported a comprehensive LCA of a finished cosmetic product formulated using side streams or their derived functional ingredients.

According to standardized frameworks such as ISO 14040 and ISO 14044, LCA is a structured methodology based on four main phases: (i) goal and scope definition, (ii) life cycle inventory, (iii) impact assessment, and (iv) interpretation, which enable the evaluation of environmental impacts across the entire life cycle of a product. However, the application of these principles in the context of side-stream-derived cosmetic ingredients remains limited and methodologically inconsistent.

Existing studies are predominantly restricted to the assessment of extraction processes. For example, some studies adopt a cradle-to-gate approach, focusing only on extraction efficiency, while others include partial downstream processes, leading to significant variability in reported environmental impacts. In addition, functional units differ widely (e.g., per kg of extract vs. per functional dose), further limiting direct comparison between studies. For instance, Carpentieri et al. compared the environmental performance of different extraction methods for phenolic-rich extracts from date pits, citrus residues, and cherry press-cake, highlighting their potential for sustainable applications. Nevertheless, these analyses were confined to upstream processing stages, without considering formulation or end-use scenarios. Similarly, Faggian et al. applied LCA, including carbon footprint analysis, to the production of a supercritical CO₂ extract from wild strawberry waste intended for cosmetic applications; however, the study was limited to a cradle-to-gate perspective and did not include downstream stages of the product life cycle [66].

Additional studies further illustrate the fragmented nature of current LCA applications. Pagels et al. compared the environmental impact of a brown algae extract with conventional cosmetic antioxidants, demonstrating a lower environmental load for the bio-based alternative, although the analysis did not involve agro-industrial side streams [67]. Likewise, Civancik-Uslu et al. applied LCA to cosmetic packaging eco-design, achieving up to 29% impact reduction but focusing on packaging rather than ingredient sourcing [68]. Table 2 summarizes the main studies focused on scale-up adoption and LCA analyses. More broadly, reviews by Martins and Marto and Martins et al. emphasize the importance

of LCA across the cosmetic product life cycle, while also highlighting its limited application to formulations derived from agro-industrial side streams [64,70].

A critical limitation of the existing literature lies in the lack of methodological consistency, particularly in the definition of system boundaries and functional units. Most studies adopt a cradle-to-gate approach, focusing exclusively on the extraction phase while neglecting key stages such as formulation, packaging, distribution, and end-of-life, which are known to significantly influence the overall environmental impact of cosmetic products.

Furthermore, inconsistencies in the selection of functional units used to quantify the performance of the product system and variability in impact assessment categories hinder the comparability of results across studies. This lack of harmonization limits the ability to benchmark processes and draw robust conclusions regarding the sustainability of different approaches.

Therefore, the adoption of standardized LCA frameworks, including clearly defined system boundaries, consistent functional units, and full life cycle coverage, is essential to improve the reliability, transparency, and comparability of environmental assessments in this field. Such methodological alignment would provide more meaningful insights into sustainability performance and support the transition of side-stream-based cosmetic products from laboratory-scale research to industrial application.

5. Regulatory Challenges for Side Stream-Derived Cosmetic Ingredients

The regulatory dimension represents a critical but often overlooked aspect in the development of cosmetic products derived from agro-industrial side streams. In the European Union, cosmetic products are regulated under Regulation (EC) No. 1223/2009, which establishes strict requirements for safety assessment, ingredient traceability, and product notification.

The use of side-stream-derived ingredients poses specific challenges, including variability in composition, potential contamination, and the need to demonstrate safety equivalence with conventional raw materials. Furthermore, the lack of standardized extraction and processing methods complicates the regulatory approval process.

In addition, differences in regulatory frameworks across regions (e.g., EU, USA, Asia) may limit the global commercialization of these products.

Therefore, addressing regulatory compliance early in the development process is essential to ensure the successful market introduction of sustainable cosmetic products based on agro-industrial side streams.

Critical Appraisal of the Available Studies

A critical limitation of the current literature is the predominance of early-stage experimental studies. Most of the reported formulations are evaluated through in vitro assays or short-term in vivo studies involving a limited number of participants.

Additionally, important aspects such as long-term stability, batch-to-batch reproducibility, and large-scale safety assessment are rarely addressed. These limitations significantly reduce the reliability and industrial transferability of the proposed solutions.

Another relevant issue concerns the heterogeneity of experimental methodologies, which makes it difficult to compare results across studies. Differences in extraction techniques, formulation strategies, and biological assays further complicate the identification of best practices.

Therefore, future research should adopt more standardized and reproducible methodologies, combined with rigorous validation protocols, to enhance the scientific robustness and practical applicability of side-stream-based cosmetic products.

6. Key Lacks for Future Industrial Development

The present analysis highlights a substantial gap between the laboratory-scale development of cosmetic formulations based on agro-industrial side streams and their effective translation into industrial-scale manufacturing. This limitation is further compounded by the lack of comprehensive sustainability assessments, particularly those based on life cycle assessment (LCA), as well as economic evaluations such as life cycle costing (LCC) or techno-economic analysis. Current research predominantly focuses on extraction processes and preliminary formulation at the laboratory level while overlooking the challenges associated with process scale-up and full system evaluation. Future studies should therefore prioritize the development of scalable methodologies and the implementation of complete cradle-to-gate or cradle-to-grave LCA frameworks. Integrating economic assessments alongside environmental analyses would be essential to validate the feasibility and sustainability of these approaches, ultimately supporting their transition from experimental research to industrial application in accordance with the regulatory dimension.

7. Conclusions

This review highlights that, despite the significant potential of agro-industrial side streams in cosmetic applications, their development remains largely confined to laboratory-scale studies. Grape- and olive-derived side streams represent the most advanced systems, while many others are still at an early stage of technological maturity.

The main barriers to industrial implementation include the lack of scalable processes, limited regulatory consideration, and the absence of comprehensive sustainability assessments. In particular, the application of life cycle assessment remains fragmented and often restricted to individual process stages.

Future research should focus on integrating technological development, regulatory compliance, and environmental and economic assessment within a unified framework. This approach is essential to bridge the gap between experimental research and industrial application, enabling effective transition toward sustainable and circular cosmetic production systems.

Author Contributions: Conceptualization, M.M. and M.L.M.; data curation, M.M., M.L.M., M.H. and V.M.; writing—original draft preparation, M.M., M.L.M., M.H. and V.M.; writing—review and editing, M.M., M.L.M., M.H. and V.M.; supervision, M.M. and M.L.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: No human participant were involved in this review.

Data Availability Statement: Data is contained within the article.

Acknowledgments: The authors are deeply grateful to the University of Cagliari and the University of Tirana for their support. Funded by the European Union under the NextGenerationEU programme, Missione 4, Componente 1, Investimento 3.4 “Didattica e competenze universitarie avanzate”, Sotto-investimento T4 “Iniziative transnazionali in materia di istruzione”, CUP B61I24000450006, Project Proposal TNE23-00057. The project was coordinated by the University of Siena, University of Milan-Bicocca, University of Salento and University of Cagliari, with the University of Tirana, participating as a project partner.

Conflicts of Interest: The authors declare that they have no conflicts of interest.

References

- Rodrigues, L.M. Discussing Cosmetics Through a Functional Scope—A Potential Contribution to Facilitate Decisions and Procedures. In *Advances in Dermatological Sciences*; The Royal Society of Chemistry: London, UK, 2013; pp. 240–255.
- Koswara, A.; Herlina, L. Global Trends in the Halal Beauty and Skincare Industry: A Search Engine-Based Market Analysis. *Int. J. Halal Ind.* **2025**, *1*, 84–99. [\[CrossRef\]](#)
- Brancu, C.; Turcu, O. Exploring the Economic Performance and Market Trends in the Cosmetics Industry: Insights and Analysis. *Bus. Manag. Compass* **2025**, *69*, 23–32. [\[CrossRef\]](#)
- Gani, M.O.; Roy, H.; Rahman, M.S.; Faroque, A.R.; Gupta, V.; Prova, H.T. Effect of Social Media Influence on Consumer's Purchase Intention of Organic Beauty Products: The Role of Customer's Engagement and Generativity. *Int. J. Spa Wellness* **2023**, *6*, 54–77. [\[CrossRef\]](#)
- Bom, S.; Jorge, J.; Ribeiro, H.M.; Marto, J. A Step Forward on Sustainability in the Cosmetics Industry: A Review. *J. Clean. Prod.* **2019**, *225*, 270–290. [\[CrossRef\]](#)
- Nhani, G.B.B.; Di Filippo, L.D.; de Paula, G.A.; Mantovanelli, V.R.; da Fonseca, P.P.; Tashiro, F.M.; Monteiro, D.C.; Fonseca-Santos, B.; Duarte, J.L.; Chorilli, M. High-Tech Sustainable Beauty: Exploring Nanotechnology for the Development of Cosmetics Using Plant and Animal By-Products. *Cosmetics* **2024**, *11*, 112. [\[CrossRef\]](#)
- Machado, M.; Silva, S.; Costa, E.M. Byproducts as a Sustainable Source of Cosmetic Ingredients. *Appl. Sci.* **2024**, *14*, 10241. [\[CrossRef\]](#)
- Ferreira, S.M.; Santos, L. A Potential Valorization Strategy of Wine Industry By-Products and Their Application in Cosmetics—Case Study: Grape Pomace and Grapeseed. *Molecules* **2022**, *27*, 969. [\[CrossRef\]](#) [\[PubMed\]](#)
- Hoss, I.; Rajha, H.N.; El Khoury, R.; Youssef, S.; Manca, M.L.; Manconi, M.; Louka, N.; Maroun, R.G. Valorization of Wine-Making By-Products' Extracts in Cosmetics. *Cosmetics* **2021**, *8*, 109. [\[CrossRef\]](#)
- F. Maluf, D.; Gonçalves, M.M.; D'Angelo, R.W.O.; Girassol, A.B.; Tulio, A.P.; Pupo, Y.M.; Farago, P.V. Cytoprotection of Antioxidant Biocompounds from Grape Pomace: Further Exfoliant Phytoactive Ingredients for Cosmetic Products. *Cosmetics* **2018**, *5*, 46. [\[CrossRef\]](#)
- Motta, M.F.; Vattimo, A.F.; Amone, F.; Malivindi, R.; Parisi, O.I.; Puoci, F. Valorization of Grape Pomace Extract Through Dextran–Grape Conjugates: A Sustainable Approach for Cosmetic and Dermatological Applications. *Appl. Sci.* **2025**, *15*, 3220. [\[CrossRef\]](#)
- Castangia, I.; Marongiu, F.; Manca, M.L.; Pompei, R.; Angius, F.; Ardu, A.; Fadda, A.M.; Manconi, M.; Ennas, G. Combination of Grape Extract-Silver Nanoparticles and Liposomes: A Totally Green Approach. *Eur. J. Pharm. Sci.* **2017**, *97*, 62–69. [\[CrossRef\]](#)
- Dauber, C.; Parente, E.; Zucca, M.; Gámbaro, A.; Vieitez, I. Olea Europea and By-Products: Extraction Methods and Cosmetic Applications. *Cosmetics* **2023**, *10*, 112. [\[CrossRef\]](#)
- Rodrigues, R.; Alves, R.C.; Oliveira, M.B.P.P. Exploring Olive Pomace for Skincare Applications: A Review. *Cosmetics* **2023**, *10*, 35. [\[CrossRef\]](#)
- Riéffel, R.C.; Agostini, L.; Rodrigues, N.P.; Berlitz, S.J.; Marczak, L.D.F.; Külkamp-Guerreiro, I.C. Sustainable Olive Pomace Extracts for Skin Barrier Support. *Pharmaceutics* **2025**, *17*, 962. [\[CrossRef\]](#)
- Nunes, A.; Gonçalves, L.; Marto, J.; Martins, A.M.; Silva, A.N.; Pinto, P.; Martins, M.; Fraga, C.; Ribeiro, H.M. Investigations of Olive Oil Industry By-Products Extracts with Potential Skin Benefits in Topical Formulations. *Pharmaceutics* **2021**, *13*, 465. [\[CrossRef\]](#)
- Buzzi, R.; Gugel, I.; Costa, S.; Molesini, S.; Boreale, S.; Baldini, E.; Marchetti, N.; Vertuani, S.; Pinelli, P.; Urciuoli, S.; et al. Up-Cycling of *Olea europaea* L. Ancient Cultivars Side Products: Study of a Combined Cosmetic–Food Supplement Treatment Based on Leaves and Olive Mill Wastewater Extracts. *Life* **2023**, *13*, 1509. [\[CrossRef\]](#)
- Ferreira, A.M.; Alves, R.C.; Bastos, B.; Oliveira, M.B.P.P.; Casas, A.; Almeida, H. The Potential of Coffee and Olive by Products as Ingredient in Cosmetics Formulations and Their Extraction Techniques. *Cosmetics* **2025**, *12*, 206. [\[CrossRef\]](#)
- Klosowski, A.B.; Lopes, A.C.; Balado, M.G.P.; Campos, P.M.; Olivato, J.B. From a By-Product to an Active Raw Material: The Use of Brewers' Spent Grain Extract in Cosmetic Masks. *Braz. Arch. Biol. Technol.* **2025**, *68*, e25241019. [\[CrossRef\]](#)
- Bucci, P.L.; Santos, M.V.; Montanari, J.; Zaritzky, N. Nanoferulic: From a By-product of the Beer Industry toward the Regeneration of the Skin. *J. Cosmet. Dermatol.* **2020**, *19*, 2958–2964. [\[CrossRef\]](#)
- Lima, A.G.U.B.d.; Pinto, C.A.S.d.O.; Cândido, T.M.; Pessoa, F.V.L.S.; Velasco, M.V.R.; Demarque, D.P.; Baby, A.R. Valorization of Hop (*Humulus lupulus* L.) Brewing Residue as a Natural Photoprotective Adjuvant. *Photochem* **2026**, *6*, 8. [\[CrossRef\]](#)
- Grigolon, G.; Nowak, K.; Poigny, S.; Hubert, J.; Kotland, A.; Waldschütz, L.; Wandrey, F. From Coffee Waste to Active Ingredient for Cosmetic Applications. *Int. J. Mol. Sci.* **2023**, *24*, 8516. [\[CrossRef\]](#)
- Rodrigues, F.; Gaspar, C.; Palmeira-de-Oliveira, A.; Sarmiento, B.; Helena Amaral, M.; P P Oliveira, M.B. Application of Coffee Silverskin in Cosmetic Formulations: Physical/Antioxidant Stability Studies and Cytotoxicity Effects. *Drug Dev. Ind. Pharm.* **2016**, *42*, 99–106. [\[CrossRef\]](#)

24. Elezović, A.; Kelle, B.P.; Oras, A.; Mujkić, H.; Memić, M.; Kojčin, E.; Bulbulušić, M.; Mujčinović, A.; Nikolić, A.; Bečić, F. Caffeinated Skincare Development and Optimization: Upcycling Spent Coffee Grounds Into Natural Exfoliants. *J. Cosmet. Dermatol.* **2025**, *24*, e70607. [[CrossRef](#)]
25. Maciejczyk, E.; Wajs-Bonikowska, A.; Batory, M.; Budzisz, E. Tomato Pomace: Underestimated Sustainable Cosmetic/Pharmaceutical Raw Source. *Molecules* **2025**, *31*, 53. [[CrossRef](#)] [[PubMed](#)]
26. Rajkowska, K.; Otlewska, A.; Raczek, A.; Maciejczyk, E.; Krajewska, A. Valorisation of Tomato Pomace in Anti-Pollution and Microbiome-Balance Face Cream. *Sci. Rep.* **2024**, *14*, 20516. [[CrossRef](#)] [[PubMed](#)]
27. Szabo, K.; Varvara, R.-A.; Ciont, C.; Macri, A.M.; Vodnar, D.C. An Updated Overview on the Revalorization of Bioactive Compounds Derived from Tomato Production and Processing By-Products. *J. Clean. Prod.* **2025**, *497*, 145151. [[CrossRef](#)]
28. Vandorou, M.; Plakidis, C.; Tsompanidou, I.M.; Adamantidi, T.; Panagopoulou, E.A.; Tsoupras, A. A Review on Apple Pomace Bioactives for Natural Functional Food and Cosmetic Products with Therapeutic Health-Promoting Properties. *Int. J. Mol. Sci.* **2024**, *25*, 10856. [[CrossRef](#)]
29. Di Lorenzo, R.; Maisto, M.; Ricci, L.; Piccolo, V.; Marzocchi, A.; Greco, G.; Tenore, G.C.; Laneri, S. Annurca Apple Oleolite as Functional Ingredient for the Formulation of Cosmetics with Skin-Antiaging Activity. *Int. J. Mol. Sci.* **2024**, *25*, 1677. [[CrossRef](#)]
30. Barreira, J.C.M.; Arraibi, A.A.; Ferreira, I.C.F.R. Bioactive and Functional Compounds in Apple Pomace from Juice and Cider Manufacturing: Potential Use in Dermal Formulations. *Trends Food Sci. Technol.* **2019**, *90*, 76–87. [[CrossRef](#)]
31. Arraibi, A.A.; Liberal, Â.; Dias, M.I.; Alves, M.J.; Ferreira, I.C.F.R.; Barros, L.; Barreira, J.C.M. Chemical and Bioactive Characterization of Spanish and Belgian Apple Pomace for Its Potential Use as a Novel Dermocosmetic Formulation. *Foods* **2021**, *10*, 1949. [[CrossRef](#)]
32. Khan, Z.U.; Khan, T.; Khan, H.; Khan, N.U.; Ding, Y.; Ali, A.; Ni, J. Eco-Friendly Sustainable Nanocarriers to Treat Oxidative Stresses and Skin Aging-Related Ailments, Valorization of a By-Product. *Bioengineering* **2023**, *10*, 798. [[CrossRef](#)]
33. Amer, R.I.; Ezzat, S.M.; Aborehab, N.M.; Ragab, M.F.; Mohamed, D.; Hashad, A.; Attia, D.; Salama, M.M.; El Bishbishy, M.H. Downregulation of MMP1 Expression Mediates the Anti-Aging Activity of Citrus Sinensis Peel Extract Nanoformulation in UV Induced Photoaging in Mice. *Biomed. Pharmacother.* **2021**, *138*, 111537. [[CrossRef](#)]
34. Babatolu, A.O.; Akinlami, O.O.; Oloyede, H.O. Ecofriendly Formulation and Biological Activities of Cosmetic Prepared from the Oil of Citrus Paradisi and Citrus Lemon Seeds. *Int. Res. J. Pure Appl. Chem.* **2025**, *26*, 13–24. [[CrossRef](#)]
35. Kaur, H.; Pancham, P.; Kaur, R.; Agarwal, S.; Singh, M. Synthesis and Characterization of Citrus limonum Essential Oil Based Nanoemulsion and Its Enhanced Antioxidant Activity with Stability for Transdermal Application. *J. Biomater. Nanobiotechnol.* **2020**, *11*, 215–236. [[CrossRef](#)]
36. Sriarumtias, F.F.; Najihudin, A.; Putri, I.R.; Akmal, A.; Hamdani, S. Microemulgel Formulation of Kepok Banana Peel Extract (*Musa paradisiaca* L.) as an Antioxidant. *J. Phys. Conf. Ser.* **2019**, *1402*, 055090. [[CrossRef](#)]
37. Meitasari, A.D.; Zulpadly MH, M.F.; Kurnianingsih, R.; Wigatiningtyas, A.; Juliyanti. Optimization of Carrageenan Concentration as an Emulsifier in Banana Peel Extract Body Lotion with Irritation Assessment. *J. Trop. Pharm. Chem.* **2025**, *9*, 319–325. [[CrossRef](#)]
38. Debnath, M.; Aneja, D. Waste Valorization Utilizing Green Nanotechnology: A Sustainable Approach for Pomegranate Peel Agro Wastes in Skincare Formulations. *Bioresour. Bioprocess.* **2025**, *12*, 152. [[CrossRef](#)]
39. Jahurul, M.H.A.; Zaidul, I.S.M.; Ghafoor, K.; Al-Juhaimi, F.Y.; Nyam, K.-L.; Norulaini, N.A.N.; Sahena, F.; Mohd Omar, A.K. Mango (*Mangifera indica* L.) by-Products and Their Valuable Components: A Review. *Food Chem.* **2015**, *183*, 173–180. [[CrossRef](#)] [[PubMed](#)]
40. Brito, I.; Ferreira, S.M.; Santos, L. On the Path to Sustainable Cosmetics: Development of a Value-Added Formulation of Solid Shampoo Incorporating Mango Peel Extract. *Cosmetics* **2023**, *10*, 140. [[CrossRef](#)]
41. García-Villegas, A.; Fernández-Ochoa, Á.; Rojas-García, A.; Alañón, M.E.; Arráez-Román, D.; Cádiz-Gurrea, M.d.I.L.; Segura-Carretero, A. The Potential of *Mangifera indica* L. Peel Extract to Be Revalued in Cosmetic Applications. *Antioxidants* **2023**, *12*, 1892. [[CrossRef](#)]
42. Khan, Z.U.; Khan, T.; Mannan, A.; Ali, A.; Ni, J. In Vitro and Ex Vivo Evaluation of *Mangifera indica* L. Extract-Loaded Green Nanoparticles in Topical Emulsion against Oxidative Stress and Aging. *Biomedicines* **2022**, *10*, 2266. [[CrossRef](#)] [[PubMed](#)]
43. Varhadi, L.; Kitture, S.; Desai, N.; Palshetkar, A. Topical Gel of Extract of *Mangifera indica* L. Seed Kernels.; an Indigenous Plant Waste for Potential Anti-Acne Activity. *Indian Drugs* **2021**, *58*, 73–76. [[CrossRef](#)]
44. Kaur, B.; Panesar, P.S.; Anal, A.K. Ultrasound-assisted Extraction of Mango Seed Kernel Butter and Assessment of Its Physico-chemical, Thermal, and Structural Properties. *J. Food Process Eng.* **2023**, *46*, e14174. [[CrossRef](#)]
45. Messias, M.A.; Ferreira, S.M.; Tavares, L.; Santos, L. A Comparative Study between Onion Peel Extracts, Free and Complexed with β -Cyclodextrin, as a Natural UV Filter to Cosmetic Formulations. *Int. J. Mol. Sci.* **2023**, *24*, 15854. [[CrossRef](#)]
46. Guillaume, D.; Charrouf, Z. Argan Oil and Other Argan Products: Use in Dermocosmetology. *Eur. J. Lipid Sci. Technol.* **2011**, *113*, 403–408. [[CrossRef](#)]

47. Bouhoute, M.; Nakajima, M.; Isoda, H. Design of Nanoemulgel Using Argania Spinosa Microfibrillated Cellulose and Natural Emulsifiers Foreseeing Melanogenesis Enhancement. *Carbohydr. Polym.* **2021**, *274*, 118632. [[CrossRef](#)]
48. Bouhoute, M.; Taarji, N.; Vodo, S.; Kobayashi, I.; Zahar, M.; Isoda, H.; Nakajima, M.; Neves, M.A. Formation and Stability of Emulsions Using Crude Extracts as Natural Emulsifiers from Argan Shells. *Colloids Surf. A Physicochem. Eng. Asp.* **2020**, *591*, 124536. [[CrossRef](#)]
49. Mirpoor, S.; Giosafatto, C.; Mariniello, L.; D'Agostino, A.; D'Agostino, M.; Cammarota, M.; Schiraldi, C.; Porta, R. Argan (*Argania spinosa* L.) Seed Oil Cake as a Potential Source of Protein-Based Film Matrix for Pharmaco-Cosmetic Applications. *Int. J. Mol. Sci.* **2022**, *23*, 8478. [[CrossRef](#)]
50. Atmanto, D.; Ambarwati, N.S.S. Application of Activated Charcoal from Coconut Shell Waste for the Manufacture of Skin Lightening Creams and the Mechanism of the Process. *AIP Conf. Proc.* **2021**, *2331*, 040027. [[CrossRef](#)]
51. Solihah, R.; Ze'roh, H. Evaluasi Formulasi Sediaan Krim Body Scrub Dari Ampas Kelapa (*Cocos nucifera* L.). *J. Pharm. Health Res.* **2023**, *3*, 75–79. [[CrossRef](#)]
52. Alsohaimi, A.; Fouda, A.-M. Assessment of the Effect of Extract Formulation of Date Palm Kernel on Facial Skin Wrinkles: Biophysical Measurements and Digital Profilometry. *J. Cosmet. Sci.* **2019**, *70*, 277.
53. Al-Habsi, N. Date Palm (*Phoenix dactylifera* L.) Fruit: Strategic Crop for Food Security, Nutritional Benefits, Postharvest Quality, and Valorization into Emerging Functional Products. *Sustainability* **2025**, *17*, 7491. [[CrossRef](#)]
54. Turcov, D.; Barna, A.S.; Apreutesei Ciuperca, O.T.; Trifan, A.; Puitel, A.C.; Suteu, D. Valorization of Bioactive Compounds from Residual Saffron Biomass (*Crocus sativus* L.) to Obtain High Value Added Dermato-Cosmetic Products. *Bioresources* **2022**, *17*, 4730–4744. [[CrossRef](#)]
55. Pagano, C.; Ceccarini, M.R.; Faieta, M.; di Michele, A.; Blasi, F.; Cossignani, L.; Beccari, T.; Oliva, E.; Pittia, P.; Sergi, M.; et al. Starch-Based Sustainable Hydrogel Loaded with Crocus Sativus Petals Extract: A New Product for Wound Care. *Int. J. Pharm.* **2022**, *625*, 122067. [[CrossRef](#)]
56. Mandalari, G.; Arcoraci, T.; Martorana, M.; Bisignano, C.; Rizza, L.; Bonina, F.; Trombetta, D.; Tomaino, A. Antioxidant and Photoprotective Effects of Blanch Water, a Byproduct of the Almond Processing Industry. *Molecules* **2013**, *18*, 12426–12440. [[CrossRef](#)]
57. D'Antuono, I.; Carola, A.; Sena, L.M.; Linsalata, V.; Cardinali, A.; Logrieco, A.F.; Colucci, M.G.; Apone, F. Artichoke Polyphenols Produce Skin Anti-Age Effects by Improving Endothelial Cell Integrity and Functionality. *Molecules* **2018**, *23*, 2729. [[CrossRef](#)]
58. Morganti, P.; Gao, X.; Vukovic, N.; Gagliardini, A.; Lohani, A.; Morganti, G. Food Loss and Food Waste for Green Cosmetics and Medical Devices for a Cleaner Planet. *Cosmetics* **2022**, *9*, 19. [[CrossRef](#)]
59. Verdon, J.; Bonnans, M.; Restellini, L.; Morel, C.; Imbert, I. Valorization of Apple Byproduct from the Food Industry for the Production of a Sustainable Active Cosmetics Ingredient. *J. Investig. Dermatol.* **2023**, *143*, S237. [[CrossRef](#)]
60. Cardenas-Toro, F.; Carrillo-Quezada, M.; Nakama-Hokamura, K.; Pariona-La Torre, L. Design of a Sunscreen Considering the Valorization of Agroindustrial Waste from the Wine Industry. In *Proceedings of the 17th LACCEI International Multi-Conference for Engineering, Education, and Technology: "Industry, Innovation, and Infrastructure for Sustainable Cities and Communities"*, Montego Bay, Jamaica, 24–26 July 2019; Latin American and Caribbean Consortium of Engineering Institutions: Boca Raton, FL, USA, 2019.
61. Kumar, A.; Porwal, M.; Rastogi, V. Comprehensive Review of Topical Phytoformulations and Pharmacological Activities for the Treatment of Wrinkles. *Prospect. Pharm. Sci.* **2025**, *23*, 186–204. [[CrossRef](#)]
62. Ferreira, S.M.; Gomes, S.M.; Santos, L. A Novel Approach in Skin Care: By-Product Extracts as Natural UV Filters and an Alternative to Synthetic Ones. *Molecules* **2023**, *28*, 2037. [[CrossRef](#)] [[PubMed](#)]
63. Khang, D.T.; Tien, L.T.T.; Men, T.T.; Thuy, N.P. Potential of Fermented Fruit Peel Liquid in Cosmetics as a Skin Care Agent. *Cosmetics* **2021**, *8*, 33. [[CrossRef](#)]
64. Martins, A.M.; Silva, A.T.; Marto, J.M. Advancing Cosmetic Sustainability: Upcycling for a Circular Product Life Cycle. *Sustainability* **2025**, *17*, 5738. [[CrossRef](#)]
65. Krzyżostan, M.; Wawrzyńczak, A.; Nowak, I. Use of Waste from the Food Industry and Applications of the Fermentation Process to Create Sustainable Cosmetic Products: A Review. *Sustainability* **2024**, *16*, 2757. [[CrossRef](#)]
66. Faggian, M.; Lucchetti, S.; Ferrari, S.; De Nadai, G.; Francescato, S.; Baratto, G.; De Zordi, N.; Stanic, S.-M.; Peron, G.; Sut, S.; et al. An Integrated Approach to Develop Innovative, Sustainable, and Effective Cosmetic Ingredients: The Case Report of Fatty-Acids-Enriched Wild Strawberry Waste Extract. *Appl. Sci.* **2024**, *14*, 10603. [[CrossRef](#)]
67. Pagels, F.; Arias, A.; Guerreiro, A.; Guedes, A.C.; Moreira, M.T. Seaweed Cosmetics under the Spotlight of Sustainability. *Phycology* **2022**, *2*, 374–383. [[CrossRef](#)]
68. Civancik-Uslu, D.; Puig, R.; Voigt, S.; Walter, D.; Fullana-i-Palmer, P. Improving the Production Chain with LCA and Eco-Design: Application to Cosmetic Packaging. *Resour. Conserv. Recycl.* **2019**, *151*, 104475. [[CrossRef](#)]

69. Barbulova, A.; Colucci, G.; Apone, F. New Trends in Cosmetics: By-Products of Plant Origin and Their Potential Use as Cosmetic Active Ingredients. *Cosmetics* **2015**, *2*, 82–92. [[CrossRef](#)]
70. Martins, A.M.; Marto, J.M. A Sustainable Life Cycle for Cosmetics: From Design and Development to Post-Use Phase. *Sustain. Chem. Pharm.* **2023**, *35*, 101178. [[CrossRef](#)]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.