Heliyon 9 (2023) e21876

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Review article

Natural alternatives from your garden for hair care: Revisiting the benefits of tropical herbs

Sze-Huey Sang [a], Gabriel Akyirem Akowuah [a], Kai Bin Liew [b], Siew-Keah Lee [c], Jing-Wen Keng [a], Sue-Kei Lee [a], Jessica-Ai-Lyn Yon [a], Ching Siang Tan [d,**], Yik-Ling Chew [a,*]

[a] Faculty of Pharmaceutical Sciences, UCSI University, Cheras, 56000, Kuala Lumpur, Malaysia
[b] Faculty of Pharmacy, University of Cyberjaya, Persiaran Bestari, Cyber 11, 63000, Cyberjaya, Selangor, Malaysia
[c] M. Kandiah Faculty of Medicine and Health Sciences, Universiti Tunku Abdul Rahman, Jalan Sungai Long, Bandar Sungai Long, 43000, Kajang, Selangor, Malaysia
[d] School of Pharmacy, KPJ Healthcare University College, Nilai, 71800, Malaysia

ARTICLE INFO

Keywords:
Acacia concinna
Camellia oleifera
Azadirachta indica
Emblica officinalis
Sapindus mukorossi
Garcinia mangostana
Hair

ABSTRACT

Hair shampoos containing botanical ingredients without synthetic additives, such as parabens, petrochemicals, sulfates and silicones are more skin- and environmentally friendly. In recent years, there is a growing demand for shampoo products with botanical extracts. Shampoos with botanical extracts are well-known for their perceived health benefits. They are also generally milder, non-toxic, natural, and less likely to disrupt the hair and scalp's natural pH and oil balance. Many also believe that shampoos with botanical origins have higher standards of quality. Numerous botanical extracts had been used as natural active ingredients in cosmetic formulations to meet consumer demands. In this review, we have revisited six tropical plants commonly added as natural active ingredients in shampoo formulations: *Acacia concinna, Camellia oleifera, Azadirachta indica, Emblica officinalis, Sapindus mukorossi, and Garcinia mangostana*. These plants have been traditionally used for hair care, and scientific research has shown that they exhibit relevant physicochemical properties and biological activities that are beneficial for hair care and scalp maintenance.

1. Introduction

Hair is regarded as a sign of beauty in almost every culture. This had led to a massive growth in demands for cosmetic hair and scalp care products. Shampoos are used for personal hygiene and cleansing purposes, such as removing the dirt, sebum, debris, and other environmental pollutants accumulated in the hair. It is one of the most fundamental hair care tips for maintaining healthy hair. However, many commercial hair shampoos now include additional benefits and qualities, such as improving hair manageability, maintaining the hair's moisture level, imparting gloss, preventing hair fall, and inhibiting dandruff formation.

Numerous shampoo products are available in the market, and these products are marketed based on specific cosmetic purposes and functions. Several types of shampoos are available on the shelves such as daily shampoos, conditioning shampoos, anti-dandruff

* Corresponding author.
** Corresponding author.
E-mail addresses: tcsiang@kpjuc.edu.my (C.S. Tan), chew.yikling@gmail.com (Y.-L. Chew).

https://doi.org/10.1016/j.heliyon.2023.e21876
Received 9 April 2023; Received in revised form 30 August 2023; Accepted 31 October 2023
Available online 7 November 2023

shampoos, anti-hair fall shampoos, baby shampoos, and dry shampoos. Each of these shampoos serves its own purposes (Table 1). However, most of the commercial shampoos in the market are formulated using synthetic ingredients. Numerous concerns have been raised about the health risk and adverse effects of exposure to synthetic ingredients, such as skin irritation, scalp flaking, hair follicle corrosion, allergic reaction, hair dryness, dandruff problem, and other associated risks reported (Table 2). Therefore, the market had witnessed significant demand due to the rising consumer preference for products that are scientifically proven to be organic and contain natural ingredients. Additionally, hair shampoos from natural renewable sources are more eco-sustainability, easily availability, and possess bioactivities such as antioxidant, antibacterial, antifungal, anti-inflammatory, and other medicinal properties [1,2]. These brands and products are highly regarded for their product quality, effectiveness, and corporate reputation, and they actively align with the United Nations' Sustainable Development Goals (SDGs).

The environmental impact of synthetic ingredients in hair care products can have implications for several Sustainable Development Goals (SDGs). To address these environmental impacts and align with the SDGs, the hair care industry can adopt more sustainable practices, such as using natural and biodegradable ingredients, implementing green chemistry principles, and supporting initiatives to protect water resources and biodiversity. Consumer awareness and demand for eco-friendly hair care products can also drive positive change and contribute to achieving the SDGs related to environmental sustainability.

Synthetic ingredients in hair care products, such as those derived from petroleum, could cause unsustainable production and consumption patterns. The extraction, manufacturing, and disposal of these petroleum-based ingredients can lead to resource depletion, pollution, and waste generation, which may affect the goal of promoting responsible consumption and production (SDG 12: Responsible Consumption and Production) [3]. Additionally, synthetic ingredients washed off during shampooing could potentially contaminate freshwater sources, compromising access to clean water and sanitation and hindering progress toward SDG 6: Clean Water and Sanitation [4]. Moreover, some synthetic ingredients in hair care products, such as surfactants and microplastics, may cause water pollution and disrupt aquatic and marine ecosystems, impacting the goal of preserving life below water (SDG 14: Life Below Water) [5]. Finally, many studies have reported that synthetic ingredients could potentially cause skin and scalp irritations, health issues, and compromise the goal of promoting good health and well-being (SDG 3: Good Health and Well-being) [6].

2. Botanical herbs and their functional role in hair care

Botanical extracts have continued to be a top global claim for hair care products, especially in hair shampoos and conditioners. The surge in market demand for botanical extracts-based shampoos in Asia Pacific region is boosted by the increasing consumer demand for natural, sustainable, chemical-free, and eco-friendly products. In addition, the growing preference for shampoos using natural ingredients is also due to the strong heritage of traditional and plant-based medicines. Plants and herbs have been traditionally used in hair care and hair growth since ancient times in Ayurveda, Chinese and Unani systems of medicine [57,58]. Many botanical extracts and formulations have been used in daily hair care routine. These extracts were used in the form of pastes, decoctions, and juices. In this review, six selected herbs with hair care properties were discussed, including their roles, functions, physicochemical properties, biological activities, and phytochemical constituents. An overview of these botanical herbs and their functions in hair care is summarised (Table 3).

Acacia concinna, Camellia oleifera, and *Sapindus mukorossi* consist of natural surfactants. These natural surfactants can cleanse and remove sebum and oil from hair as effectively as synthetic surfactants. However, the behaviour of natural and synthetic surfactants in hair shampoos can vary in terms of their cleansing ability, foaming properties, mildness, impact on the hair and scalp, and overall performance. Natural surfactants effectively cleanse the hair by removing dirt, oil, and impurities, but they may produce less foam. On the other hand, synthetic surfactants have a high foaming ability and are generally highly effective at removing dirt and oil from the hair [59–62]. However, foam production does not necessarily correlate with cleansing ability. Natural surfactants are also milder on the hair and scalp compared to synthetic surfactants. They are less likely to cause irritation and dryness, making them more compatible with sensitive skin [63]. Moreover, natural surfactants are less likely to cause hair dryness and frizziness, and they maintain the natural moisture balance of the hair [60,64]. On the other hand, synthetic surfactants may be harsh and strip the natural oils of the hair, leading to hair dryness.

Table 1
Types of commercial shampoos and their purposes.

Types of shampoos	Purposes
Daily shampoo	Designed for all hair types. It leaves hair feeling refreshed, clean, looking shiny, and maintaining a healthy and balanced scalp.
Conditioning shampoo	For daily hair cleansing and makes the hair more manageable. It removes the excess sebum, dust, dirt and pollutants from hair and scalp. It has ingredients that help to make hair softer, more manageable and moisturises the hair strand.
Anti-dandruff shampoo	Medicated shampoos formulated to treat fungal infections on the hair scalp. It works by slowing or inhibiting the growth of dandruff-causing fungus.
Anti-hair fall shampoo	Shampoos are formulated to nourish the hair scalp and strengthen the hair strands. It removes dead skin cells, excess sebum, and other impurities from the hair scalp. It is used for daily scalp maintenance. These shampoos consist of ingredients that can nourish the hair roots, promote a healthy scalp, and reduce hair fall.
Baby shampoo	Specially formulated for infants and young children with delicate skin. The ingredients used are less irritating to the eyes and skin compared to regular shampoos. It removes excess sebum, dust, dirt and pollutants from hair and scalp gently.
Dry shampoos	It uses powders, starches, and other absorbent materials to absorb the dirt, oil and grease of hair scalp, without rinsing. The particles cling to the oils and dirt on the scalp and hair strands, which are then lifted away from the scalp and hair.

Table 2
Synthetic ingredients in shampoo and the associated risk reported.

Synthetic ingredients	Functions in shampoo formulation	Associated risk reported	References
Sodium Lauryl Sulphate (SLS) and Sodium Laureth Sulphate (SLES)	Surfactant	Caused skin irritation, dry, cracked, and inflamed skin; could provoke slight to moderate allergy reaction at concentrations as low as 0.5–10 %; caused skin dryness was noticed after one-week usage of products with 5 % SLS and 5 % SLES surfactants; caused skin irritation to the stratum corneum layer of the skin; disrupted the skin barrier; disturbed the skin physiology and skin integrity; reduced the stratum corneum layer; resulted in dry, irritated, itchy, and flaky hair scalp; disturbed the balance between commensals and pathogens (i.e. *Propionibacterium* spp., *Corynebacterium* spp., and *Micrococcus* spp.) and resulting in skin disease; increased in sensitisation reaction in seborrheic dermatitis patients; and may lead to the development of benign, premalignant, or malignant tumour, morphological change of epithelium cells, organ toxicity (predominantly heart, liver, lungs, and brain), ophthalmic irritation, cataract formation, carcinogenic effect, and hair loss upon long term exposure.	[7–17]
Cocamidopropyl Betaine (CAPB)	Surfactant	Increased the prevalence rates of allergic contact dermatitis among young children after exposure to baby shampoos containing CAPB; cosmetic-allergic patients experienced scalp itching, inflammation on the ears, neck, and forehead, and developed eczema on the face and neck; and caused dermatological sensitisation upon exposure to impurities in CAPB, such as 3-dimethylaminopropylamine (DMAPA) and amidoamine (AA).	[18–22]
Ethylene oxide (EtO)	Sterilant	Increased in the risk of breast and lymphohematopoietic cancer; exerted a genotoxicity effect and increased in prevalence of mortality; and potentially form macromolecular adducts with nucleic acids and proteins and causes mutation.	[23–25]
Alkanolamines: Triethanolamine (TEA) Diethanolamine (DEA) Monoethanolamine (MEA) Cocamide diethanolamine (CDEA)	Surfactants, Emulsifying agents pH adjusters	Caused skin sensitisation; developed occupationally and dermatitis and skin sensitivity upon exposure; resulted in carcinogenicity effect with continuous exposure of DEA, even at low doses; and caused choline deficiency and resulted in irreversible changes in hippocampal function, including altered long-term potentiation and memory.	[6,26–35]
Ethylenediaminetetraacetic acid (EDTA)	Sequestering agents	Developed recurrent pruritic erythema on the scalp, neck, and face upon exposure to cosmeceutical products containing 0.1 % and 1 % disodium EDTA.	[36]
Formaldehyde	Preservative	Caused allergic contact dermatitis; and resulted in carcinogenicity, toxicity, and genotoxicity effects after prolong exposure.	[37–39]
Parabens: Methylparaben Ethylparaben, Propylparaben Butylparaben	Preservative	Caused contact allergic dermatitis; caused breast cancer in females; reduced fertility in males; and increased the prevalence of obesity, gestational diabetes mellitus, adipogenesis, necrosis, collagen degradation, risk of malignant melanoma, skin cancer.	[40–52]
Selenium sulphide	Anti-dandruff	Increased sebum excretion; and caused scalp discolouration and dysplasia of hair roots in young children and adults; exerted a toxic effect on the hair root papillae; and caused alopecia (baldness) and fragile hair.	[53–56]

Various studies reported that synthetic surfactants exhibit toxicity to health and environment. It is interesting to see the comparison of the physical and chemical properties of synthetic and natural surfactants. Panda et al. [65] recently investigated various properties of synthetic and natural surfactants. Natural surfactants in *S. mukorossi* were anionic surfactants which could significantly reduce the surface tension and contact angle. The surfactants are biodegradable, free from corrosive materials, and it is environmental friendly [66]. On the other hand, synthetic surfactants were not only possess risk to aquatic life, it could also trigger allergenic effects, such as skin, respiratory and eye irritations [66]. In addition, natural surfactants could exhibit better foaming ability, more stable and bigger foam than synthetic surfactants. The authors explained that this is due to reduction in surface tension, increase in viscosity and density [65]. The emulsification index of natural surfactants is also better than the synthetic ones [67].

Table 3
Botanical herbs and theirs functions in hair care.

Plant name	Family	Common name	Functions	References
Acacia concinna	Fabaceae	Shikakai	Surfactant, foaming agent, hair conditioning, hair volumizing, hair strengthening, hair growth, anti-bacterial, anti-dandruff	[68]
Camellia oleifera	Theaceae	Tea tree	Surfactant, foaming agent, emulsifier, anti-oxidant, anti-microbial, and preservative	[69–71]
Azadirachta indica	Meliaceae	Neem	Anti-dandruff, and anti-lice.	[72–74]
Emblica officinalis	Phyllanthaceae	Amla, Indian gooseberry	Anti-hair loss, hair growth promoter, hair strengthening, hair pigmentating (hair tanning), hair moisturizing, hair conditioning agents, hair protecting from ultraviolet radiation and anti-dandruff.	[75,76]
Sapindus mukorossi	Sapindaceae	Reetha, Soapnut	Surfactant, foaming agent, emulsifier, anti-microbials, anti-dandruff, hair nourishing, and hair restoring agents.	[62]
Garcinia mangostana	Guttiferae	Mangosteen	Anti-oxidant, anti-inflammatory, anti-bacterial, anti-fungal, anti-dandruff, preservative, hair growth promoter, and hair tanning agents	[77–79]

2.1. *Acacia concinna (shikakai), the natural source of surfactant in hair shampoo*

Acacia concinna (Shikakai) (Fig. 1) is a climbing shrub, from the Fabaceae family. This plant is commonly cultivated in Asia, especially in central and southern India. Shikakai's pods are traditionally used as a natural detergent for hair cleansing. The pods are rich in saponins which are natural cleaning agents. The saponins are triglycosides of acacia acid, made up of varieties of saccharine derivatives. These triglycosides consist of glycons/sugar moieties such as glucose, arabinose, and xylose, which are linked through oxygen to the acacia acid moiety (aglycone) [80]. They are amphiphilic in nature, consisting of hydrophilic heads and hydrophobic tails [80]. They function as non-ionic surfactants, reducing the surface tension of water and interfacial tensions, solubilise the oils and dirt from hair strands and scalp. The lower the surface tension, the better the cleansing ability of the shampoo. A shampoo is considered to be of good quality if the surfactants could decrease the surface tension of pure water from 72.28 mN/m to about 40 mN/m or lower [81].

The saponins in Shikakai could adsorb to the surface of the water in the form of a foam film. They can also reduce the surface tension of the water by decreasing the density of water molecules at the air-water interface. The amphiphilic nature of saponins possesses hydrophobic tails, which can pull the surfactant molecules upward, creating weakly attracted molecules on the water's surface. Intermolecular hydrogen bonds of water molecules can result in higher surface tension. The disruption of hydrogen bonds between the water molecules reduces the surface tension and generates a large surface area during foaming.

The physicochemical properties of shampoo formulations with Shikakai saponins as surfactants have been studied. Pradhan et al. [82] evaluated the foaming ability, foam stability, surface tension, dirt dispersion, wetting and cleaning abilities of the formulation and compared them with the synthetic shampoo, Johnson's Baby Shampoo. The formulated shampoo with Shikakai showed very prominent surface tension reduction and high foaming ability. The evaluation of surface tension using tensiometer showed that the Shikakai formulated shampoo lowered the surface tension of pure water from 72.28 mN/m to 35.6 mN/m (<40 mN/m). This indicates that the shampoo formulation was considered of good quality. Additionally, it also exhibited lower surface tension and higher detergency effect than the Seto Siris extract [82].

Naturally, Shikakai has a mild pH, which is ideal for gentle cleansing without stripping off the natural oils of the hair [68]. Shikakai is also an excellent natural cleanser that eliminates dirt, oil, sweat, and other impurities from the hair and scalp. The high amount of saponins in the Shikakai pods can create a nice and rich foamy lather in shampoo [83].

The leaves of Shikakai are also useful in hair care product formulation. The leaf extract of Shikakai could exhibit promising

Fig. 1. *Acacia concinna.* The figure is adapted from Valke [84], under the Creative Commons Attribution License.

antibacterial activity [68]. It controls scalp infection by exhibiting antimicrobial activity against a broad spectrum of bacteria and fungi, including *Ganoderma lucidum, Bacillus subtilis, Staphylococcus aureus*, *Escherichia coli*, *Proteus vulgaris*, *Micrococcus luteus*, *Streptococcus aeruginosa* [68,85], dermatophytes, *Candida albicans, Cryptococcus neoformans* and *Penicillium marneffei* [86]. However, no study has reported that Shikakai alone is effective in inhibiting *Malassezia furfur*, the main fungus causing dandruff. However, studies have shown the combination of other herbal extracts with Shikakai in hair shampoo formulation could exhibit good antifungal activity against *M. furfur*. For instance, the combination of henna and Shikakai extracts was found to be very effective in controlling dandruff. This is likely due to the synergistic effect of henna and Shikakai in inhibiting the growth of the fungus.

Shikakai has good cleansing ability. It cleans and removes excessive sebum from hair and scalp, alters the microenvironment, and inhibits the fungal growth [87]. It is a good candidate for natural surfactant that could be included in hair shampoo.

2.2. Camellia oleifera, tea tree oil and saponins for hair care formulation

Camellia oleifera originated from tropical and subtropical East Asia regions, particularly China (Fig. 2) [88]. Its seeds consist of an average of 47 % oil content, and it is commonly cultivated for high quality vegetable oil [88]. The seeds oil is rich in unsaturated fatty acids (up to 88 %). Among the unsaturated fatty acids, oleic acid is the major one present (approximately 78 %). Other saturated and unsaturated fatty acids include palmitic acid (~10 %), linoleic acid (~9 %), stearic acid (~2 %), eicosenoic acid (~1 %), linolenic acid, palmitoleic acid, and tetracosanoic acid (<0.3 %) [88] (Table 4). The seeds oil is reported to have good moisturizing properties. It has an excellent occlusive property that promotes the formation of a hydrophobic barrier [89], which locks the moisture of hair strands and improve moisture retention in the cortex layer [90]. It could also restore the physical properties of healthy hair strands, reduce hair static and hair frizziness [91].

C. oleifera seeds oil could exhibit strong antioxidant activity against free radicals and inhibit peroxidation. The antioxidant activities of the seed oils were evaluated using 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical, 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid (ABTS) radical cation, ferric reducing power, and β-carotene bleaching assays. It exhibited moderate DPPH free radical scavenging activity (EC_{50} 35.20 μg/mL), Trolox equivalent antioxidant capacity (0.4250 ± 0.2903 mM), reducing power (0.1676 ± 0.0510 mM) and good lipid peroxidation inhibition effects (IC_{50} 0.52 μg/mL) [70,71]. Multiple studies have reported that the fatty acids in seed oils could exhibit promising antioxidant activities and are able to reduce cell oxidative stress [71,89,92,93]. The antioxidant activity of Camellia seed oil showed excellent activity in the Ferric Ability Reducing of Plasma method, where the antioxidant activity was the highest (1005.50 mg Fe/g sample) among other plant oils tested, including rose hip, flax, hemp, thistle, and safflower oils [92]. Another study also demonstrated that the seed oils and oleic acid could exhibit significant cell protection against hydrogen peroxide peroxidation. The cell viability increased by more than 90 % with the presence of seed oil (1 %) and oleic acid (0.0001 mg/mL) [93]. Wang et al. [94] also reported that Camellia oil exhibited free radical scavenging activities, The free radical scavenging activities were evaluated using DPPH, ABTS, hydroxyl radical and superoxide anion free radical scavenging assays, and the results showed that the fatty acids could exhibit antioxidant activities and alleviate the oxidative damage of cells caused by hydrogen peroxide. These promising antioxidant activities could potentially reduce and protect the hair strands from damages due to the exposure to ultraviolet rays, free radicals, and oxidative stress, and hence preserve the hair protein structure.

Besides antioxidant activity, Camellia seeds oil and oleic acid could also exhibit a moderate inhibitory action on the growth of microorganisms. Feás et al. [70] evaluated the antimicrobial activity of the seeds oil using the microbroth dilution method on three microorganisms, namely *E. coli* (ESA 34) (MIC 3.917 ± 3.406 mg/mL), *C. albicans* (ESA 567) (MIC 20.833 ± 7.217 mg/mL) and *B. cereus* (ESA 239) (MIC 52.083 ± 18.042 mg/mL). It was found that *E. coli* was the most sensitive to the seeds oil while *B. cereus* was the least sensitive. Recently, Wang et al. [94] reported that variation in fatty acids content of Camellia oil produced from different areas. These variations have also led to different antimicrobial strengths. Camellia seeds oil consists of various fatty acids that possess antimicrobial activities. The fatty acids in the oil can penetrate the lipid bilayer of microbial cell membranes, disintegrate the bacterial

Fig. 2. *Camellia oleifera.* The figure is adapted from Kunming Expo Garden, China [95], under the Creative Commons Attribution License.

Table 4
Fatty acid composition of *Camellia oleifera* seeds.

Fatty acids	Percentages of fatty acid (%)
Palmitic acid (C16:0)	9.67 ± 0.02
Palmitoleic acid (C16:1)	0.16 ± 0.01
Stearic acid (C18:0)	1.87 ± 0.03
Oleic acid (C18:1)	77.59 ± 0.05
Linoleic acid (C18:2)	8.96 ± 0.03
Linolenic acid (C18:3)	0.28 ± 0.02
Eicosenoic acid (C20:1)	0.90 ± 0.02
Tetracosenoic acid (C24:1)	0.12 ± 0.02
Saturated fatty acids	11.82 ± 0.19
Monounsaturated fatty acids	78.90 ± 0.12
Polyunsaturated fatty acids	9.24 ± 0.05
Unsaturated fatty acids	88.14 ± 0.17

Data were summarised from Yang et al. [88].

cell membrane, leading to destabilization and leakage of intracellular contents [96,97]. This disruption ultimately impairs the integrity and function of the microorganisms They also disrupt the cell cytoplasm, inhibit the action of core enzymes and cause cell lysis and cell death [98].

Saponins are also abundantly present in *C. oleifera* seeds. Up to 8.34 % of crude saponin could be extracted from the seeds. These natural saponins could be used as a substituent for synthetic surfactants in a shampoo formulation [99]. The evaluation of physico-chemical properties of the saponins from *C. oleifera* showed that the wetting time (10.9 min), surface tension (50.0 mN/m), and detergent ability (53.8 %) were satisfactory. Although the ratio of foam height (R5) of saponins from *C. oleifera* (85 %) was slightly lower than Tween 80 (96.3 %) and SLS (93.6 %), its foaming capability was considered good, and the foam was metastable (R5 greater than 50 %) [100]. Metastable foam cleans better than the stable form. Schad et al. [101] discovered that metastable foam cleaned *via* the wiping action. The foam would rearrange, and continuously create wiping motion between the foam and interface. It wipes with very thin wetting films and the bubbles' menisci along the surface create strong shear stresses with improved cleaning efficiency.

Saponins are secondary metabolites produced in some plants as a plant defense against pathogens. They possess a cytotoxic effect on microbes, able to damage the cell wall of bacteria and cause antibiotic infiltration by the bacterial cell membrane [102]. Saponins from *C. oleifera* seeds were also found to exhibit antimicrobial activity [103,104]. The saponins could inhibit the growth of *C. albicans*, *Saccharomyces cerevisiae* and *Penicillium* at MIC 0.078, 0.156, and 0.156 mg/mL, respectively. They killed the fungus at MFC 0.312, 0.625, and 0.625 mg/mL, respectively [103]. The saponins were found to have better antimicrobial potency against both bacteria and fungi than the seeds oil [104]. They inhibit various pathogenic microorganism commonly present on the skin, namely *S. aureus* (MIC 31.3 μg/mL), *E. coli* (MIC 31.3 μg/mL), and *B. subtilis* (MIC 62.5 μg/mL) [104]. Hence, saponins from *C. oleifera* seeds could play the role of surfactants, foaming agents, cleansing agents as well as antimicrobial agents in hair care products. These criteria are extremely important in a hair shampoo.

Fig. 3. *Azadirachta indica.* The figure is adapted from Chew et al. [106], under the Creative Commons Attribution License.

2.3. *Azadirachta indica (neem) as natural ingredient in hair care and cleaning*

Azadirachta indica (neem) (Fig. 3) is an indigenous herb from the family Meliaceae. It is native to most tropical and subtropical countries, such as India, Pakistan, Nepal, and Bangladesh. Neem tree extracts are commonly applied as complementary medicine in Ayurveda, Unani, and homeopathy [105].

The importance of neem in the cosmeceutical industry is increasing due to its medicinal values. Neem leaves and neem-based products have been popularly used in hair care routines. The anti-dandruff activity of neem leaves has been reported by Niharika et al. [72] where the inhibitory action on the growth of *Malassezia furfur* was exhibited in a concentration-dependent manner. *M. furfur* could cause various skin disorders, including hair dandruff, itchy scalp, seborrheic dermatitis, and pityriasis versicolor [107–109]. The mean zone of inhibition exhibited by neem leaves extract at 25 %, 50 %, 75 %, and 100 % concentration were 6.67 mm, 9.33 mm, 11.33 mm, and 17.33 mm, respectively. Based on the antifungal evaluation, the authors reported that the optimum concentration of the leaves extract to exhibit significant antifungal activity against *M. furfur* was at a minimum concentration of 75 %. Besides leaves, neem bark could also exhibit excellent anti-fungal activity against *Malassezia* sp. The bark extracts inhibited the growth of *Malassezia globosa* and *Malassezia restricta,* which are the commensal fungal species on the hair scalp, [110]. The bark extracts (at 100 μg/mL) exhibited excellent antifungal activity (31.5–39.1 % inhibition), and the activity was comparable to the standard drug, ketoconazole (38–41.1 %). Another study reported that the shampoo product which consisted of neem seeds extract was highly effective against pediculus capitis, a highly contagious head lice infestation, caused by *Pediculus humanus capitis* [74]. Up to 94.1 % of *Pediculus humanus capitis* was killed after 3 h of neem shampoo treatment, and the effect was 20 % more potent than the standard drug, permethrin (73.7 %) [74]. This shows that the neem extracts are highly potential to be used as natural ingredients for various hair care and cleaning purposes, such as dandruff, lice, and other scalp-related parasites.

Oxidative stress breaks down cells and causes progressive damage to the hair strands and the cellular structures of the scalp. Neem extracts have promising antioxidant activities. Neem extracts are rich in various polyphenols which are also powerful antioxidants that could help to combat free radicals and inhibit oxidative stress and aging of hair. The polyphenols reported in neem were quercetin, hydroxy-tyrosol, tyrosol, vanillic acid, caffeic acid, vanillin, *p*-coumaric acid, vitamin D, vitamin E, ferulic acid, luteolin, pinresinol, oleuropein aglycon, ligstroside aglycon, avicularin, castalagin, gallic acid, 2,3-(S)-hexahydroxydiphenoyl-(α/β)-D-glucopyranose, ellagic acid, quercetin, and quercetin-3-*O*-glucoside [111]. The total tannins, phenolic and flavonoids detected in neem were 11.51 ± 0.385 mg/g, 9.19 ± 0.1 mg/g and 0.02 ± 0.005 %, respectively [112]. A recent report by Baby et al. [113] had highlighted the dermocosmetic effectiveness and the potential health risks possessed by neem. The Organization for Economic Cooperation and Development (OECD) outlined the health risks of neem such as ocular irritation, skin sensitisation and irritation, acute oral toxicity, subacute oral toxicity, acute dermal toxicity, reproductive toxicity, teratogenicity, inhalation toxicity, mutagenicity, and genotoxicity.

Fig. 4. *Emblica officinalis.* The figure is adapted from National Park Singapore [117], under the Creative Commons Attribution License.

Low-to-moderate primary skin irritation was also reported when the concentrated neem extract was applied intradermally to the *in vivo* model [113]. Overall, neem is an excellent candidate for exploratory tests for hair care products, in replacement of synthetic ingredients. The safety evaluation of neem-derived products reported by Boeke et al. [114] clearly mentioned that the non-aqueous extracts are more toxic than the unprocessed seed oil and aqueous extracts. The estimated safe dose (ESD) for non-aqueous extracts is 0.002 and 12.5 μg/kg body weight/day, while the seed oil and aqueous extracts ESD is 0.26 and 0.3 mg/kg body weight/day, and 2 μL/kg body weight/day. The ESD of azadirachtin is 15 mg/kg body weight/day. Although the ESD of neem extracts had been determined, United States Food and Drug Administration (FDA) has not approved neem oil for internal human use [115].

2.4. *Emblica officinalis (amla)*

Emblica officinalis (Amla) (Fig. 4) belongs to the plant family Phyllanthaceae. Amla is a traditional Indian herb that has been extensively used in Ayurvedic preparations due to its preventive, restorative, and curative medicinal properties [116]. This plant is grown throughout the Indian subcontinent and is well known as an excellent ingredient for hair care, a stimulant for hair growth, and an improver of hair quality.

Numerous hair health benefits associated with the use of amla have been described in the literature. Tewani et al. [118] reported that amla oil had been proven to be effective in hair growth and hair strengthening. It was reported that amla consists of approximately 28 % of tannins. Two hydrolysable tannins, emblicanin A and B, were discovered in this plant. They could be hydrolysed into phenolic acids and glucose molecules. One on hydrolysis would give rise to gallic acid, ellagic acid, and glucose, while another would produce ellagic acid and glucose. These hydrolysable tannins and the hydrolysis products could exhibit antioxidant activities [119]. In addition, various phenolic compounds and flavonoids, such as gallic acid, ethyl gallate, corilagin, furosin, geraniin, quercetin, kaempferol, and others, were also present in amla [119–123]. These polyphenols are known to have good antioxidant properties, as reported in many scientific literatures. Other antioxidative compounds reported in amla were summarised in Table 5 below.

Amla fruit extracts could exhibit strong free radical scavenging activity. The extract was effective in producing 50 % of the maximal response (EC_{50}) at 4.53–6.00 μg/mL [124]. Although it was slightly weaker than ascorbic acid (EC_{50} 2.99 μg/mL), the activity was considered good as the extracts consisted of mixtures of numerous compounds. Furthermore, another study had also reported that amla could increase the concentration of anti-oxidative enzymes, superoxide dismutase (SOD), glutathione peroxidase (GPx) and catalase (CAT), which could strengthen the defense mechanism against free radicals, oxidative stress, and reduce lipid peroxidation of cell membranes [125]. It is believed that reducing the oxidative stress at the hair scalp would allow the pre-emergent hair fiber to mature in an optimal environment and strengthen the root of hair follicles [126].

Amla fruit infused in coconut oil has been used as a home remedy for hair darkening and premature greying [127]. Tannins in amla had been reported to create affinity between hair dye and hair strand. It is usually added to the hair products with other natural hair dyes, such as henna. Microscopic evaluation showed that the penetrability of dye in shampoo with amla was comparable to commercial shampoo [128], and it is effective in reducing hair greying. Amla had also been reported to stimulate hair pigmentation and preserve hair melanin.

Hair growth is equally important for healthy hair. The antioxidant properties of tannins, phenolic compounds, and flavonoids could help to strengthen the hair follicles [129]. Furthermore, tannins are also good natural astringents that could remove excessive sebum on the scalp, strengthen the hair roots and prevent hair falls [130]. Kumar et al. [75] reported that amla could promote hair growth. The mean active hair follicle count in the transverse section of rat's dorsal skin area (46.4 ± 3.0 hair follicles per area) treated with amla extract was significantly higher than the control group (24.2 ± 2.8 hair follicles per area) and it was comparable to the standard anti-hair loss drug, minoxidil (36.3 ± 4.1 hair follicles per area). Clinical examination also showed that the dermal papilla cells (DPCs) proliferation increased upon the treatment. The hair growth effect exhibited by amla is likely due to its 5α-reductase inhibitor activity. It inhibits or suppresses the 5α-reductase. The inhibition or downregulation of testosterone into dihydrotestosterone was beneficial for hair growth. A high level of dihydrotestosterone could shorten the hair life cycle, shrink the hair follicles, and result in excessive hair loss [75]. Luanpitpong et al. [76] also supported that amla could stimulate hair growth, where the proliferation of DPCs increased in a dose-dependent manner.

Amla extract could also exhibit good inhibition activity against dandruff-causing fungus, *Malassezia* sp. The disc diffusion assay showed that the zone of inhibition of amla extract had yielded strong anti-fungal activity (zone of inhibition 10–15 mm diameter) [87], while another study reported a zone of inhibition up to 22 mm [131]. Besides, the anti-fungal activity of amla was enhanced when henna and shikakai were also included in the shampoo formulation [87]. These scientific pieces of evidence have showed that amla is a good natural candidate for hair care, as it exhibits promising hair protection and hair care properties, such as hair growth,

Table 5
Antioxidative compounds reported in *Emblica officinalis*.

Classes of compounds	Name of compounds	References
Hydrolysable tannins	Emblicanin A and B, punigluconin, pedunculagin, chebulinic acid (ellagitannin), chebulagic acid (Benzopyran tannin), corilagin (ellagitannin), geraniin (dehydroellagitannin), ellagitannin	[119, 121–123]
Phenolic compounds	Gallic acid, methyl gallate, ethyl gallate. Ellagic acid, trigallayl glucose, 3-ethylgallic acid, glucogallin	[119,121, 122]
Flavonoids	kaempferol-3-*O*-*α*-L-(6″-methyl)-rhamnopyranoside, quercetin, acylated apigenin glucoside, and kaempferol-3-*O*-*α*-L-(6″-ethyl)-rhamnopyranoside	[119,122]

strengthening, tanning, antioxidative and anti-dandruff properties.

2.5. *Sapindus mukorossi (reetha)*

Sapindus mukorossi (reetha or soapnut) (Fig. 5) is native to warm temperate regions, tropical and subtropical Asia and belongs to the Sapindaceae family [62,121]. Reetha is a natural surfactant which could be included in plant-based shampoos. The fruit pericarp is rich in saponins (10–11 %) [17], which are well known for surface activity, detergency, and lathering effect.

An earlier study had evaluated and compared the physicochemical properties of several natural and synthetic surfactants. Reetha showed fairly good surface tension (35.30 mN/m), although the synthetic surfactant, Henko, showed a slightly better surface tension (about 1.6 fold greater) [62]. However, reetha exhibits good detergency ability, surface activity, and better emulsification activity than Henko and Pyagi Phool, naturally-derived surfactants. The creamy oil-in-water emulsion was stable for 2 h [62]. The authors concluded that reetha is a good natural surfactant as it exhibited better or comparable emulsion stability, viscosity, dirt dispersion, foaming, wetting and cleaning ability to Henko. Furthermore, it has been proven to be non-toxic and it will not cause dermal irritation.

Alcoholic leaves extract of reetha was reported to exhibit antimicrobial activity against several pathogenic bacteria and fungi, including *S. aureus*, *Enterobacter aerogenes*, *Salmonella Typhimurium*, *Klebsiella pneumoniae*, *E. coli*, *Vibrio cholerae*, *Pseudomonas aeruginosa, C. albicans*, *C. tropicalis*, and *C. parapsilosis* [133], but the activity was fairly weak. On the other hand, the saponins in the fruit pericarp possess antimicrobial properties. Eleven saponins isolated from reetha exhibited antifungal activity against *C. albicans* SC5314 and *Trichophyton rubrum* ATCC 20188. Nine of them showed moderate antifungal activity against *C. albican* [134]. Oleanolic acid 3-*O*-D-xylopyranosyl-(1/3)-α-L-rhamnopyranosyl-(1/2)-α-L-arabinopyranoside, oleanolic acid 3-*O*-α-L-arabinopyranosyl-(1/3)-α-L-rhamnopyranosyl-(1/2)-α-L-arabinopyranoside and α-hederin showed MIC 8–16 mg/mL. A time-kill assay was performed using these three saponin analogues, and the results showed fungicidal activity at 2 × MIC: 16 mg/mL of α-hederin and 32 mg/mL of oleanolic acid 3-*O*-D-xylopyranosyl-(1/3)-α-L-rhamnopyranosyl-(1/2)-α-L-arabinopyranoside. A-Hederin caused more than 99.9 % cell death within 4 h, while oleanolic acid 3-*O*-α-L-arabinopyranosyl-(1/3)-α-L-rhamnopyranosyl-(1/2)-α-L-arabinopyranoside exhibited the same fungicidal efficacy after 12 h [134]. A recent study by Pavithra et al. [135] reported the anti-dandruff activity of reetha seed extract. The seed extract was mixed with *C. albicans,* and the antifungal activity was evaluated using the spread plate method after 24 h incubation. Although the reetha seed extract antifungal activity was lower compared to the standard control, selenium di-sulphate (99.7 % growth reduction), the fungal growth was reduced up to 52.5 % upon treatment. Zaynab et al. [102] explained that the antifungal action of saponins, where they cause membrane lipid re-arrangement, create pores in the cell membrane of fungus, and finally cell lysis. Hence, the saponins from reetha are promising natural antimicrobial agents which could be used to reduce yeast on hair scalp.

2.6. *Garcinia mangostana (mangosteen)*

Garcinia mangostana L. (mangosteen) (Fig. 6) belongs to the family Guttiferea. It is native to Malaysia and has a wide distribution in the tropical rainforest of Southeast Asia countries. *G. mangostana* pericarp is rich in phytochemicals that could contribute to the aforementioned activities. Among the classes of phytochemicals reported are polyphenols (anthocyanins, xanthones, phenolic acids, condensed tannins), flavonoids, terpenoids, and alkaloids [136–139]. α-Mangostin is the xanthone that is present predominantly (69 %) in the mangosteen pericarp. It could exhibit multiple biological activities, including antioxidant, anti-inflammatory, anti-bacterial, and anti-fungal, all of which are closely related to hair care and scalp maintenance.

Excellent antioxidant activities, particularly free radical scavenging activity have been reported in *G. mangostana* pericarp [141]. Moreover, α-mangostin present in the pericarp has been found to exhibit significant antioxidant properties in terms of free radical scavenging, chelating of metal ions, and reducing activity. More specifically, α-mangostin can scavenge free radicals such as singlet

Fig. 5. *Sapindus mukorossi.* The figure is adapted from Arizona Wildscape [132], under the Creative Commons Attribution License.

Fig. 6. *Garcinia mangostana.* The figure is adapted from Chew et al. [140].

oxygen (IC_{50} = 4.6 μM), $O_2^{\bullet-}$ (IC_{50} = 24.8 μM) and $ONOO^-$ (IC_{50} = 23.3 μM) in a concentration-dependent manner [140]. γ-Mangostin, which is also found in the pericarp, is the only xanthone which could scavenge OH• (IC_{50} = 0.20 μg/mL). Interestingly, literature has reported that the inhibitory activity of γ-mangostin on lipid peroxidation was significantly greater than other well-known antioxidant compounds like butylated hydroxyanisole (BHA) and α-tocopherol. Such high antioxidant activities could essentially protect the hair from oxidative damage.

Antioxidant activity is closely associated with anti-inflammatory activity. The anti-inflammatory properties of *G. mangostana* could be contributed by its antioxidant and radical scavenging activity, apart from its ability to modulate activities of proinflammatory enzymes. Notably, α-mangostin in *G. mangostana* can inhibit the secretion of important proinflammatory mediators, such as tumour necrosis factor (TNF)-α, interleukin (IL)-4, cyclooxygenase-2 (COX-2), IL-6, and IL-1β [142]. Through intermolecular hydrogen bonds, π-π and π-alkyl hydrophobic interactions, α-mangostin may bind with COX-2 and NF-κB proteins to form complexes [143]. This inhibits the translocation of NF-κB and COX-2 enzymes, ultimately leading to anti-inflammatory activity. The resulting anti-inflammatory activity could possibly control hair folliculitis, the infection on hair scalp [140].

Ketonazole is conventionally incorporated into anti-dandruff shampoo. As an anti-dandruff agent, ketoconazole is effective in suppressing the growth of dandruff-causing fungus, *M. furfur*. However, it could trigger an allergic reaction and lead to contact dermatitis. *G. mangostana* pericarp extract has been proven to exhibit a promising antifungal activity against *M. furfur*. Ni'maa et al. [144] reported that *G. mangostana* could inhibit the growth of *M. furfur,* and the inhibitory action of its pericarp extract towards *M. furfur* was comparable to 2 % ketoconazole. Therefore, it is believed that *G. mangostana* pericarp extract could be used as a natural substituent to ketoconazole in hair care products with promising anti-dandruff properties. Repeated injury to the hair follicles due to inflammation may eventually slow or stop hair growth. The combination of anti-fungal and anti-inflammatory activities of *G. mangostana* pericarp extract could prevent excess proliferation of *M. furfur* on hair scalp. This reduces the risks of possible inflammation in the hair follicles, which could promote hair growth.

G. mangostana pericarp could promote hair rejuvenation. It was reported that the hair growth activity significantly improved up to 157.56 % in the treatment group, which had been treated with 500 μg/mL of *G. mangostana* pericarp water extract [78]. In addition to increasing dermal papilla cells tyrosinase activity, the extract was also found to enhance melanin production in dermal papilla cells by four times compared to the control group. These melanogenic stimulating and tyrosinase effect of *G. mangostana* pericarp water extract are essential in hair tanning [78]. Similar findings on melanogenesis-inducing property of *G. mangostana* had also been reported in its leaf extract by Hamid et al. [145]. B16F1 cells were treated with different concentrations of leaf extract (4–32 μg/mL), and the melanin secreted by B16F1 cells into the culture medium and present inside cells were measured. It was noticed that the melanin produced increased with concentration, whereby maximum melanin secretion was recorded at the highest dosage of leaf extract. Studies had also shown that flavonoids contained in *G. mangostana* could induce morphological changes in melanoma cells [146–149]. Exposure to these flavonoids promotes expression of melanocyte differentiation-related markers, including melanin synthesis, tyrosinase and microphthalmia-associated transcription factor [146]. The resultant increase in intracellular accumulation of β-catenin and phosphorylation of glycogen synthase kinase-3β protein were thought to stimulate melanogenesis in the hair.

Hair dermal papilla cells are specialized mesenchymal cells lining the bottom of hair follicles. They serve an important role in the regulation of hair growth and cycling. *G. mangostana* pericarp could stimulate hair growth, as significant increase (157.56 %) in hair papilla cells proliferation was noticed after treatment with 500 μg/mL of pericarp extract as reported by Tan [78]. Furthermore, tannins and flavonoids could remarkably increase the hair rejuvenation capacity. The hair growth completion time was reportedly shortened by 10 days upon treatment with the pericarp extract. With treatment, Rambwawasvika et al. [150] also observed that the length of the hair in the treatment group was significantly longer than in the control group (11.04 mm and 11.86 mm for male and female in treatment group; 5.15 mm and 5.33 mm for male and female in control group), and the results were comparable to standard drug, 2 % w/v minoxidil.

3. Potential health issues caused by natural ingredients

While natural ingredients in shampoos are often perceived as safer, they can pose certain health risks. Some ingredients have the potential to cause toxicity and allergenicity in certain individuals. Substances such as essential oils, plant extracts, and herbal additives may contain compounds that can trigger allergic reactions or skin sensitivities in susceptible individuals [151]. For instance, Guzmán et al. [152] reported that Chitosan is widely regarded as a biocompatible and non-toxic polymer. It is approved for various applications by the regulatory agencies. However, it is not recognised as a safe (GRAS) material, due to the fact that their safety profile can change by the interaction of chitosan with cells and the microenvironment, which may potentially lead to toxicity of formulations.

Additionally, even though natural ingredients are derived from plants or other renewable sources, they can still be potent and require proper formulation and usage to ensure safety. It is crucial for consumers to be aware of their own sensitivities and allergies and to carefully read product labels to identify any potential allergens. Essential oils are commonly included in the skin care formulation as preservatives and fragrances. There are reports that highlight essential oil could cause allergic reaction in certain individuals. The use of low-grade essential oils can lead to skin irritation, allergic reactions, or even cause hepatotoxicity. They also possess strong photosensitizing properties and cause skin damage upon exposure to sunlight [1]. Therefore, manufacturers must conduct thorough safety assessments and use appropriate concentrations of natural ingredients to minimize the risk of adverse reactions. A balanced approach, considering both the benefits and potential risks of natural ingredients, is essential to create safe and effective hair care products.

4. Conclusion and perspectives

Botanical extracts have been used conventionally in daily hair care. They contain bioactive phytochemicals which can clean the hair scalp and improve skin conditions to a considerable extent without causing side effects. Scientific studies have shown that botanical extracts are effective in improving the biological function of the skin, hair and scalp. Furthermore, natural-based ingredients can be used as essential components in hair care formulations, such as surfactants, hair moisturisers, anti-dandruff agents, sebum removers, cleansing agents, and others. Cosmetics with botanical extracts are emerging, and this segment is expected to experience robust growth in the cosmeceutical market. The sales of botanical extracts hair care are expected to increase significantly. The current trend has shifted towards the use of botanical based products and to adopting a more natural way of life. The fundamental shift in demand for botanical extract hair care products is boosted by increased consumer demand for sustainable, natural, and chemical-free products. Manufacturers are also investing in the research and development of hair care products using natural and plant-based ingredients to combat various hair problems such as scalp irritation, dandruff, hair fall, etc.

Author contributions

S.-H.S, Y.-L.C., S.-K.L., J.-W.K. and K.-B.L. original draft preparation. G.A.A., J.A.-L.Y., and S.-K.L. writing-review and editing. C.S. T. made final correction. All authors have read and agreed to the published version of the manuscript.

Funding

The study was funded by the Malaysian Ministry of Higher Education through the Fundamental Research Grant Scheme (FRGS) (FRGS/1/2021/STG02/UCSI/02/1) and UCSI University Research Excellence & Innovation Grant (REIG) (REIG-FPS-2023/037).

Informed consent statement

Not applicable.

Data availability

Not applicable.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Yik-Ling Chew reports administrative support was provided by UCSI University.

References

[1] E. Guzmán, A. Lucia, Essential oils and their individual components in cosmetic products, Cosmetics 8 (2021) 114.
[2] M. Giustra, F. Cerri, Y. Anadol, L. Salvioni, T. Antonelli Abella, D. Prosperi, P. Galli, M. Colombo, Eco-luxury: making sustainable drugs and cosmetics with Prosopis cineraria natural extracts, Front. Sustain. 3 (2022), 1047218.
[3] R. Mori, Replacing all petroleum-based chemical products with natural biomass-based chemical products: a tutorial review, RSC Sustain. 1 (2023) 179–212.
[4] K. Masakorala, A. Turner, M.T. Brown, Toxicity of synthetic surfactants to the marine macroalga, Ulva lactuca, Water Air Soil Pollut. 218 (2011) 283–291.
[5] A.L.V. Cubas, R.T. Bianchet, I.M.A.S.d. Reis, I.C. Gouveia, Plastics and microplastic in the cosmetic industry: aggregating sustainable actions aimed at alignment and interaction with UN sustainable development goals, Polymers 14 (2022) 4576.
[6] E.A. Silva, M.R.M. Bosco, É. Mozer, Study of the frequency of allergens in cosmetics components in patients with suspected allergic contact dermatitis, An. Bras. Dermatol. 87 (2012) 263–268.
[7] C. Ade-Browne, M. Mirzamani, A. Dawn, S. Qian, R.G. Thompson, R.W. Glenn, H. Kumari, Effect of ethoxylation and lauryl alcohol on the self-assembly of sodium laurylsulfate: significant structural and rheological transformation, Colloids Surf. Physicochem. Eng. Aspects 595 (2020), 124704.
[8] G. Turner, M. Hoptroff, C. Harding, Stratum corneum dysfunction in dandruff, Int. J. Cosmet. Sci. 34 (2012) 298–306.

[9] S. Leoty-Okombi, F. Gillaizeau, S. Leuillet, B. Douillard, L. Fresne-Languille, T. Carton, A. De Martino, P. Moussou, C. Bonnaud-Rosaye, V. André, Effect of sodium lauryl sulfate (SLS) applied as a patch on human skin physiology and its microbiota, Cosmetics 8 (2021) 6.
[10] Y.-C. Chen, P.-R. Wang, T.-J. Lai, L.-H. Lu, L.-W. Dai, C.-H. Wang, Using therapeutic ultrasound to promote irritated skin recovery after surfactant-induced barrier disruption, Ultrasonics 91 (2019) 206–212.
[11] H. Törmä, M. Lindberg, B. Berne, Skin barrier disruption by sodium lauryl sulfate-exposure alters the expressions of involucrin, transglutaminase 1, profilaggrin, and kallikreins during the repair phase in human skin in vivo, J. Invest. Dermatol. 128 (2008) 1212–1219.
[12] G.J.M. Christensen, H. Brüggemann, Bacterial skin commensals and their role as host guardians, Benef. Microbes 5 (2014) 201–215.
[13] G. Basílico, C.A. Roger, M. Seigelchifer, N. Kerner, UV-specific DNA repair recombinant fusion enzyme: a new stable pharmacologically active principle suitable for photoprotection, J. Dermatol. Sci. 39 (2005) 81–88.
[14] M.M. Ramsey, M.O. Freire, R.A. Gabrilska, K.P. Rumbaugh, K.P. Lemon, Staphylococcus aureus shifts toward commensalism in response to Corynebacterium species, Front. Microbiol. 7 (2016) 1230.
[15] N. Cowley, P. Farr, A dose-response study of irritant reactions to sodium lauryl sulphate in patients with seborrhoeic dermatitis and atopic eczema, Acta Derm. Venereol. 72 (1992) 432–435.
[16] J.H. Baert, R.J. Veys, K. Ampe, J.A. De Boever, The effect of sodium lauryl sulphate and triclosan on hamster cheek pouch mucosa, Int. J. Exp. Pathol. 77 (1996) 73–78.
[17] K. Barve, A. Dighe, The Chemistry and Applications of Sustainable Natural Hair Products, Springer, 2016.
[18] G. Militello, S.E. Jacob, G.H. Crawford, Allergic contact dermatitis in children, Curr. Opin. Pediatr. 18 (2006) 385–390.
[19] C.L. Burnett, W.F. Bergfeld, D.V. Belsito, R.A. Hill, C.D. Klaassen, D. Liebler, J.G. Marks Jr., R.C. Shank, T.J. Slaga, P.W. Snyder, Final report of the cosmetic ingredient review expert panel on the safety assessment of cocamidopropyl betaine (CAPB), Int. J. Toxicol. 31 (2012) 77S–111S.
[20] A. Schnuch, H. Lessmann, J. Geier, W. Uter, Is cocamidopropyl betaine a contact allergen? Analysis of network data and short review of the literature, Contact Dermatitis 64 (2011) 203–211.
[21] H. Löffler, D. Becker, J. Brasch, J. Geier, G.C.D.R. Group, Simultaneous sodium lauryl sulphate testing improves the diagnostic validity of allergic patch tests. Results from a prospective multicentre study of the German Contact Dermatitis Research Group (Deutsche Kontaktallergie-Gruppe, DKG), Br. J. Dermatol. 152 (2005) 709–719.
[22] J.D. Welling, T.F. Mauger, L.R. Schoenfield, A.J. Hendershot, Chronic eyelid dermatitis secondary to cocamidopropyl betaine allergy in a patient using baby shampoo eyelid scrubs, JAMA Ophthalmol. 132 (2014) 357–359.
[23] K. Steenland, E. Whelan, J. Deddens, L. Stayner, E. Ward, Ethylene oxide and breast cancer incidence in a cohort study of 7576 women (United States), Cancer Causes Control 14 (2003) 531–539.
[24] F. Zhang, M.J. Bartels, M.J. LeBaron, M.R. Schisler, Y.-C. Jeong, B.B. Gollapudi, N.P. Moore, LC–MS/MS simultaneous quantitation of 2-hydroxyethylated, oxidative, and unmodified DNA nucleosides in DNA isolated from tissues of mice after exposure to ethylene oxide, J. Chromatogr. B 976 (2015) 33–48.
[25] J. Jinot, J.M. Fritz, S.V. Vulimiri, N. Keshava, Carcinogenicity of ethylene oxide: key findings and scientific issues, Toxicol. Mech. Methods 28 (2018) 386–396.
[26] H. Lessmann, W. Uter, A. Schnuch, J. Geier, Skin sensitizing properties of the ethanolamines mono-, di-, and triethanolamine. Data analysis of a multicentre surveillance network (IVDK*) and review of the literature, Contact Dermatitis 60 (2009) 243–255.
[27] M. Kraeling, J. Yourick, R. Bronaugh, In vitro human skin penetration of diethanolamine, Food Chem. Toxicol. 42 (2004) 1553–1561.
[28] H.-W. Leung, L.M. Kamendulis, W.T. Stott, Review of the carcinogenic activity of diethanolamine and evidence of choline deficiency as a plausible mode of action, Regul. Toxicol. Pharmacol. 43 (2005) 260–271.
[29] W. Stott, M. Bartels, K. Brzak, M.-H. Mar, D. Markham, C. Thornton, S. Zeisel, Potential mechanisms of tumorigenic action of diethanolamine in mice, Toxicol. Lett. 114 (2000) 67–75.
[30] L.D. Lehman-McKeeman, E.A. Gamsky, S.M. Hicks, J.D. Vassallo, M.-H. Mar, S.H. Zeisel, Diethanolamine induces hepatic choline deficiency in mice, Toxicol. Sci. 67 (2002) 38–45.
[31] W.H. Meck, R.A. Smith, C.L. Williams, Pre-and postnatal choline supplementation produces long-term facilitation of spatial memory, Dev. Psychobiol. 21 (1988) 339–353.
[32] W.H. Meck, C.L. Williams, Metabolic imprinting of choline by its availability during gestation: implications for memory and attentional processing across the lifespan, Neurosci. Biobehav. Rev. 27 (2003) 385–399.
[33] N. Milanesi, S. Berti, M. Gola, Allergic contact dermatitis to triethanolamine in a child, Pediatr. Dermatol. 32 (2015) e112–e113.
[34] D.S. Lim, T.H. Roh, M.K. Kim, Y.C. Kwon, S.M. Choi, S.J. Kwack, K.B. Kim, S. Yoon, H.S. Kim, B.-M. Lee, Risk assessment of N-nitrosodiethylamine (NDEA) and N-nitrosodiethanolamine (NDELA) in cosmetics, J. Toxicol. Environ. Health 81 (2018) 465–480.
[35] S. Mertens, L. Gilissen, A. Goossens, Allergic contact dermatitis caused by cocamide diethanolamine, Contact Dermatitis 75 (2016) 20–24.
[36] F. Soga, K. Izawa, T. Inoue, N. Katoh, S. Kishimoto, Contact dermatitis due to disodium ethylenediamine-tetraacetic acid in cosmetics and shampoo, Contact Dermatitis 49 (2003), 105-105.
[37] I. Hauksson, A. Pontén, B. Gruvberger, M. Isaksson, M. Engfeldt, M. Bruze, Skincare products containing low concentrations of formaldehyde detected by the chromotropic acid method cannot be safely used in formaldehyde-allergic patients, Br. J. Dermatol. 174 (2016) 371–379.
[38] K. Bork, D. Heise, A. Rosinus, Formaldehyde in hair shampoos, Dermatosen in Beruf und Umwelt. Occupation Environ. 27 (1979) 10–12.
[39] I.J. Boyer, B. Heldreth, W.F. Bergfeld, D.V. Belsito, R.A. Hill, C.D. Klaassen, D.C. Liebler, J.G. Marks Jr., R.C. Shank, T.J. Slaga, Amended safety assessment of formaldehyde and methylene glycol as used in cosmetics, Int. J. Toxicol. 32 (2013) 5S–32S.
[40] A.F. Fransway, P.J. Fransway, D.V. Belsito, E.M. Warshaw, D. Sasseville, J.F. Fowler Jr., J.G. DeKoven, M.D. Pratt, H.I. Maibach, J.S. Taylor, Parabens, Dermatitis 30 (2019) 3–31.
[41] N. Matwiejczuk, A. Galicka, M.M. Brzóska, Review of the safety of application of cosmetic products containing parabens, J. Appl. Toxicol. 40 (2020) 176–210.
[42] M. Zirwas, J. Moennich, Shampoos, Dermatitis 20 (2009) 106–110.
[43] S. Alkafajy, R. Abdul-Jabbar, Comprehensive effects of parabens in human physiology, Ann. Trop. Med. Publ. Health 23 (2020) 23.
[44] R.T. Engeli, S.R. Rohrer, A. Vuorinen, S. Herdlinger, T. Kaserer, S. Leugger, D. Schuster, A. Odermatt, Interference of paraben compounds with estrogen metabolism by inhibition of 17β-hydroxysteroid dehydrogenases, Int. J. Mol. Sci. 18 (2017) 2007.
[45] A.K. Charles, P.D. Darbre, Combinations of parabens at concentrations measured in human breast tissue can increase proliferation of MCF-7 human breast cancer cells, J. Appl. Toxicol. 33 (2013) 390–398.
[46] J. Jurewicz, M. Radwan, B. Wielgomas, A. Klimowska, P. Kałużny, P. Radwan, L. Jakubowski, W. Hanke, Environmental exposure to parabens and sperm chromosome disomy, Int. J. Environ. Health Res. 27 (2017) 332–343.
[47] I. Jiménez-Díaz, L. Iribarne-Durán, O. Ocón, E. Salamanca, M. Fernández, N. Olea, E. Barranco, Determination of personal care products–benzophenones and parabens–in human menstrual blood, J. Chromatogr. B 1035 (2016) 57–66.
[48] Y. Li, S. Xu, Y. Li, B. Zhang, W. Huo, Y. Zhu, Y. Wan, T. Zheng, A. Zhou, Z. Chen, Association between urinary parabens and gestational diabetes mellitus across prepregnancy body mass index categories, Environ. Res. 170 (2019) 151–159.
[49] P. Hu, R.C. Kennedy, X. Chen, J. Zhang, C.-L. Shen, J. Chen, L. Zhao, Differential effects on adiposity and serum marker of bone formation by post-weaning exposure to methylparaben and butylparaben, Environ. Sci. Pollut. Res. 23 (2016) 21957–21968.
[50] D. Dubey, D. Chopra, J. Singh, A.K. Srivastav, S. Kumari, A. Verma, R.S. Ray, Photosensitized methyl paraben induces apoptosis via caspase dependent pathway under ambient UVB exposure in human skin cells, Food Chem. Toxicol. 108 (2017) 171–185.
[51] N. Majewska, I. Zaręba, A. Surażyński, A. Galicka, Methylparaben-induced decrease in collagen production and viability of cultured human dermal fibroblasts, J. Appl. Toxicol. 37 (2017) 1117–1124.
[52] P.D. Darbre, P.W. Harvey, Paraben esters: review of recent studies of endocrine toxicity, absorption, esterase and human exposure, and discussion of potential human health risks, J. Appl. Toxicol. 28 (2008) 561–578.

[53] P.R. Cohen, C.A. Anderson, Topical selenium sulfide for the treatment of hyperkeratosis, Dermatol. Ther. 8 (2018) 639–646, https://doi.org/10.1007/s13555-018-0259-9.
[54] K. Gilbertson, R. Jarrett, S.J. Bayliss, D.R. Berk, Scalp discoloration from selenium sulfide shampoo: a case series and review of the literature, Pediatr. Dermatol. 29 (2012) 84–88.
[55] R. Gillum, Hyperpigmentation associated with selenium sulfide lotion, J. Natl. Med. Assoc. 88 (1996) 551.
[56] V.E. Archer, E. Luell, Effect of selenium sulfide suspension on hair roots, J. Invest. Dermatol. 35 (1960) 65–67.
[57] D.G.N.D. Gamage, R.M. Dharmadasa, D.C. Abeysinghe, R.G.S. Wijesekara, G.A. Prathapasinghe, T. Someya, Ethnopharmacological survey on medicinal plants used for cosmetic treatments in traditional and Ayurveda systems of medicine in Sri Lanka, Evid. Based Complement. Alternat. Med. (2021) 2021.
[58] S. Patel, V. Sharma, N. S Chauhan, M. Thakur, V.K. Dixit, Hair growth: focus on herbal therapeutic agent, Curr. Drug Discov. Technol. 12 (2015) 21–42.
[59] K.G. Bezerra, H.M. Meira, B.O. Veras, T.C. Stamford, E.L. Fernandes, A. Converti, R.D. Rufino, L.A. Sarubbo, Application of plant surfactants as cleaning agents in shampoo formulations, Processes 11 (2023) 879.
[60] L. El-Khordagui, S.E. Badawey, L.A. Heikal, Application of biosurfactants in the production of personal care products, and household detergents and industrial and institutional cleaners, in: Green Sustainable Process for Chemical and Environmental Engineering and Science, Elsevier, 2021, pp. 49–96.
[61] D. Kregiel, J. Berlowska, I. Witonska, H. Antolak, C. Proestos, M. Babic, L. Babic, B. Zhang, Saponin-based, biological-active surfactants from plants, Appl. Characterization of Surfactants (2017) 183.
[62] A. Pradhan, A. Bhattacharyya, Quest for an eco-friendly alternative surfactant: surface and foam characteristics of natural surfactants, J. Clean. Prod. 150 (2017) 127–134.
[63] P. D'Souza, S.K. Rathi, Shampoo and conditioners: what a dermatologist should know? Indian J. Dermatol. 60 (2015) 248.
[64] L. Fernández-Peña, E. Guzmán, Physicochemical aspects of the performance of hair-conditioning formulations, Cosmetics 7 (2020) 26.
[65] A. Panda, A. Kumar, S. Mishra, S. Soapnut Mohapatra, A replacement of synthetic surfactant for cosmetic and biomedical applications, Sustain. Chem. Pharm. 17 (2020), 100297.
[66] S.-T. Muntaha, M.N. Khan, Natural surfactant extracted from Sapindus mukurossi as an eco-friendly alternate to synthetic surfactant–a dye surfactant interaction study, J. Clean. Prod. 93 (2015) 145–150.
[67] L. Tmáková, S. Sekretár, Š. Schmidt, Plant-derived surfactants as an alternative to synthetic surfactants: surface and antioxidant activities, Chem. Pap. 70 (2016) 188–196.
[68] V. Medisetti, G.R. Battu, S. Ravindra, R. Sandhya, R. Subbarao, Antibacterial and anthelmintic activities of aqueous extract of Acacia concinna Linn, Indo Am. J. Pharm. Sci. 3 (2016) 566–572.
[69] Y.-F. Chen, C.-H. Yang, M.-S. Chang, Y.-P. Ciou, Y.-C. Huang, Foam properties and detergent abilities of the saponins from Camellia oleifera, Int. J. Mol. Sci. 11 (2010) 4417–4425.
[70] X. Feás, L.M. Estevinho, C. Salinero, P. Vela, M.J. Sainz, M.P. Vázquez-Tato, J.A. Seijas, Triacylglyceride, antioxidant and antimicrobial features of virgin Camellia oleifera, C. reticulata and C. sasanqua oils, Molecules 18 (2013) 4573–4587.
[71] Q.-f. Zhou, X.-j. Jia, Q.-q. Li, R.-w. Yang, L. Zhang, Y.-h. Zhou, C.-b. Ding, Antioxidant and antimicrobial activities of Camellia Oleifera seed oils, J. Appl. Biol. Chem. 57 (2014) 123–129.
[72] A. Niharika, J.M. Aquicio, A. Anand, Antifungal properties of neem (Azadirachta indica) leaves extract to treat hair dandruff, E-Int. J. Sci. Res. 2 (2010) 244–252.
[73] G. Gebremedhin, T. Tesfay, K.K. Chaithanya, K. Kamalakararao, K. Kamalakararao, Phytochemical screening and in vitro anti-dandruff activities of bark extracts of neem (Azadirachta indica), Drug Invent. Today 13 (2020) 707–713.
[74] J. Heukelbach, F.A. Oliveira, R. Speare, A new shampoo based on neem (Azadirachta indica) is highly effective against head lice in vitro, Parasitol. Res. 99 (2006) 353–356.
[75] N. Kumar, W. Rungseevijitprapa, N.-A. Narkkhong, M. Suttajit, C. Chaiyasut, 5α-reductase inhibition and hair growth promotion of some Thai plants traditionally used for hair treatment, J. Ethnopharmacol. 139 (2012) 765–771.
[76] S. Luanpitpong, U. Nimmannit, V. Pongrakhananon, P. Chanvorachote, Emblica (Phyllanthus emblica Linn.) fruit extract promotes proliferation in dermal papilla cells of human hair follicle, Res. J. Med. Plant 5 (2011) 95–100.
[77] W. Suttirak, S. Manurakchinakorn, In vitro antioxidant properties of mangosteen peel extract, J. Food Sci. Technol. 51 (2014) 3546–3558.
[78] Y.F. Tan, Hair Growth and Hair Tanning Activities of Mangosteen Pericarp Water Extract on Hair Dermal Papilla Cells Universiti Teknologi Malaysia, 2016. Malaysia.
[79] G. Chen, Y. Li, W. Wang, L. Deng, Bioactivity and pharmacological properties of α-mangostin from the mangosteen fruit: a review, Expert Opin. Ther. Pat. 28 (2018) 415–427.
[80] D. Das, A.K. Sarangi, R.K. Mohapatra, P.K. Parhi, A. Mahal, R. Sahu, M. Kudrat-E-Zahan, Aqueous extract of Shikakai; a green solvent for deoximation reaction: mechanistic approach from experimental to theoretical, J. Mol. Liq. 309 (2020), 113133.
[81] S. Ireland, K. Carlino, L. Gould, F. Frazier, P. Haycock, S. Ilton, R. Deptuck, B. Bousfield, D. Verge, K. Antoni, Shampoo after craniotomy: a pilot study, Can. J. Neurosci. Nurs. 29 (2007) 14–19.
[82] A. Pradhan, A. Bhattacharyya, Shampoos then and now: synthetic versus natural, J. Surf. Sci. Technol. 30 (2014) 59–76.
[83] R. Utane, S. Deo, P. Itankar, Preparation of herbal shampoo (HS) by green method and their characterization, Int. J. Res. Soc. Sci. Inf. Stud 5 (2017) 254–258.
[84] Dinesh, V. Acacia concinna (5595830208).jpg. Available online: https://creativecommons.org/licenses/by/4.0/(accessed on 31 March 2023)..
[85] M.A. Hanif, H.N. Bhatti, M.S. Jamil, R.S. Anjum, A. Jamil, M.M. Khan, Antibacterial and antifungal activities of essential oils extracted from medicinal plants using CO2 supercritical fluid extraction technology, Asian J. Chem. 22 (2010) 7787.
[86] M. Wuthi-udomlert, O. Vallisuta, In vitro effectiveness of Acacia concinna extract against dermatomycotic pathogens, Phcog. J. 3 (2011) 69–73, https://doi.org/10.5530/pj.2011.19.13.
[87] S. Prachi, D. Sonal, Preparation of Herbello - an herbal antidandruff shampoo, Int. J. Pharm. Biol. Sci. 5 (2015) 220–228.
[88] C. Yang, X. Liu, Z. Chen, Y. Lin, S. Wang, Comparison of oil content and fatty acid profile of ten new Camellia oleifera cultivars, J. Lipids 2016 (2016).
[89] W. Chaiyana, P. Leelapornpisid, J. Jakmunee, C. Korsamphan, Antioxidant and moisturizing effect of Camellia assamica seed oil and its development into microemulsion, Cosmetics 5 (2018) 40.
[90] R.D. Sinclair, Healthy hair: what is it?, in: Proceedings of the Journal of Investigative Dermatology Symposium Proceedings, 2007, pp. 2–5.
[91] Z.D. Draelos, Hair Care: an Illustrated Dermatologic Handbook, CRC Press, 2004.
[92] N. Ionescu, G.-C. Ivopol, M. Neagu, M. Popescu, A. Meghea, Fatty acids and antioxidant activity in vegetable oils used in cosmetic formulations, UPB Sci. Bull. B: Chem. Mater. Sci. 77 (2015).
[93] P. Chaikul, T. Sripisut, S. Chanpirom, K. Sathirachawan, N. Ditthawuthikul, Melanogenesis inhibitory and antioxidant effects of Camellia oleifera seed oil, Adv. Pharmaceut. Bull. 7 (2017) 473.
[94] L. Wang, S. Ahmad, X. Wang, H. Li, Y. Luo, Comparison of antioxidant and antibacterial activities of Camellia oil from hainan with Camellia oil from guangxi, olive oil, and peanut oil, Front. Nutr. 8 (2021) 210.
[95] Kunming Expo Garden, C. 阿橋花譜 KHQ Flower Guide. Available online: https://creativecommons.org/licenses/by/4.0/(accessed on 31 March 2023)..
[96] Y.L. Chew, Y.Y. Lim, J. Stanslas, G.C.L. Ee, J.K. Goh, Bioactivity-guided isolation of anticancer agents from Bauhinia kockiana Korth, Afr. J. Tradit., Complementary Altern. Med. 11 (2014) 291–299.
[97] B. Sabbagh, P. Kumar, Y. Chew, J. Chin, G. Akowuah, Determination of metformin in fixed-dose combination tablets by ATR-FTIR spectroscopy, Chem. Data Collections 39 (2022), 100868.
[98] Y.-L. Chew, The beneficial properties of virgin coconut oil in management of atopic dermatitis, Phcog. Rev. 13 (2019) 25.
[99] Y.H. Cheah, F.J. Nordin, N.R. Abdullah, Z. Ismail, Effects of a local commercial herbal cleanser on hair growth in Wistar rats, J. Med. Plants Res. 7 (2013) 2906–2913.

[100] K. Lunkenheimer, K. Malysa, Simple and generally applicable method of determination and evaluation of foam properties, J. Surfactants Deterg. 6 (2003) 69–74.
[101] T. Schad, N. Preisig, D. Blunk, H. Piening, W. Drenckhan, C. Stubenrauch, Less is more: unstable foams clean better than stable foams, J. Colloid Interface Sci. 590 (2021) 311–320, https://doi.org/10.1016/j.jcis.2021.01.048.
[102] M. Zaynab, Y. Sharif, S. Abbas, M.Z. Afzal, M. Qasim, A. Khalofah, M.J. Ansari, K.A. Khan, L. Tao, S. Li, Saponin toxicity as key player in plant defense against pathogens, Toxicon 193 (2021) 21–27.
[103] Z. Yu, X. Wu, J. He, Study on the antifungal activity and mechanism of tea saponin from Camellia oleifera cake, Eur. Food Res. Technol. (2022) 1–13.
[104] J.L. Hu, S.P. Nie, D.F. Huang, C. Li, M.Y. Xie, Y. Wan, Antimicrobial activity of saponin-rich fraction from Camellia oleifera cake and its effect on cell viability of mouse macrophage RAW 264.7, J. Sci. Food Agric. 92 (2012) 2443–2449.
[105] J. Reuter, U. Wölfle, S. Weckesser, C. Schempp, Which plant for which skin disease? Part 1: atopic dermatitis, psoriasis, acne, condyloma and herpes simplex, J. Dtsch. Dermatol. Ges. 8 (2010) 788–796.
[106] Y.-L. Chew, M.-A. Khor, Z. Xu, S.-K. Lee, J.-W. Keng, S.-H. Sang, G.A. Akowuah, K.W. Goh, K.B. Liew, L.C. Ming, Cassia alata, Coriandrum sativum, Curcuma longa and Azadirachta indica: Food ingredients as complementary and alternative therapies for atopic dermatitis-A comprehensive review, Molecules 27 (2022) 5475.
[107] D.M.L. Saunte, G. Gaitanis, R.J. Hay, Malassezia-associated skin diseases, the use of diagnostics and treatment, Front. Cell. Infect. Microbiol. 10 (2020), https://doi.org/10.3389/fcimb.2020.00112.
[108] D. Gozali, R. Rudathillah, R. Mustarichie, Anti-dandruff Shampoo formulation with active substances Ethanol extract of Brassica oleracea var capitata L. and its verifying activity against fungus Malassezia furfur, Res. J. Pharm. Technol. 13 (2020) 3702–3708.
[109] K. Priya, D. Surabi, R. Sarath, R. Mohandass, Isolation and characterization of active metabolites produced from probiotic isolates against dandruff causing Malassezia (MTCC: 1374T), J. Microbiol. Biotechnol. Food Sci. 10 (2021), e3522-e3522.
[110] M. Hiruma, O. Cho, M. Hiruma, S. Kurakado, T. Sugita, S. Ikeda, Genotype analyses of human commensal scalp fungi, Malassezia globosa, and Malassezia restricta on the scalps of patients with dandruff and healthy subjects, Mycopathologia 177 (2014) 263–269, https://doi.org/10.1007/s11046-014-9748-2.
[111] S. Sarkar, R.P. Singh, G. Bhattacharya, Exploring the role of Azadirachta indica (neem) and its active compounds in the regulation of biological pathways: an update on molecular approach, 3 Biotech 11 (2021) 178.
[112] A.I. Airaodion, P.O. Olatoyinbo, U. Ogbuagu, E.O. Ogbuagu, J.D. Akinmolayan, O.A. Adekale, O.O. Awosanya, A.P. Agunbiade, A.P. Oloruntoba, O.O. Obajimi, Comparative assessment of phytochemical content and antioxidant potential of Azadirachta indica and Parquetina nigrescens leaves, Asian Plant Res. J 2 (2019) 1–14.
[113] A.R. Baby, T.B. Freire, G.d.A. Marques, P. Rijo, F.V. Lima, J.C.M.d. Carvalho, J. Rojas, W.V. Magalhães, M.V.R. Velasco, A.L. Morocho-Jácome, Azadirachta indica (Neem) as a potential natural active for dermocosmetic and topical products: a narrative review, Cosmetics 9 (2022) 58.
[114] S.J. Boeke, M.G. Boersma, G.M. Alink, J.J. van Loon, A. van Huis, M. Dicke, I.M. Rietjens, Safety evaluation of neem (Azadirachta indica) derived pesticides, J. Ethnopharmacol. 94 (2004) 25–41.
[115] B.P. Pimple, S.L. Badole, F. Menaa, Exploring Neem (Azadirachta indica) for antidermatophytic activity, in: Bioactive Dietary Factors and Plant Extracts in Dermatology, Springer, 2012, pp. 459–469.
[116] H. Bhat, P. Sampath, R. Pai, R. Bollor, M. Baliga, R. Fayad, Indian medicinal plants as immunomodulators: scientific validation of the ethnomedicinal beliefs, Bioactive Food as Dietary Interventions for Arthritis and Related Inflammatory Diseases: Bioactive Food in Chronic Disease States 22 (2012) 215.
[117] National Park of Singapore. Emblica officinalis Gaertn. Available online: https://www.nparks.gov.sg/florafaunaweb/flora/3/6/3699 (accessed on 31 March 2023)..
[118] R. Tewani, D.J.K. Sharma, D.S. Rao, Indian gooseberry (Amla) natural purgative, Int. J. Appl. Res. Technol. 2 (2017) 157–164.
[119] S. Dasaroju, K.M. Gottumukkala, Current trends in the research of Emblica officinalis (Amla): a pharmacological perspective, Int. J. Pharmaceut. Sci. Rev. Res. 24 (2014) 150–159.
[120] Habib-ur-Rehman, K.A. Yasin, M.A. Choudhary, N. Khaliq, Atta-ur-Rahman, M.I. Choudhary, S. Malik, Studies on the chemical constituents of Phyllanthus emblica, Nat. Prod. Res. 21 (2007) 775–781.
[121] D.A. Patil, V.R. Rasve, S.S. Ahemad, M.K. Shirsat, M.B. Manke, Phytochemical analysis of methano extract of Emblica offinalis leaves, World J. Pharm. Pharmaceut. Sci. 7 (2018) 971–978.
[122] B. Ahmad, N. Hafeez, A. Rauf, S. Bashir, H. Linfang, M.-u. Rehman, M.S. Mubarak, M.S. Uddin, S. Bawazeer, M.A. Shariati, Phyllanthus emblica: a comprehensive review of its therapeutic benefits, South Afr. J. Bot. 138 (2021) 278–310.
[123] P. Anitha, R.V. Priyadarsini, K. Kavitha, P. Thiyagarajan, S. Nagini, Ellagic acid coordinately attenuates Wnt/β-catenin and NF-κB signaling pathways to induce intrinsic apoptosis in an animal model of oral oncogenesis, Eur. J. Nutr. 52 (2013) 75–84, https://doi.org/10.1007/s00394-011-0288-y.
[124] C. Shishoo, S. Shah, I. Rathod, S. Patel, Quality assurance of chyavanprash through determination of free radical scavenging activity, Indian J. Pharmaceut. Sci. 60 (1998) 179.
[125] A. Bhattacharya, S. Ghosal, S.K. Bhattacharya, Antioxidant activity of tannoid principles of Emblica officinalis (amla) in chronic stress induced changes in rat brain, Indian J. Exp. Biol. (2000) 676–680.
[126] M.G. Davis, M.P. Piliang, W.F. Bergfeld, T.L. Caterino, B.K. Fisher, J.P. Sacha, G.J. Carr, L.T. Moulton, D.J. Whittenbarger, J.R. Schwartz, Scalp application of antioxidants improves scalp condition and reduces hair shedding in a 24-week randomized, double-blind, placebo-controlled clinical trial, Int. J. Cosmet. Sci. 43 (2021) S14–S25.
[127] K. Srivasuki, Nutritional and health care benefits of Amla, J. Pharmacogn. 3 (2012) 147–151.
[128] S. Phadatare, T. Nesari, D. Pokharkar, R. Pingle, Preparation, evaluation and hair dyeing activity of herbal hair oil and comparison with marketed dye, World J. Pharmaceut. Res. 4 (2015) 1469–1478.
[129] S. Rani, Management of greying of hairs (sheeb) and use of hair dyes (khizaab) in Unani medicine, Cell Med. 8 (2018), 7.1-7.12.
[130] N. Nikmanesh, Mohammadi-Motamed, S. Amla, Oil, a pharmaceutical product based on traditional knowledge for hair loss treatment, Res. J. Pharmacogn. 6 (2019) 57–61.
[131] M. Rasika, S. Parameshwari, P. Sivagurunathan, C. Uma, M. Bhuvaneswari, Antifungal activity of Amla extracts against dandruff causing pathogens (Malassezia sp.), Int. J. Adv. Res. Biol. Sci. 3 (2016) 209–214.
[132] Arizona Wildscape. Soapberry. Available online: https://creativecommons.org/licenses/by/4.0/(accessed on 31 March 2023).
[133] R. Singh, N. Kumari, G. Nath, Antimicrobial efficacy of callus and in vitro leaf extracts of Sapindus Mukorossi Gaertn. Against pathogenic microbes, Mathews J. Pharm. Sci. 2 (2016) 1–4.
[134] Q. Hu, Y.-Y. Chen, Q.-Y. Jiao, A. Khan, F. Li, D.-F. Han, G.-D. Cao, H.-X. Lou, Triterpenoid saponins from the pulp of Sapindus mukorossi and their antifungal activities, Phytochemistry 147 (2018) 1–8.
[135] A. Pavithra, N. Muralidharan, Antifungal comparison of Sapindus mukorossi and commercially available anti dandruff shampoo to against Candida albicans, Plant Cell Biotechnol. Mol. Biol. 21 (2020) 21–27.
[136] C. Sungpud, W. Panpipat, A.S. Yoon, M. Chaijan, Tuning of virgin coconut oil and propylene glycol ratios for maximizing the polyphenol recovery and in vitro bioactivities of mangosteen (Garcinia mangostana L.) pericarp, Process Biochem. 87 (2019) 179–186.
[137] W. Wang, Y. Liao, X. Huang, C. Tang, P. Cai, A novel xanthone dimer derivative with antibacterial activity isolated from the bark of Garcinia mangostana, Nat. Prod. Res. 32 (2018) 1769–1774.
[138] S. Narasimhan, S. Maheshwaran, I.A. Abu-Yousef, A.F. Majdalawieh, J. Rethavathi, P.E. Das, P. Poltronieri, Anti-bacterial and anti-fungal activity of xanthones obtained via semi-synthetic modification of α-mangostin from Garcinia mangostana, Molecules 22 (2017) 275.
[139] Y.S. Ong, V. Murugaiyah, B.H. Goh, K.Y. Khaw, Bioactive xanthones from Garcinia mangostana, in: Plant-Derived Bioactives, Springer, 2020, pp. 281–300.
[140] Y.-L. Chew, S.-H. Sang, G.A. Akowuah, K.B. Liew, Garcinia mangostana pericarp extracts and α-mangostin in hair care : an insight into their potential as functional ingredients and the biological properties, Nat. Prod. J. 13 (2023) 27–36.

[141] Y.-L. Chew, Y.-Y. Lim, Evaluation and comparison of antioxidant activity of leaves, pericarps and pulps of three Garcinia species in Malaysia, Free Radic. Antioxidants 8 (2018) 130–134.
[142] W. Widowati, L. Darsono, J. Suherman, N. Fauziah, M. Maesaroh, P.P. Erawijantari, Anti-inflammatory effect of mangosteen (Garcinia mangostana L.) peel extract and its compounds in LPS-induced RAW264. 7 cells, Nat. Prod. Sci. 22 (2016) 147–153.
[143] S. Mohan, S. Syam, S.I. Abdelwahab, N. Thangavel, An anti-inflammatory molecular mechanism of action of α-mangostin, the major xanthone from the pericarp of Garcinia mangostana: an in silico, in vitro and in vivo approach, Food Funct. 9 (2018) 3860–3871.
[144] D.K. Ni'maa, S. Subakir, S. Suhardjono, Comparison of Skin Extracts Mangosteen Fruit (Garcinia Mangostana Linn) with 2% Ketoconazole in Inhibiting the Growth of Pityrpsporum Ovale in Dandruff, 2011.
[145] M.A. Hamid, M.R. Sarmidi, C.S. Park, Mangosteen leaf extract increases melanogenesis in B16F1 melanoma cells by stimulating tyrosinase activity in vitro and by up-regulating tyrosinase gene expression, Int. J. Mol. Med. 29 (2012) 209–217.
[146] C. Niu, H.A. Aisa, Upregulation of melanogenesis and tyrosinase activity: potential agents for vitiligo, Molecules 22 (2017) 1303.
[147] P. Netcharoensirisuk, C. Abrahamian, R. Tang, C.-C. Chen, A.S. Rosato, W. Beyers, Y.-K. Chao, A. Filippini, S. Di Pietro, K. Bartel, Flavonoids increase melanin production and reduce proliferation, migration and invasion of melanoma cells by blocking endolysosomal/melanosomal TPC2, Sci. Rep. 11 (2021) 1–14.
[148] Y.-C. Huang, K.-C. Liu, Y.-L. Chiou, Melanogenesis of murine melanoma cells induced by hesperetin, a Citrus hydrolysate-derived flavonoid, Food Chem. Toxicol. 50 (2012) 653–659.
[149] N.N. Bouzaiene, F. Chaabane, A. Sassi, L. Chekir-Ghedira, K. Ghedira, Effect of apigenin-7-glucoside, genkwanin and naringenin on tyrosinase activity and melanin synthesis in B16F10 melanoma cells, Life Sci. 144 (2016) 80–85.
[150] H. Rambwawasvika, P. Dzomba, L. Gwatidzo, Hair growth promoting effect of Dicerocaryum senecioides phytochemicals, Int. J. Med. Chem. (2019) 1–10.
[151] Y.-L. Chew, M.-A. Khor, Y.-Y. Lim, Choices of chromatographic methods as stability indicating assays for pharmaceutical products: a review, Heliyon 7 (2021).
[152] E. Guzmán, F. Ortega, R.G. Rubio, Chitosan: a promising multifunctional cosmetic ingredient for skin and hair care, Cosmetics 9 (2022) 99.