frontiers in Sustainability

SYSTEMATIC REVIEW
published: 28 October 2021
doi: 10.3389/frsus.2021.697092

OPEN ACCESS

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Specialty section:
This article was submitted to
Sustainable Supply Chain
Management,
a section of the journal
Frontiers in Sustainability

Received: 18 April 2021
Accepted: 29 September 2021
Published: 28 October 2021

Citation:
Carvalho Neto DPd,
Gonot-Schoupinsky XP and
Gonot-Schoupinsky FN (2021) Coffee
as a Naturally Beneficial and
Sustainable Ingredient in Personal
Care Products: A Systematic Scoping
Review of the Evidence.
Front. Sustain. 2:697092.
doi: 10.3389/frsus.2021.697092

Coffee as a Naturally Beneficial and Sustainable Ingredient in Personal Care Products: A Systematic Scoping Review of the Evidence

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This systematic scoping review presents evidence from 52 primary research articles for the beneficial, and sustainable, use of coffee in personal care products. The identification and evaluation of natural ingredients that harbor bioactive compounds capable of supporting healthy personal care and protecting and improving the appearance and condition of skin and hair is topical. Demand for natural and sustainable ingredients in beauty and personal care products is driving growth in a market valued at over $500 billion. Coffee, as one of the world's favorite beverages, is widely studied for its internal benefits. External benefits, however, are less known. Here the potential of coffee and its by-products as ingredients in cosmetic and personal care formulations is explored. Diverse applications of a range of bioactive compounds from the coffee bean, leaves, and by-products, are revealed. Research is evaluated in light of economic and environmental issues facing the coffee industry. Many of the 25 million smallholder coffee farmers live in poverty and new markets may assist their economic health. Coffee by-products are another industry-wide problem, accounting for 8 million tons of residual waste per year. Yet these by-products can be a rich source of compounds. Our discussion highlights phenolic compounds, triacylglycerols, and caffeine for cosmetic product use. The use of coffee in personal care products can benefit consumers and industry players by providing natural, non-toxic ingredients and economic alternatives and environmental solutions to support sustainability within the coffee production chain. Database searches identified 772 articles. Of those included ($k = 52$), a minority ($k = 10$; $N = 309$) related to clinical trials and participant studies. Applications were classified, using the PERSOnal Care products and ingredients classification (PERSOC). Sustainability potential was evaluated with the *Coffea* Products Sustainability (COPS) model. Overall objectives of the systematic scoping review were to: (1) scope the literature to highlight evidence for the use of coffee constituents in externally applied personal care products, and (2) critically evaluate findings in view of sustainability concerns.

Keywords: phytocosmetics, *Coffea*, green cosmetics, coffee by-products, phytochemicals, sustainability

INTRODUCTION

The preparation and use of personal care products and cosmetics can be traced back to 10,000 B.C. in ancient Egypt and Persia, where scented herbal oils were used for moisturizing and hygienic purposes (Kumar, 2005; Chaudhri and Jain, 2009). The market for cosmetics and body care is one of the fastest growing consumer markets; its value exceeded $500 billion in 2021 (Statista, 2021). The global market for "green cosmetics," personal care products containing natural ingredients (e.g., extracts, natural oils, or by-products of fruits and grains processing plants) as substitutes for volatile organic compounds (VOCs) and synthetic chemicals, is particularly buoyant and is predicted to increase to US$54 billion by 2027 (Statista, 2019). In Europe alone, green cosmetics have achieved a compound annual growth rates of 20% and represented over 30% of total cosmetic sales in 2015 (Liobikiene and Bernatoniene, 2017). Growing concerns and awareness of consumers about environmental risks and potential chemical toxicity are the main reasons for the on-going development of the "green cosmetics" market (Zillich et al., 2015; Lin et al., 2018). Coffee, well-known for its unique and pleasant sensorial and organoleptic characteristics, possesses wide-ranging and beneficial properties. These are relevant to the personal care product industry as green credentials, and functional active ingredients, increase in importance.

The study of coffee, coffeaology as we term it (Gonot-Schoupinsky, 2021), has unveiled over 1,000 different volatile and non-volatile compounds (Pereira et al., 2019), presenting a range of functional properties, including antioxidant, anti-inflammatory, anti-hypertensive, and antimicrobial activities (Esquivel and Jiménez, 2012; Pereira et al., 2020). The mature fruit consists of: (i) an external husk (exocarp), which is rich in caffeine, chlorogenic acids, and tannins (Pereira et al., 2019); (ii) an intermediary pulp and mucilaginous layer (mesocarp), source of carbohydrates, such as glucose, fructose, and pectin (Janissen and Huynh, 2018); (iii) parchment, composed of cellulose, caffeine, and minerals (Esquivel and Jiménez, 2012); (iv) silverskin (integument), composed of polysaccharides, such as cellulose and hemicelluloses, as well as proteins and phenolic compounds (Pereira et al., 2020); and (v) finally the seeds (endocarp), containing significant concentrations of caffeine, polyphenols, flavonoids, and triacylglycerols (TAG), bioactive compounds with high antioxidant and antimicrobial activities (Yashin et al., 2013; Haile and Kang, 2019). Coffee leaves also carry important bioactive compounds, including alkaloids, polyphenols, tannins, xanthonoids, and TAG, that can be explored by the cosmetic industry (Chen, 2019; Ngamsuk et al., 2019). Least explored are coffee flowers, which also harbor several secondary metabolites with antioxidant activity, including trigonelline, gallic acid, chlorogenic acid, and caffeine (Pinheiro et al., 2021).

The two most cultivated coffee species are Arabica (*Coffea arabica*), which comprises 60% of traded coffee, and Robusta (*Coffea canephora*), which comprises the majority of remaining industrial production; nevertheless, there are 124 wild *Coffea* species which merit more attention, with some under threat of extinction (Davis et al., 2019). Coffeaology has to date focused on the cultivation, harvesting, drying, pulping, and roasting of Arabica and Robusta beans for drinking coffee and issues relating to by-products from these processes (Rezende et al., 2007; Silva et al., 2011; Huch and Franz, 2015; Pereira et al., 2017). Interest relating to sustainability issues surrounding the waste generated by the roasting, grinding, and percolation processes is increasing; silverskin and spent coffee grounds are the main residual wastes (Murthy and Naidu, 2012; del Pozo et al., 2020). Over 8 million tons of residual coffee is disposed in landfills resulting in serious environmental challenges including toxicity in humans, animals and aquatic organisms (Fernandes et al., 2017). The use of these residues with varying concentrations of high-added value compounds (e.g., polyphenols, terpenes, flavonoids, caffeine, chlorogenic acids) is proposed as a renewable source of active ingredients for the cosmetic industry (Barbulova et al., 2015; Bessada et al., 2018). This is opportune, as players in the coffee industry must find a solution to the wastage from by-products (Esquivel and Jiménez, 2012; Murthy and Naidu, 2012; Jiménez-Zamora et al., 2015; Blinová et al., 2017).

The economic health of 25 million smallholder farmers, many of whom struggle and must rely on a seasonal crop, is also problematic (Mohan et al., 2016; Vanderhaegen et al., 2018; Davis et al., 2019). Therefore, the exploration of new income streams for coffee farmers supporting multiple harvest opportunities, such as coffee wastes, leaves and flowers, is pertinent. Based on these developments, this paper performs a systematic scoping review of the literature to uncover, classify, and discuss the use of coffee constituents in personal care products. Our exploration of active green and sustainable coffee ingredients was framed using the PERSOnal Care products and ingredients classification (PERSOC), and *Coffea* Products Sustainability (COPS) model. The research questions were (1) what is the evidence for the use of coffee constituents in externally applied personal care products? and (2) what is the potential to harness coffee as a sustainable ingredient?

METHODS

Design

A scoping review design, as opposed to a systematic design, best supported our objective to comprehensively investigate this broad and diverse field (Munn et al., 2018). In addition, the Preferred Reporting Items for Systematic Reviews Scoping Review (PRISMA-ScR) was followed (Peters et al., 2015; Tricco et al., 2018), as shown in **Table 1**.

Search Strategy

Searching commenced in November 2020 to identify relevant articles, published in English, since 1970, initially in PubMed/Medline, and then in Web of Science. The PICO framework was used to refine the search strategy: Population (all), Interventions (testing cosmetics and personal care formulations), Comparison (none), Outcome (use of coffee in cosmetic and personal care formulations) (Schardt et al., 2007). Because the search term "coffee" and "personal care" resulted in thousands of articles, we searched for "*Coffea,*" i.e., the botanical term, alongside "skin," "hair," and "cosmetics."

TABLE 1 | PRISMA-ScR checklist.

Section	Item[a]	Included	Explanation if excluded
Title	1. Title	√	
Abstract	2. Structured summary	√	
Introduction	3. Rationale	√	
	4. Objectives	√	
Methods	5. Protocol and registration	x	Not registered as: PROSPERO[b] no longer supports scoping reviews
	6. Eligibility criteria	√	
	7. Information sources	√	
	8. Search	√	
	9. Selection of sources of evidence	√	
	10. Data charting process	√	
	11. Data items	√	
	12. Critical appraisal of individual sources of evidence	x	Not mandatory for scoping reviews
	13. Synthesis of results	√	
Results	14. Selection of sources of evidence	√	
	15. Characteristics of sources of evidence	x	Not mandatory for scoping reviews
	16. Critical appraisal within sources of evidence	√	
	17. Results of individual sources of evidence	√	
	18. Synthesis of results	√	
	19. Summary of evidence	√	
	20. Limitations	√	
	21. Conclusions	√	
Funding	22. Funding	√	

[a]Details in PRISMA-ScR (Tricco et al., 2018)–https://www.equator-network.org/reporting-guidelines/prisma-scr/; [b]PROSPERO, The International prospective register of systematic reviews.

Complementary searches in Google Scholar and Scopus up until February 2021 were also undertaken as shown in the PRISMA diagram (**Figure 1**).

Screening and Data Extraction

Articles were imported into the Rayyan systematic review platform (Ouzzani et al., 2016) for initial assessment. Following the removal of duplicates, title and abstract screening was undertaken on 772 articles, and 180 records were assessed for eligibility as shown in the PRISMA flow diagram (**Figure 1**). Critical appraisal of sources of evidence, optional for scoping reviews (Peters et al., 2015; Munn et al., 2018), was not undertaken (as shown in **Table 1**). Data extraction followed JBI methodology (Peters et al., 2015) and was undertaken for 52 primary research articles.

Oral products were not investigated in this study. Data extraction included: (i) application discussed; (ii) part of the coffee plant, or extract used, and coffee type; (iii) active ingredients and how they were tested; (iv) main findings of the research; (v) potential impact of findings on sustainability issues.

Classification of Articles

Articles were classified to facilitate the analysis according to the personal care application of the formulation or final product investigated. These applications were defined as: (1) Protect (e.g., sunscreens); (2) Embellish (i.e., products that can color, decorate, or alter e.g., make-up, hair color, hair sprays); (3) Remedy (i.e., any products claiming healing or medicinal qualities, such as the stimulation of hair follicles, or the reduction of cellulite); (4) Sanitize (e.g., soaps, scrubs, foams); (5) Odorize (e.g., perfume); or (6) Condition (e.g., moisturizers, creams, shaving creams, among others). The PERSOnal Care products and ingredients classification (PERSOC) is shown in **Figure 2**.

Critical Assessment Relating to Sustainability

Articles were evaluated according to the potential of coffee to be harnessed in a sustainable way. The *Coffea* Products Sustainability model (COPS) (**Figure 3**) was conceived to consider: (1) development of non-toxic products; (2) utilization of coffee industry waste; (3) new income streams for coffee farmers. Scoring is detailed in **Table 2**.

RESULTS

The articles assessed ($k = 52$) were all empirical primary research studies; in fact only one relevant review (Bessada et al., 2018) was identified. Data extraction highlights categorized according to the formulation functionality to Protect, Embellish, Remedy, Sanitize, Odorize, Condition (PERSOC), and the results of the *Coffea* Products Sustainability model (COPS) analysis are shown in **Tables 3–5**. Statistical analysis of the articles according to coffee genotype and part, and cosmetic production, application area, and formulation development within the PERSOC classification are shown in **Tables 6**, **7**.

General Findings

Over 90% of the selected articles ($k = 47$) were conducted in the last decade (**Tables 3–5**). The country of origin showed a heterogeneous distribution with Brazil being the foremost contributor for this topic ($k = 10$; 19.23%), followed by Indonesia ($k = 8$; 15.38%), Portugal ($k = 7$; 13.46%), South Korea ($k = 5$; 9.61%), and Thailand and United States (both with $k = 4$; 7.69%). In terms of study design, 81% ($k = 42$) described *in vitro*, non-human participant *in vivo,* characterization, or a combination of these methods, many of which were carried out to assess the safety or irritability that products with the addition of coffee extracts could cause. The remaining studies 19% ($k = 10$) reported clinical trials ($k = 7$) and other studies involving participants ($N = 309$).

Coffee Use in PERSOC Products

The 52 articles were categorized using PERSOC (section Classification of articles; **Figure 2**) as follows: Protect ($k = 14$; 27%); Embellish ($k = 2$; 4%); Remedy ($k = 25$; 48%);

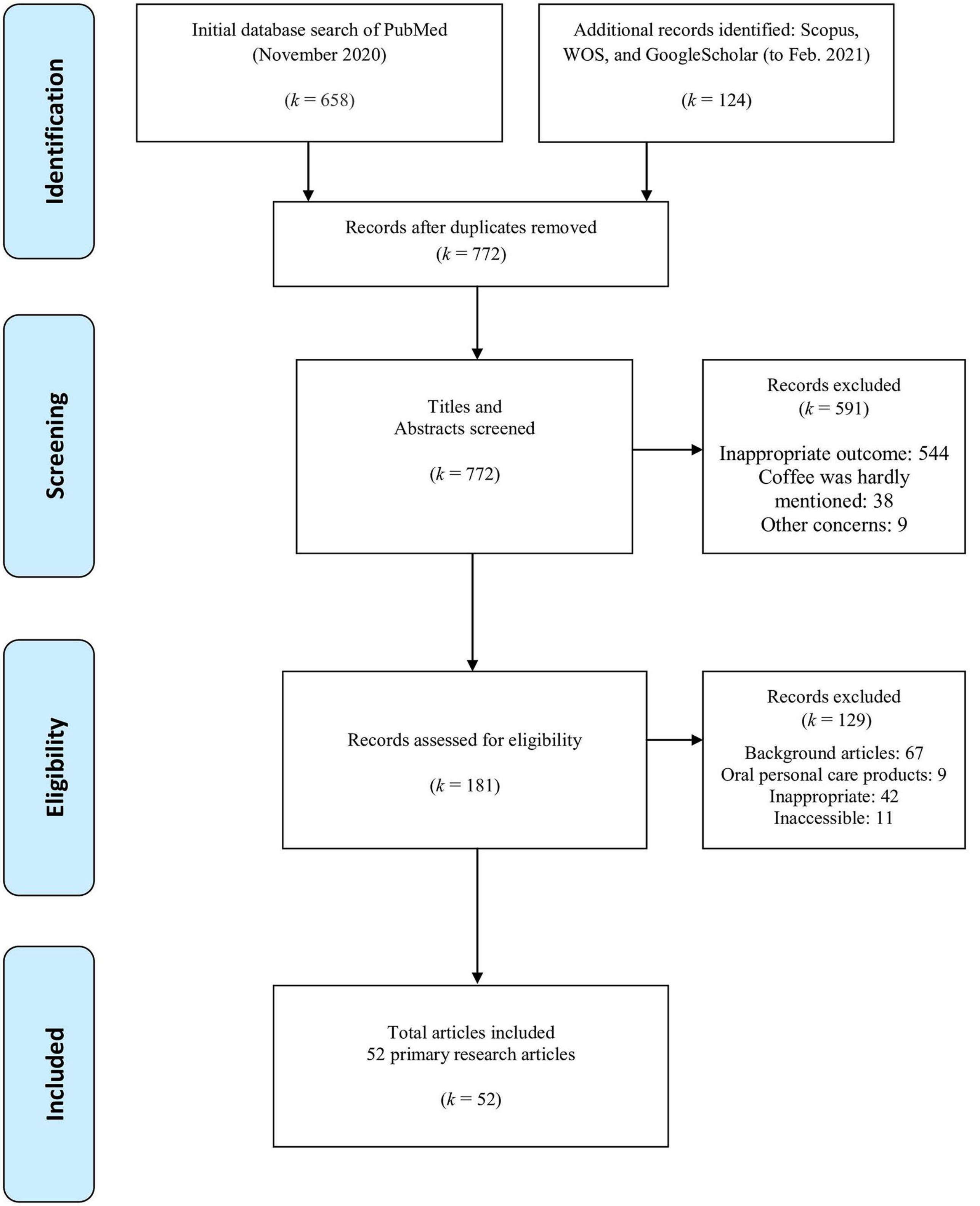

FIGURE 1 | PRISMA flow diagram.

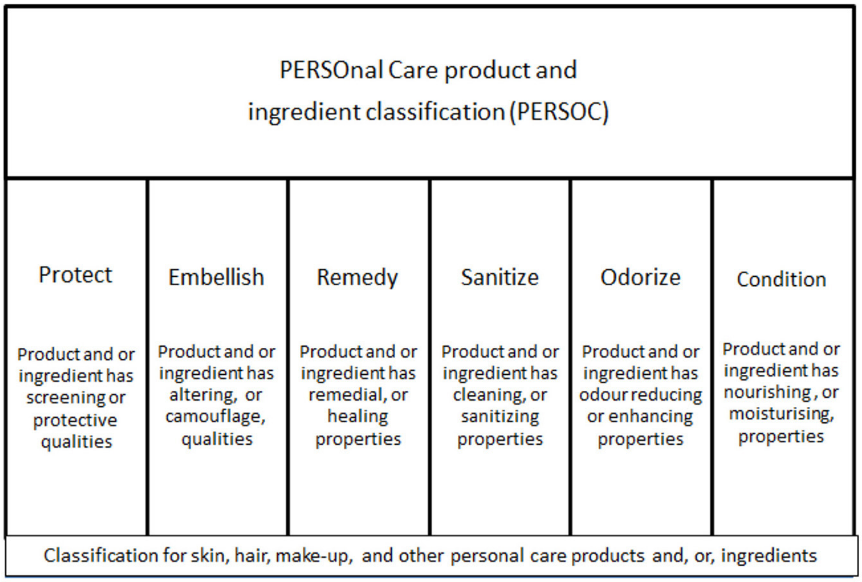

FIGURE 2 | The PERSOnal Care products and ingredients classification (PERSOC). The PERSOnal Care products and ingredients classification (PERSOC) enables classification according to whether the product or ingredient can Protect, Embellish, Remedy, Sanitize, Odorize, or Condition (PERSOC). Thus, PERSOC is a dual acronym. It should be noted that products and ingredients may have multiple uses, thus could be classified in one or more PERSOC category.

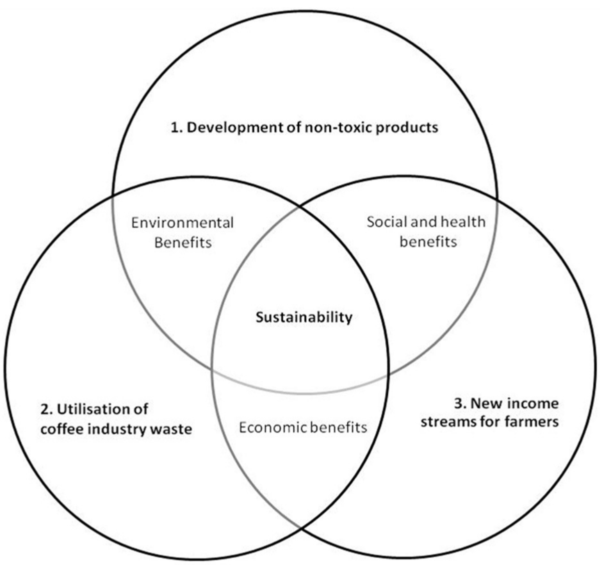

FIGURE 3 | *COffea* Products Sustainability model (COPS). 1. Development and promotion of bio-degradable non-toxic personal care products and ingredients for consumer and environmental health benefits; 2. Utilization of coffee industry waste (e.g., spent coffee grounds, husks, silverskin) in personal care products to address environmental challenges relating to waste disposal; 3. Environmentally friendly diversification and new income streams for farmers including supporting multiple harvest opportunities (e.g., leaves, flowers) which leave farmers less dependent on coffee bean seasonality.

TABLE 2 | Sustainability assessment criteria and scoring.

***Coffea* products sustainability model (COPS)**			
COPS assessment criteria	**COPS Scoring system[a]**		
	1 point	**2 points**	**3 points**
1. Development of non-toxic products	Addition of coffee parts or its extracts without the removal of synthetic or toxic active principles	Addition of coffee parts or its extracts in the formulation with the removal of some synthetic or toxic active ingredients	Use or intended use of coffee parts or its extracts as the only active ingredient
2. Utilization of coffee industry waste	Use of coffee beans and their extracts	Use of coffee leaves, flowers, and their extracts	Use of by-products including silverskin, husks, and spent coffee grounds
3. New income streams for coffee farmers	Use of green or roasted coffee beans and their extracts, which are already commercialized in the food industry	Use of coffee leaves, flowers, and their extracts	Use of by products including silverskin, husks, and spent coffee grounds

[a]*Overall scores can range from 3 points (minimum) to 9 points (maximum). Overall scores of 3–4 points are interpreted as "Low;" 5–6 points as "Medium;" and 7–9 points as "High".*

Sanitize (k = 3; 6%), Odorize (k = 2; 4%); and Condition (k = 6; 11%) (**Tables 3–5**). Coffee has multi-functional properties, thus the PERSOC categories can overlap. Here, anti-aging effects are categorized as protective where anti-UV properties or anti-oxidant properties are reported as dominant, and remedial where cell renewal (e.g., anti-wrinkle), healing, anti-inflammatory, and/or anti-microbial effects are highlighted. A

TABLE 3 | Data extraction and COPS classification of the 14 papers classified according to PERSOC where "Protect" is perceived as the dominant aim.

PERSOC	Application and detail	Study design	Country	Coffee part (and type)	Active ingredients	Main findings	COPS (Score)	References
Protect	Skin care: anti-aging/Sunscreen	*In vitro*	Taiwan	Leaves (Arabica)	Chlorogenic acid, cafestol, and caffeic acid	Arabica coffee leaf extract prevented UV-B skin damages through inhibition of matrix metalloproteinase-1 (MMP-1), an enzyme expressed in photo-damaged cells that breakdowns elastin fibers	High (9)	Chiang et al., 2011
Protect	Skin care: sunscreen	*In vitro*	Brazil	Bean (NA)	Tocopherols and linoleic acid	A cosmetic formulation using green coffee oil resulted in a 20% improvement in sun protection factor (SPF) and thus increased its efficiency to protect the skin against sun damage showing a synergistic effect between phenolic compounds and the ethylhexyl methoxycinnamate	Low (3)	Chiari et al., 2014
Protect	Skin care: anti-aging/sunscreen	*In vitro*	South Korea	Bean (Arabica)	Chlorogenic acid, pyrocatechol and 3,4,5-tricaffeoyl quinic acid	Chlorogenic acid (CGA) isolated from *Coffea arabica* beans inhibited reactive oxygen production (ROS) stimulated by UV radiation, and displayed good SPF qualities. CGA can be a preventative agent against skin aging by UV radiation CGA fraction significantly reduced the ROS of UV-exposed mouse fibroblast cells and inhibited enzyme-mediated oxidative stress	Medium (5)	Cho et al., 2017
Protect	Skin care: anti-aging/sunscreen	*In vivo* (mice)	South Korea	By-product (NA)	NA	An ethanol extract of spent coffee grounds inhibited the intracellular reactive oxygen production ROS content of UVB-damaged HaCaT keratinocytes in mouse skin; topical application of the ethanolic extract diminished the wrinkle area in the irradiated area	High (7)	Choi et al., 2015
Protect	Skin care: sunscreen	*In vivo* (mice)	USA	Soluble coffee (NA)	Caffeine	Topical caffeine application on mice exposed to UVB inhibited the formation of tumors and increased the apoptosis in tumors	Medium (6)	Conney et al., 2007
Protect	Skin care: anti-aging	Characterization	USA	Bean (NA)	Chlorogenic acid, proanthrocyanidins, quinic acid, and ferulic acid	Coffeeberry extract presents as an innovative antioxidant, and may be used as a topical antioxidant within a skin care regime.	Medium (5)	Farris, 2007
Protect	Skin care: anti-aging	*In vitro*	Spain	By-product (NA)	Caffeine, chlorogenic acids	Anti-aging properties of coffee silverskin aqueous extract are reported. Ethanolic water extract of coffee silver skin reduced the UV photoaging damage through ROS scavenging and down regulation of enzyme-induced stress	High (9)	Iriondo-DeHond et al., 2016
Protect	Skin care: anti-oxidant	Characterization	Thailand	Bean (Arabica)	Chlorogenic and caffeic acids	Antioxidant activities of Arabica and Robusta are compared. Higher antioxidant activity observed in Robusta unroasted bean	Medium (5)	Kaisangsri et al., 2020
Protect	Skin care: sunscreen	Characterization/ *In vitro/in vivo*	Portugal	By-product (NA)	NA	A novel sunscreen formulation was developed. Spent coffee oil can improve sunscreen performance. The combination of oil fraction from spent coffee grounds and green coffee oil showed satisfactory moisture retention and SPF	High (7)	Marto et al., 2016a
Protect	Skin care: sunscreen	Characterization *in vitro/in vivo*	Portugal	Bean (NA)	Polyphenols	A novel sunscreen formulation was developed based. Using GCO, and modified starch. GCO showed a synergic interaction with TiO_2 (titanium dioxide) increasing the sun protective factor	Low (4)	Marto et al., 2016b

(Continued)

TABLE 3 | Continued

PERSOC	Application and detail	Study design	Country	Coffee part (and type)	Active ingredients	Main findings	COPS (Score)	References
Protect	Skin care: sunscreen/ hydration	Characterization	Guatemala	Leaves (Arabica)	Flavonoids	Formulations containing *Coffea arabica* leaves ethanolic extract and coffee oil increased the sun protective factor of the product	Medium (6)	Sandoval et al., 2020
Protect	Skin care: sunscreen	Characterization	Brazil	Bean (10 species)	Linolenic, palmitic, oleic, and stearic acids	Ten species of *Coffea* sp. (including *C. arabica* and *C. canephora*) were tested according to the oil content, composition, and presence of unsaponifiable matter. Due to high availability, composition of the oil fraction and high sun protective factor, *C. arabica* was selected as most appropriate for cosmetic purposes	Medium (5)	Wagemaker et al., 2011
Protect	Skin care: sunscreen/ antimicrobial	Characterization/ *in vitro*/*in vivo*	Brazil	Bean (Arabica)	NA	Unsaponifiable matter, a fraction of GCO showed higher sun protective factor and antimicrobial activity against *S. epidermis, E. coli,* and *P. aeuroginosa*	Medium (5)	Wagemaker et al., 2016
Protect	Skin care: sunscreen	NA	Indonesia	Leaves (Robusta)	NA	Robusta coffee leaves were investigated for their benefits to maintain skin health. Ethyl acetate fraction of coffee leaves ethanolic extract increased the sun protective factor of sunscreen formulations	High (7)	Yuliawati et al., 2019

NA, not available, informed or found; GCO, green coffee oil; ROS, reactive oxygen production; SPF, skin protection factor; UV, Ultraviolet (UVB, ultraviolet B rays).

schematic of potential applications of coffee in personal care products according to PERSOC is found in the **Figure 4**.

The major application segments and the proposition of formulated cosmetics containing coffee extracts revealed anti-aging ($k = 19$) as the main cosmetic application, followed by sunscreen ($k = 8$), hydration ($k = 6$), and hyperpigmentation ($k = 3$) (**Table 7**). A majority of studies (60%) elaborated cosmetic formulations containing coffee parts or its extracts accounted ($k = 31$) (**Table 7**). Phenolic compounds, including chlorogenic acids, flavonoids, and terpenes, were the main phytochemicals identified 73% ($k = 37$). Oil fraction, composed mainly of triacylglycerols (TAG) such as linoleic, linolenic, and oleic acids, and caffeine, was reported in 6 publications (**Tables 3–5**). Eleven papers did not inform or propose any bioactive compounds responsible for the observed results.

Coffea arabica (Arabica) and *C. canephora* (Robusta) were specified as investigated by most studies 62% ($k = 32$), but 38% ($k = 20$) did not specify the species. Wagemaker et al. (2011) was the only research that included eight other coffee species (*C. congensis, C. eugenioides, C. heterocalyx, C. kapakata, C. liberica, C. racemose, C. salvatrix,* and *C. stenophylla*). Green or roasted coffee beans were the main parts investigated as potential natural substituents of synthetic active ingredients in cosmetic formulations ($k = 29$; 56%), followed by by-products ($k = 13$; 25%), and leaves ($k = 5$; 10%) (**Table 6**). Only four studies evaluated the use of end products (*i.e.,* milled roasted coffee and instant coffee): two as potential hair colorants (Singh et al., 2015; Gonot-Schoupinsky and Gonot-Schoupinsky, 2020), one as a lipstick herpes remedy (Toscano, 2015), and one as a sunscreen (Conney et al., 2007).

Classification of Data According to COPS

Evaluation of impact of article findings using COPS scoring (section Critical assessment relating to sustainability) rated 35% ($k = 18$) as having a potentially high sustainability impact, 54% ($k = 28$) as a medium, and 11% ($k = 6$) as a low impact (**Tables 3–5**).

DISCUSSION

This systematic scoping review is, to the best of our knowledge, the first to investigate the beneficial and sustainable use of coffee as a natural ingredient in personal care formulations. Our assessment of 52 empirical studies showed coffee has wide-ranging potential as a natural and beneficial source of bioactive compounds that can be of great interest to the cosmetic industry. Results are discussed according to: (1) active biocompounds; (2) applications of coffee extracts in the cosmetic and personal care industry; and (3) sustainability implications.

Active Compounds as Replacement for Synthetic Substances

The prospection of plant-derived metabolites in the cosmetic industry can be related to green label certifications. Although these date to 1992, commercial interest in natural and organic ingredients gathered pace in 2008 when the NATRUE Standard and Label by the International Natural and Organic Cosmetics Association called for the proportion of natural or organic

TABLE 4 | Data extraction and COPS classification of the 25 papers classified according to PERSOC where "Remedy" is perceived as the dominant aim.

PERSOC	Application and detail	Study design	Country	Coffee part (and type)	Active ingredients	Main findings	COPS (Score)	References
Remedy	Skin care: wound healing	*In vitro/in vivo* (animal)	Brazil	Bean (Arabica)	Chlorogenic acids	Topical use of coffee beans residual press cake significantly reduced wound area size	Medium (6)	Affonso et al., 2016
Remedy	Hair care: hair growth	Clinical ($n = 52$)	Argentina	Bean (Arabica)	Quercetin derivatives and nordihydroguaiaretic acid (Chlorogenic acids)	The spray product (ECOHAIR®) using extracts from coffee beans induced hair growth and significantly reduced hair loss, improving the overall volume and appearance	High (7)	Alonso and Anesini, 2017
Remedy	Make-Up: hair growth	Clinical ($n = 10$)	Argentina	Bean (Arabica)	Quercetin derivatives and nordihydroguaiaretic acid (Chlorogenic acids)	The gel mascara (ECOHAIR®) using extracts from coffee beans increased eyelash and eyebrow growth in pre- and post-menopausal women	High (7)	Alonso et al., 2019
Remedy	Skin care: hyper-pigmentation	*In vitro*	Indonesia	Bean (Robusta)	Flavonoids and polyphenols	The formulated gel using green coffee bean extract had face lightening properties with desirable pH, viscosity, and spreadability after 28 days of storage	Medium (5)	Aulifa et al., 2020
Remedy	Skin care: hyper-pigmentation	Characterization	Thailand	Bean (Arabica and Robusta)	Caffeine	Coffee bean extracts were evaluated and found safe and stable for cosmetic and anti-aging products. High antioxidant activity and inhibition of tyrosinase, showing application as skin brightening agent	Medium (5)	Kiattisin et al., 2016
Remedy	Skin care: anti-aging	*In vivo* (rats)	Brazil	Bean (NA)	Phenolic compounds	Administration of roasted coffee oil increased the interleukin expression and serum levels, accelerating the wound healing in rats	Medium (5)	Lania et al., 2017
Remedy	Skin care: anti-aging/anti-wrinkle	*In vivo* (mice)	Indonesia	Bean (Robusta)	Chlorogenic acids	Coffee extract cream prevented wrinkles in mice. Increased epidermal thickness and collagen content through inhibition of matrix metalloprotease-1 (MMP-1) expression, an enzyme associated with collagen degradation, was reported	Medium (5)	Mariati et al., 2021
Remedy	Skin care: anti-aging/anti-wrinkle	Clinical ($n = 30$)	USA	Bean (Arabica)	Chlorogenic acid, condensed proanthocyanidins, quinic acid, and ferulic acid	CoffeeBerry® extract creams were tested; they appeared to improve the appearance of photoaged skin. Reduction of the fine lines, wrinkles and pigmentation after 6 weeks of administration	Medium (5)	McDaniel, 2009
Remedy	Skin care: cellulite reduction	Randomized control trial ($n = 21$)	Thailand	Bean (Arabica)	Caffeine	Steamed hot herbal compresses containing GCO extracts provide useful cellulite reduction without detectable side effects	Medium (5)	Ngamdokmai et al., 2018

(Continued)

TABLE 4 | Continued

PERSOC	Application and detail	Study design	Country	Coffee part (and type)	Active ingredients	Main findings	COPS (Score)	References
Remedy	Skin care: anti-aging/antioxidant// sunscreen	Clinical ($n = 40$)	USA	Bean (Arabica)	Phenolic compounds	Evaluation of a high antioxidant, polyphenol, skin care regime, containing *Coffea arabica*. The formulated product reduced wrinkles, blotchy redness, tactile roughness, and clarity in photodamaged skin	Medium (5)	Palmer and Kitchin, 2010
Remedy	Skin care: anti-aging/anti-wrinkle/antimicrobial	*In vitro*	South Korea	Bean (NA)	Phenolic compounds	Dutch coffee extract grounds had strong antimicrobial, antioxidant, and anti-wrinkle properties. Inhibition of elastase activity, an enzyme associated with elastin and collagen breakdown, and antimicrobial activity against *Escherichia coli*, *Bacillus* sp., and *Propinobacterium acnes*	Medium (5)	Park et al., 2018
Remedy	Skin care: anti-inflammatory	*In vivo* (rats)	Italy	Bean (Robusta)	Phenolic compounds	Treatment with an ointment containing methanolic extract of green beans reduced paw oedema in rats. Green coffee extract appears to be beneficial in reducing inflammation	Medium (5)	Pergolizzi et al., 2020
Remedy	Skin care: anti-aging	*In vivo* ($n = 69$)	Italy	Bean (Arabica)	NA	Biocellulose masks containing *Coffea arabica* seed extract were tested for anti-aging, lifting, and cell renewal effects. Decrease in skin roughness and breadth of wrinkles after 2 months were reported, and the masks were well-tolerated	Medium (6)	Perugini et al., 2020
Remedy	Skin care: hyper-pigmentation/anti-aging	*In vitro*	Portugal	By-product (NA)	Phenolic acids, alkaloids	Formulas containing spent coffee ground extract showed a dose-dependent increase on antioxidant and ROS scavenging effect; inhibition of enzymatic-mediated elastin degradation was observed	High (9)	Ribeiro et al., 2018
Remedy	Skin care: cellulitis reduction	*In vitro*	Brazil	By-product (NA)	Caffeine	Coffee silverskin presents a therapy for cellulitis. Nanostructured lipids increased the permeation of caffeine from coffee silver skin extract	High (9)	Rodrigues et al., 2016a
Remedy	Skin care: anti-aging/anti-wrinkle	*In vitro/in vivo* ($n = 20$) Clinical ($n = 20$)	Portugal	By-product (NA)	Caffeine	Coffee silverskin allows an increased penetration of caffeine, showing similar activities results on skin elasticity, moisture, and viscoelasticity to a commercial formulation containing HyaCare® Filler CL	High (9)	Rodrigues et al., 2016c
Remedy	Skin care: anti-aging	*In vivo* (rats)	Indonesia	Bean (Arabica)	Trigonelline	Coffee extract was able to increase skin collagen levels and rejuvenate the skin of aging rats	Low (4)	Safrida and Sabri, 2017
Remedy	Skin care: anti-inflammatory	*In vitro/in vivo* (mice)	Brazil	Leaves (Arabica)	Flavonoids, 5-caffeoylquinic acid and mangiferin	*Coffea arabica* leaves have antioxidant and anti-inflammatory properties. Methanolic extract from coffee leaves and its hexane fraction inhibited lipid peroxidation and reduced oil-, phenol- and histamine-induced edema thickness in mice	High (7)	Segheto et al., 2018
Remedy	Skin care (lip): anti-viral	*In vivo*	Ecuador	Soluble coffee (Arabica)	Polyphenols, flavonoids, and chalcones	An anti-herpes lipstick containing soluble coffee decreased itching and swelling. Superior healing factor of herpes lip wounds in comparison to control were noted	Medium (6)	Toscano, 2015
Remedy	Skin care: anti-aging	*In vitro/in vivo*	Portugal	Bean (NA)	Linoleic and palmitic acids	GCO formulations showed high compatibility and safety of coffee bean oil for cosmetic purposes	Medium (5)	Wagemaker et al., 2015a

(Continued)

TABLE 4 | Continued

PERSOC	Application and detail	Study design	Country	Coffee part (and type)	Active ingredients	Main findings	COPS (Score)	References
Remedy	Skin care: anti-aging/sunscreen	*In vitro/in vivo* (mice)	Brazil	Bean (Arabica)	NA	GCO improved the sun protective factor when added to formulations through reduction of transepidermal water loss	Medium (5)	Wagemaker et al., 2015b
Remedy	Skin care: anti-aging/sunscreen	*In vitro/in vivo*	Taiwan	Leaves (Arabica)	Chlorogenic acid, caffeine, cafestol, and caffeic acid	*Coffea arabica* extract was investigated for antioxidant and anti-inflammatory properties, and effect on UV-B induced photodamage. Topical application of ethanolic extracts from coffee leaves reduced the expression of MMP-1 and, consequently, the collagen degradation	High (7)	Wu et al., 2017
Remedy	Skin care: anti-aging/sunscreen	*In vitro*	South Korea	By-product (Arabica)	Caffeine and phenolic compounds	The antioxidant capacity of coffee silverskin was found to be high indicating suitability for use in multifunctional cosmetics. Ethanolic extract of silver skin reduced intracellular ROS level and MMP-1 expression	High (9)	Xuan et al., 2019a
Remedy	Skin care: anti-aging/sunscreen	Characterization	South Korea	By-product (NA)	Terpenoid	The anti-photoaging effects of atractyligenin were investigated. Inhibition of MMP expression, intracellular ROS, and homeostasis promotion of collagen were reported	High (9)	Xuan et al., 2019b
Remedy	Skin care: anti-aging/sunscreen	*In vitro/in vivo* (mice)	Taiwan	By-product (NA)	Linoleic, palmitic, stearic, oleic, arachidi, gadoleic, and linolenic acids	A nanoemulsion made with spent coffee grounds ameliorated skin erythema, melanin formation, and subcutaneous blood flow rate during irradiation of mice and inhibited melanoma cell growth	Medium (5)	Yang et al., 2017

NA, not available, informed, or found; GCO, green coffee oil; MMP, Matrix Metalloproteinases; ROS, reactive oxygen production; UV, Ultraviolet (UVB, ultraviolet B rays).

compounds to be at least 75% (Cervellon and Carey, 2011). This may explain the scarcity of research we found prior to 2008. We report on three groups of bioactive compounds: phenolic compounds, triacylglycerols, and caffeine.

Phenolic Compounds

Phenolic compounds are a ubiquitous class of secondary metabolites found in virtually all structures of coffee plants. Although found in higher concentration on seeds, the exocarp, silverskin, spent coffee grounds also contains appreciable amounts (10.70 ∼ 15.82% weight) of these molecules (Murthy and Naidu, 2012; Janissen and Huynh, 2018). A recent study revealed that young leaves also contain high concentrations of phenolic compounds (Ngamsuk et al., 2019). Chiang et al. (2011) and Segheto et al. (2018) suggested the coffee leaf as an appropriate source of bioactive compounds, proposing the applicability of leaf extract as an anti-inflammatory and to prevent photo-damaged skin. Challenges of using phenolic compounds in cosmetic formulations include (i) addition of surfactants or solid carriers to increase the migration of polyphenols into the skin and prevent its precipitation; and (ii) the interaction with proteins and saccharides from the final product, which may lead to the immobilization of these molecules (Zillich et al., 2015).

Among the several classes of phenolic compounds are flavonoids (e.g., kaempferol, catechin, and epicatechin) and phenolic acids (e.g., chlorogenic, caffeic, ferulic, and coumaric acids), molecules well-known for their high antioxidant activity *via* donation of a hydrogen atom from its hydroxyl group to the reactive oxygen species (ROS) and free radicals (Minatel et al., 2017; Santos-Sánchez et al., 2019). This radical scavenging ability is known as a defense mechanism against lipid oxidation and UV-protection in plant tissues (Minatel et al., 2017). Topical administration is commonly associated with a sunscreen effect, the reduction of oxidative stress, and antioxidant and antimicrobial properties (Zhang et al., 2015; Abdel-Daim et al., 2018). The characterization and *in vitro* studies performed by Cho et al. (2017) and Farris (2007) showed that the presence of chlorogenic and ferulic acids can also increase the sun protective factor in human cells through inhibition of ROS.

Chlorogenic acids (CGA) are the most abundant of phenolic compounds in coffee fruit with concentrations ranging from 0.98 to 46.14 mg/g of coffee beans according to the species (Ayelign and Sabally, 2013; Lemos et al., 2020). Although over 69 CGA were already identified in green coffee beans (Jaiswal et al., 2010), 3-caffeoylquinic acid, 3,4-dicaffeoilquinic acid, and 5-caffeolylquinic acid are commonly reported in the literature due to its higher concentrations and impacts on coffee beverage quality (Santos et al., 2021). Our study revealed that CGA present in coffee bean extract, residual press cake, and spent coffee grounds were successfully applied in *in vitro* trials to reduce skin hyperpigmentation and promote skin wound healing (Affonso et al., 2016; Ribeiro et al., 2018; Aulifa et al., 2020).

Flavonoids are another clade of secondary metabolites in plants produced under biotic or abiotic stress factors with a phenyl benzopyran basic structure (C_6-C_3-C_6) (Górniak et al., 2019). Flavonoids can be use as natural organic dyes, but these

TABLE 5 | Data extraction and COPS classification of the 13 papers classified according to PERSOC where "embellish," "sanitize," "odorize," or "condition" are perceived as the dominant aim.

PERSOC	Application and detail	Study design	Country	Coffee part (and type)	Active ingredients	Main findings	COPS (Score)	References
Embellish	Hair care: dye	Pre-pilot study ($n = 2$)	Monaco	Soluble coffee (Arabica)	NA	A solution of instant coffee was tested as a hair coloring agent by applying it to partially gray hair over 7 months. The appearance of grayness reduced, but coverage was partial and semi-permanent; reduced scalp sensibility was also noted	Medium (5)	Gonot-Schoupinsky and Gonot-Schoupinsky, 2020
Embellish	Hair care: dye	Clinical ($n = 25$)	India	Commercial roasted coffee (Arabica)	NA	Hair colorants containing roasted coffee powder showed high acceptance between volunteers, and exhibited promising results in combination with other ingredients	Medium (5)	Singh et al., 2015
Sanitize	Skin care: exfoliating scrub	Characterization	Colombia	By-product (NA)	Polyphenols	Exfoliating body cream made with spent coffee grounds showed desirable exfoliating and antioxidant capacities	High (9)	Delgado-Arias et al., 2020
Sanitize	Skin care: body scrub	Characterization	Indonesia	Bean (Arabica)	Flavonoids, alkaloids, saponins, quinones, tannins, coumarin, and steroids and triterpenoids	A body scrub cream using green coffee extract at 1, 3, and 5% was formulated and tested. The body scrub formulations were all positively evaluated	Medium (5)	Hilda et al., 2021
Sanitize	Skin care: soap	Characterization	Cameroon	By-product (NA)	Potassium source	Potash, a raw material for soap production, was obtained using Robusta coffee husk waste. Coffee husks are a natural and renewable source of potassium for soap production	High (9)	Pauline et al., 2010
Odorize	Skin care: fragrance (body splash)	Characterization	Indonesia	Bean (Arabica)	Alkaloid compounds, phenols, flavonoids, tannins, quinones, steroids	A fragrance formula using essential oil with natural fragrance in java pre-anger coffee was tested as a body splash; it was safe, stable, and left no stains. Organoleptic aspects did not change with the increase of the concentration; however, the oil may affect the dispersion of the product	Low (4)	Handayani et al., 2019
Odorize	Skin care: foot odor	*In vitro*	Indonesia	Bean (NA)	NA	A foot sanitizer formula using the synergistic benefits of coffee and ginger showed desirable organoleptic and physico-chemical features, and high antimicrobial effect against *Staphylococcus epidermis*	Low (3)	Santoso and Riyanta, 2019
Condition	Skin care: hydration	Characterization	Thailand	Bean (Arabica)	Gallic, protocatechuic, and chlorogenic acids	The body lotion and hand moisturizing cream containing coffee extract were suitable for topical use and nourished and protected the skin and were stable for 3 months after preparation	Medium (5)	Chaiyasut et al., 2018
Condition	Skin care: hydration	Characterization	Brazil	Bean (Arabica)	Fatty acids and tocopherols	A cream containing coffee extracts had organoleptic characteristics and antioxidant properties; the chloroform fraction of the ethanolic coffee bean extract showed stability even when submitted to extreme temperatures (5 and 45°C)	Medium (5)	Diamantino et al., 2019

(Continued)

TABLE 5 | Continued

Condition	Skin care: hydration	*In vitro*	Brazil	Bean (Arabica)	Phenolic diterpenes (kahweol and cafestol), fatty acids, and α-tocopherol	Green coffee oil may improve skin hydration. Oil fraction was able to increase the synthesis of growth factors in human fibroblasts and expression of iAQP-3 mRNA expression, leading to a superior hydration	Medium (5)	Pereda et al., 2009
Condition	Skin care: hydration	*In vivo* (mice)	Indonesia	Bean (Robusta)	NA	Cream containing *Coffea canephora* showed the best increase on the hydration and firmness levels	Low (3)	Putri et al., 2019
Condition	Skin care: hand cream	Characterization/ *In vitro*	Portugal	By-product (NA)	Chlorogenic and caffeic acids	A hand cream containing coffee silver skin extract was evaluated for shelf life. Ethanolic extract from coffee silverskin showed high antioxidant activity with no toxicity effect	High (9)	Rodrigues et al., 2016b
Condition	Skin care: hydration	Characterization/ *In vitro/in vivo* (*n* = 20)	Portugal	By-product (NA)	Chlorogenic and caffeic acid	A new body formulation containing silver skin ethanolic extract improved skin hydration; organoleptic and sensorial attributes was considered as pleasant	High (9)	Rodrigues et al., 2016d

NA, not available, informed, or found.

heterocyclic pigments are not stable to light and other chemicals (Pozharskii et al., 2011). Color fixation issues have been observed when using coffee as hair dye (Singh et al., 2015; Gonot-Schoupinsky and Gonot-Schoupinsky, 2020). A patented and commercialized product containing coffee bean extracts rich in quercetin derivates (ECOHAIR®) showed significant hair growth in volunteers with alopecia eyebrow growth and thickness in pre- and post-menopausal women (Alonso and Anesini, 2017; Alonso et al., 2019). In the coffee plant, flavan-3-ols [e.g., (+)-catechin and (–)-epicatechin], and kaempferol are the main representants identified in coffee beans, silverskin, and spent coffee grounds (Mussatto et al., 2011; Nzekoue et al., 2020). Some of the investigated studies associated the presence of flavonoids in leaves and soluble coffee extracts to the increase in sun protective factor in cosmetic formulations and anti-viral properties against the herpes virus (Toscano, 2015; Sandoval et al., 2020).

Titanium dioxide (TiO_2), a biologically inert material with ability to confer opacity to cosmetic formulations, is widely applied as an inorganic ingredient in sunscreens. Although the use of TiO_2 has been authorized since 1999 by the Food and Drugs Administration (FDA), recent studies revealed that nanoparticles of this inorganic material may lead to induced oxidative stress (Kim et al., 2010; Shrivastava et al., 2014), genotoxicity (Ghosh et al., 2010; Charles et al., 2018), and neurotoxic effects (Song et al., 2015). As polyphenols are natural pigments, these compounds are able to completely absorb the UV-B spectrum and partially the UV-A and UV-C spectra when applied topically, being a suitable replacer for TiO_2 nanoparticles (Nichols and Katiyar, 2010; Tomazelli et al., 2018). Studies analyzed in our work demonstrated the safety and efficiency of polyphenols present in coffee extracts through the absence of cytotoxic effects in mouse fibroblast (CCRF) and human epidermal keratinocyte (HaCaT) cell lines, and increase in SPF in cosmetic formulations (Choi et al., 2015; Cho et al., 2017; Sandoval et al., 2020).

The constant use of synthetic phenolic antioxidants SPA, an extremely varied molecular weight class synthesized through catalytic reactions between a phenolic group with oleofins, can result in harmful and carcinogenic effects in personal care products (Vandghanooni et al., 2013; Yang et al., 2018; Ham et al., 2020; Liu and Mabury, 2020). In this sense, coffee beans, leaves, and processing by-products are a potential source of renewable phenolic and antioxidant compounds for the cosmetic industry to replace SPA.

Triacylglycerols

Triacylglycerols are a rich and complex mixture of free fatty acids in a combined state with glycerol, including palmitic, oleic, linoleic, linolenic, and stearic acids, which are concentrated in the endosperm (99.6%) (Cheng et al., 2016). The oil fraction in coffee plants ranges between 7 and 17%, being significantly influenced by the genotype, fruit maturity, altitude of cultivation, and edaphoclimatic conditions (Villarreal et al., 2009). Sterols, tocopherols, and diterpene alcohols are least found. A small portion of the oil fraction is found in outer layers of the fruit (e.g., silverskin, parchment, and husk) and in spent coffee grounds,

TABLE 6 | Selected statistics of overall articles.

Personal care product/ingredient classification		Overall		Skin, hair, other (e.g., Make-up)			Part of coffee plant used[c]			
PERSOC	**Detail**	**% articles[a]**	**% arabica[b]**	**% skin**	**% hair**	**% other**	**% bean**	**% leaves**	**% by-product**	**% other**
P	Protect	26.92	22.22	100.0	–	–	50.00	21.43	21.43	7.14
E	Embellish	3.85	7.41	–	100.0	–	–	–	–	100.0
R	Remedy	48.08	51.86	92.0	4.00	4.00	64.00	8.00	24.00	4.00
S	Sanitize	5.77	3.70	100.00	–	–	33.33	–	66.67	–
O	Odorize	3.85	3.70	100.00	–	–	100.0	–	–	–
C	Condition	11.53	11.11	100.00	–	–	66.67	–	33.33	–
	Total	100.0	100.0	92.31	5.77	1.92	57.69	9.61	25.00	7.70

[a]*Based on k = 51,* [b]*Coffea Arabica,* [c]*where specified, n = 27.*

TABLE 7 | Application area of the selected papers according to the PERSOC classification and the percentage of formulation development in each segment.

PERSOC	Application area	% articles	Formulation development (%)[a]
Protect	Sunscreen	57.14 (k = 8)	50.00 (k = 4)
	Anti-Aging	35.72 (k = 5)	20.00 (k = 1)
	Anti-Oxidant	7.14 (k = 1)	–
Embellish	Dye	10.53 (k =2)	100.0 (k = 2)
Remedy	Wound healing	4.00 (k = 1)	–
	Hair growth	8.00 (k = 2)	100.0 (k = 2)
	Anti-Aging	56.00 (k = 14)	50.00 (k = 7)
	Hyperpigmentation	12.00 (k = 3)	66.67 (k = 2)
	Cellulitis	8.00 (k = 2)	100.0 (k = 2)
	Anti-Inflammatory	8.00 (k = 2)	50.00 (k = 1)
	Anti-Viral	4.00 (k = 1)	100.0 (k = 1)
Sanitize	Soap	33.33 (k = 1)	–
	Body scrub	33.33 (k = 1)	100.0 (k = 1)
	Exfoliating products	33.34 (k = 1)	100.0 (k = 1)
Odorize	Fragrance	50.00 (k = 1)	100.0 (k = 1)
	Food odor	50.00 (k = 1)	100.0 (k = 1)
Condition	Hydration	100.0 (k = 6)	83.33 (k = 5)

[a]*Percentage calculated within the application area.*

namely coffee wax, with a similar constitution in TAG (Speer and Kölling-Speer, 2006).

In cosmetic industries, mineral oils and waxes provide viscosity and consistency or lubricating and protective properties, being classified as mineral oil saturated hydrocarbons (MOSH) or mineral oil aromatic hydrocarbons (MOAH) (Chuberre et al., 2019). These substances are commonly obtained from the purification of crude petroleum oil (Cosmetics Europe, 2018). The MOAH fraction represents a public health risk (Chuberre et al., 2019). TAG are increasingly applied as emulsifiers in cosmetic formulations due to the rheological similarities with mineral oil and the absence of toxicity (Alvarez and Rodríguez, 2000; Burnett et al., 2017). Classified as a saponifiable lipid, TAG can easily penetrate lipophilic fraction of the epidermis and create a barrier to promote water retention (Burlando et al., 2010).

Characterization studies analyzed in this systematic scoping review showed a rich composition of TAG in green coffee oil, including linoleic, palmitic, stearic, oleic, arachidi, gadoleic, and linolenic acids (Wagemaker et al., 2011, 2015a). The presence of such compounds provided desirable organoleptic and physico-chemical characteristics in cosmetic formulations, besides enhancing the hydration of the skin (Pereda et al., 2009; Diamantino et al., 2019; Hilda et al., 2021). An *in vivo* study revealed that the combination of coffee and algae oil can mitigate trans-epidermal water loss, skin erythema, melanin formation, subcutaneous blood flow, and induced apoptosis of melanoma cells in UVA-induced BALB/c mice (Yang et al., 2017). To the best of our knowledge, the evaluated studies did not demonstrate any cytotoxic effects, which supports the use of coffee oil or wax as a mineral oil substitute in cosmetics.

Caffeine

Caffeine is a natural alkaloid produced in the aerial and germinative regions of the *Coffea* plant, which is accumulated in both internal and external structures of the fruit during the development as a defensive mechanism against insect attacks. This compound has a neurostimulatory effect on humans and it is associated with the bitter taste in coffee beverages (Pereira et al., 2020). Besides these well-known characteristics, caffeine has also demonstrated anti-inflammatory and antioxidant activity (Devasagayam et al., 1996; Horrigan et al., 2006; Köroglu et al., 2014), prevention of skin cancer (Kerzendorfer and O'Driscoll, 2009; Song et al., 2012), and potential weight loss (Greenway, 2001; Boozer et al., 2002). This versatility has also been observed in our study, since caffeine was associated with cellulitis reduction (Rodrigues et al., 2016a; Ngamdokmai et al., 2018), inhibition and induced apoptosis of melanomas (Conney et al., 2007), reduction of hyperpigmentation (Kiattisin et al., 2016), and anti-aging properties (Iriondo-DeHond et al., 2016; Xuan et al., 2019a). However, it is important to highlight that this alkaloid tends to precipitate depending on the vehicle used, necessitating the use of carriers or micelles for an optimum dispersion in topical formulations (Fernandes et al., 2015).

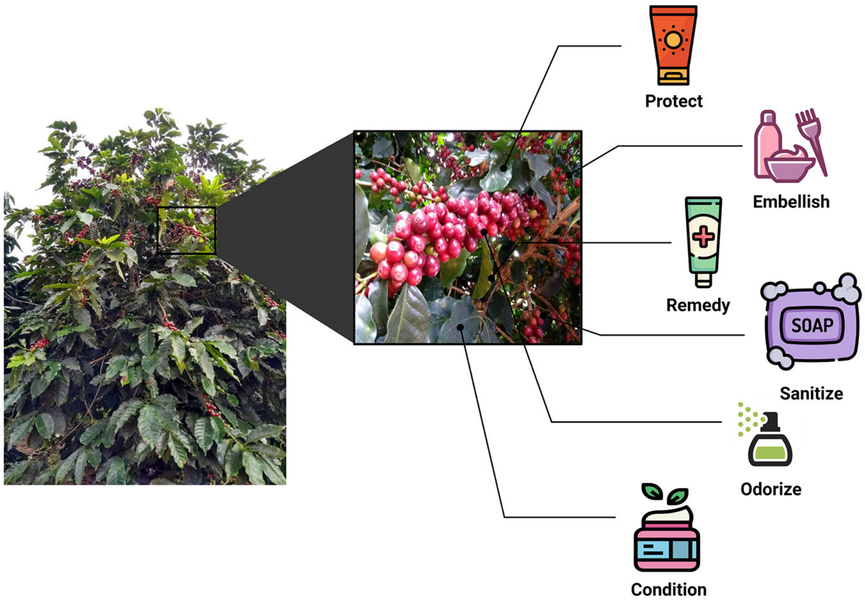

FIGURE 4 | Schematics of main cosmetic applications of coffee bean plant extracts. Created with BioRender.com. This schematic explores applications of coffee phytochemicals in personal care products using the PERSOnal Care products and ingredients classification (PERSOC) (see **Figure 2**).

Major Applications of Coffee Extracts in Cosmetic and Personal Care Industry

Active ingredients in the coffee plant present wide-reaching application opportunities for personal care products. We found evidence for this in particular regarding the development of cosmetic products with protective and healing properties. This finding reflects the worldwide trend that these two categories constituted the major cosmetic market share in 2019 (Chouhan et al., 2021). Key applications are described for all six of the PERSOC categories.

Sunscreen (PERSOC: Protect)

The development of sunscreens was the main product investigated, comprising 23.08% ($k = 12$) of studies (**Table 3**). Although most studies are categorized as fundamental research (i.e., characterization, *in vitro*), their results confirmed the safety assessment and identification of the active photoprotective ingredients. An *in vitro* study performed by Cho et al. (2017) evaluated the absorbance capacities of green coffee extracts extracted fractions in the UV-B wavelength range (290-320 nm). The results revealed a dose-dependent sun protective factor (SPF) of the chlorogenic acid content in the green coffee extracts. This absorbance capacity was associated with the presence of conjugated double bonds in chlorogenic acid structure, which were previously reported as efficient absorbers of the UV-A and UV-B wavelength ranges (Korać and Khambholja, 2011; Yuan and Cao, 2016). Sandoval et al. (2020) demonstrated the synergistic effect between *Coffea* leaves and seed extract with a cream-like formulation containing 2.5% of each extract showing a SPF 6.5-times superior to one containing only ethanolic extracts of coffee leaves. Despite the lack of identification of the compounds present in the extracts, the authors attributed the photoprotective effect to the presence of phenolic compounds.

Coffee bean oil, rich in palmitic acid, also displayed strong potential as a natural sunscreen, revealing high sun protective factor when used as a sole active ingredient in cosmetic formulations (Wagemaker et al., 2011, 2015b; Yang et al., 2017) or when enhancing the protection through synergistic interactions with synthetic sunscreen (ethylhexyl methoxycinnamate) (Chiari et al., 2014). However, the presence of palmitic acid alone does not explain the increase in SPF, since this fatty acid only shows absorption capacity at short-wavelength 210 nm (Cason and Sumrell, 1951).

An *in vitro* study performed by Iriondo-DeHond et al. (2016) evaluated the cytotoxic and sun protective effect of coffee silverskin ethanolic extract in UV-induced photodamaged cells of *C. elegans*. According to the results, chlorogenic acids and caffeic acid from coffee silverskin extracts diminished UV-induced photoaging by inhibiting the action of matrix metalloproteinases, a group of enzymes expressed during UV-B radiation exposure that promotes the breakdown of elastin fibers, and through ROS scavenging. Such studies demonstrate a tangible possibility of creating a sustainable and complementary process between the coffee and cosmetic industries.

Anti-aging (PERSOC: Protect or Remedy)

Degradation of elastin and type-I collagen are the main effects of prolonged exposure to UVB radiation. Sagging skin and premature wrinkle formation is enhanced by the overexpression of matrix metalloproteinases (MMP-1, MMP-3, and MMP-9) and elastase mediated by UVB radiation exposure (Ra et al., 2006). Several studies revealed that phenolic compounds are able to reduce or inhibit the MMP to prevent accelerated skin aging. Chiang et al. (2011) evaluated the potential of coffee leaf extracts and its hydrolysates on the inhibition of enzymes of MMP complex and elastase in UVB-induced human foreskin fibroblasts. The results revealed that the coffee leaf extracts were able to reduce significantly ($p < 0.001$) the activity of MMP-1, MMP-3, and MMP-9. The authors attributed this inhibition to the presence of caffeic acid and chlorogenic acids present in coffee leaves. Interestingly, the coffee leaf extracts were able to restore of type-I procollagen, a precursor, in human foreskin fibroblast cells in 60% in comparison to the UV-control treatment. Similar *in vitro* results were also observed using coffee beans and spent coffee grounds extracts (Choi et al., 2015; Cho et al., 2017; Wu et al., 2017).

The use of coffee oil fraction as a substituent for mineral oil in the cosmetic industry is a new and prosperous avenue, since studies have demonstrated the absence of cytotoxic effect due to a composition similar to edible oils (Wagemaker et al., 2015a, 2016). This commercial trend is also reflected in the academic field. In our review 21.15% of articles reported TAG as the principal active ingredient responsible for the protective properties (**Tables 3–5**). An *in vivo* study performed by Choi et al. (2015) evaluated the effects of topical application of a basic cream formulation containing oil fraction of spent coffee grounds in photoaged hairless mice. The results showed that the TAG from coffee wax prevented wrinkle formation by reducing epidermal thickness, decrease erythema area, and increasing water holding capacity.

Four participant studies were performed concerning the applicability of coffee extracts for the reduction of fine lines, wrinkles, and skin roughness. The first ($n = 69$; healthy women aged 42 to 64) evaluated the anti-aging effect against lines, wrinkles, and loss of skin tone of active biocellulose masks containing, amongst other phytochemicals, *Coffea arabica* seed-cake extract (Perugini et al., 2020). Volunteers applied the masks three times a week for 1 and 2 months, and pre-post 3D images of the forehead and cheekbones were taken and compared. Significant decreases in skin roughness and wrinkles area were observed in both periods. Skin thickness and homogeneity also showed a significant increase following the treatment. Although the authors do not directly attribute the effects to a specific extract, it is possible to speculate that the coffee-seed cake extract was able to inhibit MMP enzymes, as previously discussed in *in vitro* studies (Chiang et al., 2011).

The second, a clinical trial ($n = 30$), investigated the use of a commercial product, CoffeeBerry®, manufactured with *Coffea arabica* seeds extracts, and revealed a significant reduction of fine lines, wrinkles, pigmentation, and overall appearance in all subjects after 6 weeks (McDaniel, 2009). The third, a clinical trial, used volunteers ($n = 20$) with visible wrinkles. It found that the use of coffee silver skin as a cosmetic active ingredient had similar effects as that of hylauronic acid (Rodrigues et al., 2016c). In the fourth, also a clinical trial ($n = 40$), Palmer and Kitchin (2010) evaluated the efficiency of a skin care system composed of facial wash, day lotion, night crème, and eye serum containing immature coffee bean extracts against wrinkles, blotchy redness, hyperpigmentation, tactile roughness, and flaccidity. Volunteers had Fitzpatrick skin types II and III and a specific test regiment for each formulation. After instrumentation (e.g., cutometer, photography, and corneometer measures) and self-assessment evaluations, the study revealed statistically significant results in the appearance of photo damaged skins, including improved hydration, skin extensibility, and the reduction of the appearance of wrinkles, blotchy redness and hyperpigmentation without any adverse events. The safety and efficiency demonstrated in this study supported the creation of the REPLERE® skin care line for photodamage prevention.

In our review, anti-aging products was the most prospected topic in the application of coffee extracts in cosmetic formulation with 18 such studies classified, in "Protection" or "Remedy" depending on the perceived dominant ingredient agency. Of these, 60% proposed or evaluated the formulation of cosmetics with coffee extracts, enabling the conduction of *in vivo* tests and clinical trials. The interaction between base and applied studies also helped to elucidate the biochemical mechanisms associated with the amelioration of photodamaged skin, which directly contributed to the development of a commercial product.

Anti-cellulite (PERSOC: Remedy)

Cellulite is an alteration on the skin topography, resulting in swelling in the subcutaneous region, enlargement and thickening of the vascular endothelium, and alterations from the adipocytes (Tokarska et al., 2018). Although the causes are considered multifactorial and unclear, studies indicate that the fat deposition on the dermal-subcutaneous interface is one of the main causes (Hexsel et al., 2009; Hamishehkar et al., 2015). This condition affects millions of women worldwide and the existent laser, ultrasound, and radial pulses treatments are considered expensive and, its effectiveness, doubtful (Tokarska et al., 2018). However, studies evaluating the topical application of coffee extracts containing caffeine on the affected area showed promising results.

A clinical trial ($n = 21$) conducted in Thailand used a hot herbal compress containing milled coffee beans in the lateral, posterior, inner, and anterior thigh surfaces and the results were compared with a placebo compress during a 9 week interval (Ngamdokmai et al., 2018). The results showed a significant ($p < 0.05$) reduction on the measurements of the skin-fold thicknesses and circumferences. The action mechanism of caffeine in the reduction of cellulite is associated with the promotion of lipolysis in adipocytes through the increase of phosphorylation in hormonesensitive lipases *via* cAMP (Diepvens et al., 2007) or through the blockage of α-adrenergic receptors, thus preventing the fat deposition (Panchal et al., 2012). An *in vitro* study conducted in Brazil revealed the safety of the topical application of caffeine extracted from silverskin and the efficiency of nanostructured lipid carriers (NLC) in crossing the skin barrier (Rodrigues et al., 2016a). The increase of hydrophobicity in NLC-conjugated caffeine improves the topical absorption of caffeine and, thus, increases the local lipolytic activity without requiring a systemic distribution of the substance (Santos et al., 2021).

Hair Coloration (PERSOC: Embellish)

Gray hair (canities) can impact quality of life and well-being, and result in psychological effects (psychocanities) including low self-esteem; hair loss (alopecia) can also impact everyday life (Gonot-Schoupinsky and Gonot-Schoupinsky, 2020). Alternative hair dying options are relevant as some are considered cytotoxic and are associated with acute toxicity, contact allergy, and genetic toxicity (Nohynek et al., 2004). However, natural organic alternatives can be less persistent in color as previously mentioned (Pozharskii et al., 2011; Singh et al., 2015; Gonot-Schoupinsky and Gonot-Schoupinsky, 2020).

Gonot-Schoupinsky and Gonot-Schoupinsky (2020) investigated ($n = 2$) the use of a pure instant coffee solution as an alternative stain for dark brown hair and to mask the gray hair. Despite the low persistence in tone, the 7-month treatment was acceptable. One participant reported decreased scalp irritability, probably due to anti-inflammatory activities of the phenolic compounds. Singh et al. (2015) proposed fourteen hair colorants containing extracts from several plants, including roasted coffee beans. After *in vitro* assessments with wool fibers, six colorant formulations with desired fixation were tested with volunteers ($n = 25$). All but one of the five formulations containing coffee powder, including the most accepted with a percentage of 96%, were effective.

The toning capability of roasted coffee beans can be associated with melanoidin, a polymeric, high molecular weight molecule originated from non-enzymatic Maillard reactions between carbohydrates and compounds with a free amino residue during the roasting process (Chandra et al., 2008; Moreira et al., 2012). These studies open new avenues for the exploration of coffee as a natural source of hair colorants; however, coffee by-products (including silverskin and spent coffee grounds) can be a more sustainable alternative, as residual wastes are also rich in coffee melanoidins (Jiménez-Zamora et al., 2015).

The commercial product ECOHAIR®, elaborated with extracts of *Coffea arabica* and *Larrea divaricate*, was investigated in two clinical trials to evaluate the efficiency of the product in (*i*) patients with non-cicatricial alopecia during a 3-month treatment, and (*ii*) eyebrow and eyelash growth in healthy pre- and post-menopausal women (Alonso and Anesini, 2017; Alonso et al., 2019). In the first study, volunteers ($n = 52$) applied the product once a day during 90 days and overall volume, appearance, and thickness of hair, and decrease of dandruff were determined by ocular inspection aided by a magnifying glass. The authors reported an overall improvement on hair appearance in 50 participants and the visual reduction of dandruff in 45. These characteristics were attributed to coffee bean extracts stimulating the hair growth in the anagen phase and inhibiting the growth of *Malassezia furfur*, a yeast associated with alopecia and dandruff, as reported in participants of the same group. The other study, Alonso et al. (2019) evidenced a significant eyelash and eyebrows in 100 and 80% of their participants ($n = 10$) after a 2- and 3-month treatment with the product, respectively.

Soaps and Scrubs (PERSOC: Sanitize)

Research relating to the application of coffee by-products (Delgado-Arias et al., 2020) and coffee beans (Hilda et al., 2021) for body scrubs report satisfactory results. The abrasive nature of the coffee grinds likely work in conjunction with the bioactive compounds. A novel use for coffee husks to make potash, a raw material for soap, was reported by researchers in Cameroon (Pauline et al., 2010) reflecting the potential for inexpensive and sustainable solutions using coffee for basic and necessary personal care products. A recent study conducted by Deotale et al. (2019) revealed that chlorogenic acids and hydrocarbons in coffee oil are able to self-assemble, create stable micelles and reduce the surface tension. Despite coffee oil being a natural surfactant, its use for this application in soaps was not highlighted in the review findings.

Anti-microbial (PERSOC: Odorize)

Unpleasant odors in the human body can be caused by several factors, including normal sweat and sebaceous gland secretions. However, when the odors generate discomfort and embarrassment it can be associated with the proliferation of common skin-resident bacteria (Nestora et al., 2016). The *Staphylococcus epidermis* plays a major role in foot odor through the conversion of leucine, present in the sweat, into isovaleric acid, a volatile organic compound with a sour and pungent odor (Ara et al., 2006). Methylparaben is a common substance added to cosmetics with antimicrobial activity through the disruption of the plasmatic membrane and the denaturation of enzymes (Soni et al., 2002). Although there are no studies showing the acute toxicity or accumulation of this substance in animal models (Soni et al., 2002), research relating to the replacement or reduction of this chemical for plant-extracted compounds is on-going. An *in vitro* research conducted by Santoso and Riyanta (2019) in Indonesia revealed that a foot sanitizer spray using the ethanolic extract from coffee beans and ginger showed significant antimicrobial activity against *S. epidermis*. Although not being fully elucidated, the antimicrobial activity could be correlated with the high concentration of chlorogenic acid and caffeine found in the coffee beans (Duangjai et al., 2016). In this sense, polyphenolic-rich coffee by-products could be explored in further studies as a source material for sanitizing cosmetic formulations.

Hydration (PERSOC: Condition)

Moisturizing cosmetics are developed to replace the intracellular lipids removed during the cleansing or exfoliation of the skin's surface, and retard the transepidermal water loss through the formation of a thin lipophilic film on the surface of the skin (Draelos, 2018). This role is performed by occlusive substances, including hydrocarbons, stearic acid, linolenic acid, and sterols, commonly found in plants oils. The coffee bean has been extensively investigated as a natural ingredient in moisturizing cosmetics due to its rich oil composition and antioxidant activity (Pereda et al., 2009; Chaiyasut et al., 2018; Diamantino et al., 2019; Putri et al., 2019). However, recent studies also demonstrated the effectiveness of hydro-alcoholic extracts of coffee silverskin as an occlusive agent (Rodrigues et al., 2016b,d). In a single blinded study ($n = 20$), Rodrigues et al. (2016c) evaluated the effect of coffee silverskin on skin hydration with promising results (note that a clinical trial also described in this article is discussed under "Remedy" and the article is categorized under "Remedy"). *In vitro* studies performed using human immortalized non-tumorigenic keratinocyte and foreskin fibroblasts cell lines showed no cytotoxicity when compared to the control. Long-term organoleptic characteristics, pH, microbial count, and antioxidant activity were stable both at 20 and 40°C during 180 days, showing that coffee silverskin extract is suitable as an active ingredient in cosmetic formulations (Rodrigues et al., 2016b).

Sustainability Implications

Cosmetic companies are challenged to drive innovation-oriented investments but also to appeal to green consumers, and take responsibility for sustainable, social, economic, and environmental solutions. The industry must thus develop products that are commercially attractive, natural, non-toxic, and sustainable (McEachern and McClean, 2002; Feng et al., 2018). Recent interest in sustainability has led to increased attention in the use of molecules from raw plant materials and by-products of food processing due to their rich composition in bioactive compounds, including phenolic compounds and fatty acids, affordable costs, and high availability (Nunes et al., 2017). Our critical evaluation using COPS assessed firstly the development of non-toxic products; secondly the potential of coffee waste as renewable sources of natural active ingredients; and, thirdly, new environmentally friendly income sources for coffee producers and their environmental impact.

The assessment of new organic molecules in coffee components capable of replacing synthetic chemicals showed satisfactory results. Of the 52 articles, only six (11.54%) had a low impact regarding the non- or partial replacement of synthetic components (Chiari et al., 2014; Marto et al., 2016a; Safrida and Sabri, 2017; Handayani et al., 2019; Putri et al., 2019; Santoso and Riyanta, 2019). This finding is extremely favorable, but our review suggests that the "green label" term may be used in a unilateral way. Many articles met the criteria of proposing or performing the total substitution of synthetic compounds in formulations. However, the majority used coffee beans as raw material, which has a low impact on the social and environmental sustainability of this cosmetic-coffee industry interrelation, leading to half of the studies being classified as medium (50.00%; $k = 26$).

The environmental and social sustainability pillars of the coffee industry must also be pursued, and it may require a more transparent position from the cosmetic industry regarding the production process using coffee extracts and wastes to avoid "greenwash" (Cervellon and Carey, 2011). The coffee industry generates over 6 million tons of solid residual waste yearly that are processed using basic waste management techniques (Blinová et al., 2017; Pereira et al., 2020). Nevertheless, the involvement of some global coffee producers in the search for the valorisation of coffee residues in high-added value products may accelerate sustainable solutions. According to our research, 16 papers (30.77%) proposed the prospection of residues as a reliable source of active ingredients and achieved a high COPS score concerning the environmental sustainability. Interestingly, our findings found residual wastes and leaf extracts were explored mainly by producing countries (e.g., Brazil, Taiwan, Indonesia, and Thailand) and South Korea (**Tables 3–5**). According to the Observatory of Economic Complexity (OEC, 2019), South Korea imported over US$ 1.3 million in coffee husks in 2019, indicating a growing interest in the potential applications of the rich composition of this agro-industrial waste.

Finally, when the economically cosmetic appealing "green" label also addresses the social sphere, bilateral sustainability can be achieved. A recent techno-economic analysis revealed that coffee beans produced with dry or wet processing methods generate an economic profit that is not socially sustainable (Magalhães Júnior et al., 2020). The use of coffee beans as raw material for active ingredients in the cosmetic industry could follow two possible scenarios: (i) part of the green bean production could be redirected to a new market niche; or (ii) investments in infrastructure, equipment, and technology could enable the processing plants to carry out extraction processes from coffee beans. Neither scenario is ideal. The first would not provide significant changes in sales prices; while the second requires high initial investment, excluding approximately 25 million smallholder farmers (Vanderhaegen et al., 2018). Therefore, the exploitation of leaves and residual wastes would better represent an additional and significant source of income in either one of the described scenarios due to their abundance and lack of a consolidated commercialization. This can also assist the disposal of coffee residues and solve the economic and ecological imbalance in the cosmetic-coffee industries relationship. Once these issues are addressed, commercial products containing coffee bean extracts as active ingredients, can present a higher sustainability impact. Despite these bottlenecks, it is possible to observe a paradigm shift as 16 studies conducted in the last 5 years were classified as "high" according to the COPS scale due to the valorization of coffee by-products or leaves.

FUTURE AREAS FOR RESEARCH

Research in this area is in its infancy, and there is great potential, in terms of investigating active ingredients within coffee, of which there are over 1,000 (Pereira et al., 2019), of exploring their PERSOC applications, and in finding solutions for sustainability problems. Furthermore, the *Coffea* genus includes 124 wild species (Davis et al., 2019), and while Arabica and Robusta varieties comprise 94% of worldwide coffee production, which explains the clear research focus on these varieties, investigation of other species may bring additional perspectives, uncover additional active ingredients, and save them from extinction.

Future research can focus on prioritizing sustainable ways to harness bioactive compounds, and filling in the many gaps that are suggested by the review results. For instance, we did not find any articles relating to the use of coffee flowers. Sweet smelling, like jasmine, coffee flowers contain a range of bioactive compounds (Pinheiro et al., 2021). Another gap was the use of coffee oil as a surfactant, for instance in soaps, or as an emulsifying agent in cosmetics. There is a need to conduct well-designed and well-populated *in vivo* and clinical trials to assess the safety, investigate the mechanisms of action, and characterize the market potential of these new green products. All applications merit further exploration. One example is the need to fully elucidate the action mechanism involving coffee oil fraction on UVA and UVB absorbencies. Another area of focus is how to harness coffee as a more effective pigment to provide a natural solution for hair coloring and care. Although hair care products were less explored than skin care (**Table 6**), our review suggests studies in this segment of the cosmetics industry are gaining attention. However, it is necessary to carry out more studies, including *in vivo* and *in vitro* tests in order to identify the bioactive molecules responsible for the hair growth stimulation and antimicrobial activity; thus, enabling the elaboration of a more efficient extraction process and the use of coffee processing residues.

Further studies should also be conducted to assess the effectiveness of cellulite reduction in clinical trials. Although caffeine concentration is superior in coffee beans, the NLC-conjugated caffeine extracted from silverskin represents a more sustainable alternative for the formulation of cosmetics. There are many academic fields that can play an important role in future research including biochemistry, waste management, food science, dermatology, trichology, health psychology, environmental science, integrative medicine, and also business and management fields. As well as scientific collaborations, cooperation between academia, industry, and farmers, is necessary to encourage the development of non-toxic products, the utilization of coffee industry waste, and encourage new income streams for coffee farmers.

LIMITATIONS OF THE REVIEW

A more comprehensive search strategy would have been preferable, as only two databases were searched. However, the purpose of this review was not to be exhaustive, but rather to give insight into the wide-ranging developments relating to the use of coffee active ingredients in personal care products, and to highlight the sustainability issues that this raises. Critical appraisal of research quality was not undertaken due to our concern being more to critique the research in terms of their implications on sustainability issues. The PERSOC classification gives an alternative perspective, but as coffee compounds manifest high multi-functionality categories can overlap.

CONCLUSIONS

The results of this systematic scoping review highlighted coffee as a naturally beneficial and potentially sustainable ingredient in personal care products. Coffee bean extracts, oils, leaves, and by-products provide an important source of bioactive compounds due to their desirable antioxidant, antimicrobial, anti-aging, and anti-inflammatory effects. Using the PERSOnal Care products and ingredients classification (PERSOC) we found that coffee constituents had beneficial applications in a wide range of personal care products that protect, embellish, remedy, sanitize, odorize, and condition the skin, hair, and face.

Despite the relevance of these findings, research into coffee bioactives for cosmetic purposes is still under development, and there are still many gaps. Of the studies reviewed ($k = 52$), only ten studies involved participants ($N = 309$), and only three discussed commercially available products containing coffee derivates. However, critical evaluation using the *Coffea* Products Sustainability (COPS) model, suggests the results are promising; moreover, by-products of the coffee processing chain represented almost 25% of the raw materials in the studies. Effective management of coffee waste is crucial for environmental and social-economic impact to result in a sustainable producing chain and additional and alternative income for coffee producers. Furthermore, as shown in this review, the use of coffee phytochemicals can be a very effective and accessible way of extending innovation within the personal care products industry, and enabling new non-toxic products for discerning consumers.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

DC and FG-S: conceptualization, methodology, systematic scoping review data–acquisition and eligibility, writing–original draft, and writing–review and editing. XG-S: conceptualization, methodology, systematic scoping review data–acquisition and eligibility, and writing–review and editing. All authors contributed to the article and approved the submitted version.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.