Research article

Polyphenols and saponins – properties and application in cosmetics

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Abstract: *The cosmetics market is an extremely dynamic, developing branch of the industry. There is a constant need for multifunctional ingredients that will meet the growing expectations of consumers. Active ingredients of natural origin are also appreciated more and more often. One of the most commonly used plant extracts are those rich in polyphenols. These ingredients are known for their antioxidant properties, but they can have many more functions in relation to human skin. They act against wrinkles, brighten skin, support protection against harmful UV rays, etc. Other interesting active plant ingredients are saponins – compounds with an amphiphilic structure – that can be natural alternative to surfactants or emulsifiers. They possess antimicrobial activity and strengthen blood vessels. This article briefly characterizes polyphenols and saponins, taking into account their structure and classification, as well as indicates and describes their properties that can be used in the cosmetics industry.*

Key words: *polyphenols; saponins; cosmetic technology; cosmetics; active ingredients*

Introduction

The cosmetics global market is one of the fastest-growing. The interest in cosmetics is constantly increasing, not only among consumers but also among producers who improve their products to meet the expectations of customers. This fact is illustrated by the total expenditure of the global cosmetics industry, that in 2020 amounted to USD 483 billion and is estimated to reach USD 716 billion annually by 2025 [1].

The growing awareness of consumers also entails their greater demands. Nowadays, great emphasis is placed on the multifunctionality of cosmetics and their natural, ecological origin [2,3]. Plant extracts are considered to be one of the most valuable ingredients in cosmetics. Extracts rich in active ingredients that slow down the signs of aging and act on the skin in a multidirectional way, strengthening and protecting it, are exceptionally eagerly used products [4].

For this reason, this article focuses on two groups of plant compounds with high cosmetic potential. The first are polyphenols, that have been very popular for years as compounds with antioxidant properties, the second are saponins, less popular, but extremely valuable due to e.g. surface activity. The article aims to briefly describe both these groups of compounds and to describe their numerous properties, which make them an attractive raw material for the cosmetics industry.

Polyphenols

Phenolic compounds are characterised by one or more hydroxyl groups attached directly to an aromatic ring. Phenols are weak acids – however, they are stronger acids than aliphatic alcohols due to the fact that phenoxy ions are stabilized by resonance of the aromatic ring, while in alkoxy ions the entire charge is located on the oxygen atom. Polyphenols include compounds that have more than one hydroxyl group attached to one or more benzene rings [5].

Phenolic compounds, including polyphenols, are secondary plant metabolites and can be found in almost all plant tissues, including fruit, nuts, seeds, tubers and plant flowers [6]. Their most important functions include participation in attracting pollinating insects and protecting plants against ultraviolet radiation, microorganisms, and herbivores, some of them also fulfill structural functions like lignin which is a phenolic polymer supports tissues of most plants [5,7,8]. Natural polyphenols generally exist in the form of links to one or more sugar moieties linked to a hydroxyl group (glycosides), although a direct linkage of the sugar unit to the aromatic carbon can also occur [5,9].

In plant-based foods, polyphenolic compounds are partly responsible for some sensory and nutritional characteristics. They can impart yellow, orange, red and blue colors [10], but also contribute to the aroma if they are volatile. In terms of taste, the presence of phenolic compounds is usually associated with astringency and bitterness, mainly caused by polymers of flavonols (proanthocyanins or condensed tannins) [10,11].

Clinical studies on animals and humans show that polyphenols have antioxidant and anti-inflammatory properties that may prevent or have therapeutic effect on cardiovascular disease, neurodegenerative disorders, cancer and obesity [7,12].

Structure and classes of phenolic compounds

Polyphenolic compounds can be classified according to their chemical structure, biological function or source of origin, but even taking up the specific classification criteria, scientists do not agree on the universal division of these compounds. According to the literature, the most commonly adopted classification takes into account the division into simple phenols, phenolic acids, flavonoids and non-flavonoid compounds, which is shown in Figure 1.

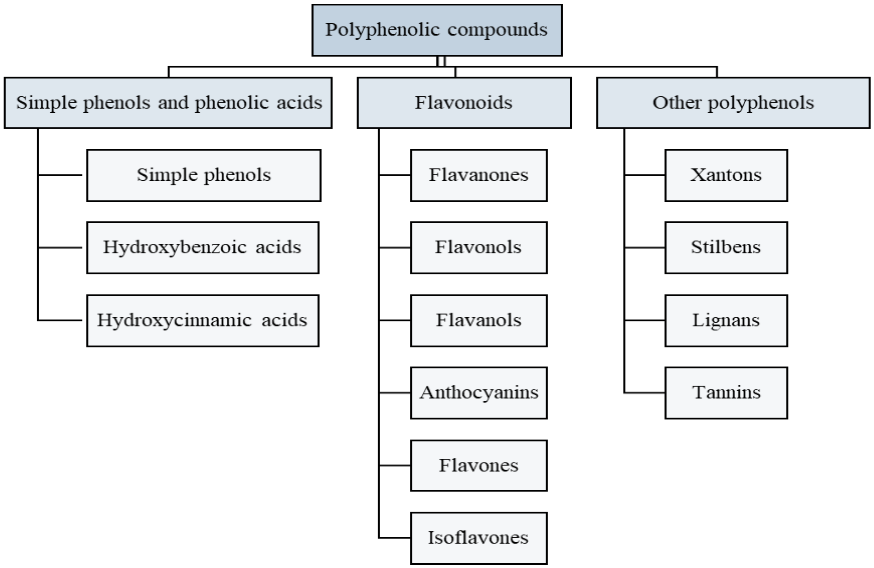

Figure 1. Classification of phenolic compounds

Simple phenols and phenolic acids

Simple phenols consist of a benzene ring with substituents attached usually in 1,2- (*ortho*-), 1,3- (*meta*-) or 1,4- (*para*-) positions, at least one of them is a hydroxyl group. An example of such compounds is phloroglucinol (1,3,5-trihydroxybenzene) [5].

Hydroxybenzoic acids (C_6-C_1 skeleton) are the simplest phenolic acids. They are characterized by the presence of a carboxyl group and at least one hydroxyl group in the benzene ring [5,13]. Examples of such compounds are gallic acid, protocatechuic acid, salicylic acid and vanillic acid [5,14].

Hydroxycinnamic acids (C_6-C_3 skeleton) are very common in plants. The most important representatives of this group include *p*-coumaric acid, caffeic acid, ferulic acid and synapic acid [5,7,14]. In plants, these acids are usually in the form of esters with quinic or shikimic acid, e.g. chlorogenic acid is an ester of caffeic acid and quinic acid [5].

Phenolic compounds with C_6-C_3 carbon backbones, also known as phenylpropanoids, include – besides hydroxycinnamic acids – coumarin derivatives, curcuminoids and chromones [5,14].

Phenylacetic acids (C_6 -C_2 skeleton) also have to be mentioned, but in nature they occurs less often than phenolic compounds with C_6 -C_1 and C_6 -C_3 skeletons [5].

Flavonoids

Compounds with the C_6-C_3-C_6 skeleton are composed of two benzene rings linked together by a group consisting of three carbon atoms [5,7,13]. Depending on the C_3 system three classes of these compounds are distinguished: aurons, chalcones, and flavonoids. Chalcones and dihydrochalcones are characterised by the C_3 system in the form of a chain linking adjacent two benzene rings [5,6]. The presence and importance of both chalcones and aurons is much lower than that of flavonoids.

Flavonoids are made up of 3 rings A, B and C (Figure 2). Ring A is formed by the condensation of three malonyl-CoA molecules. Ring B is derived from *p*-coumaroyl-CoA, it may be mono-, *ortho*-di- or *vic*-trihydroxylated, and it may also contain methoxy groups as substituents. The heterocyclic ring C may be a pyran, pyrylium or pyrone ring [5,15,16]. In nature, flavonoids usually occur in a bound form, most often as glycosides.

Heterocyclic ring C of the **flavone** with an oxygen atom contains both a carbonyl group and a double bond between C_3 and C_2. The best-known flavones are apigenin and luteolin [13,14,17]. Flavones are relatively rare and are most abundant in the peel of the fruit [13].

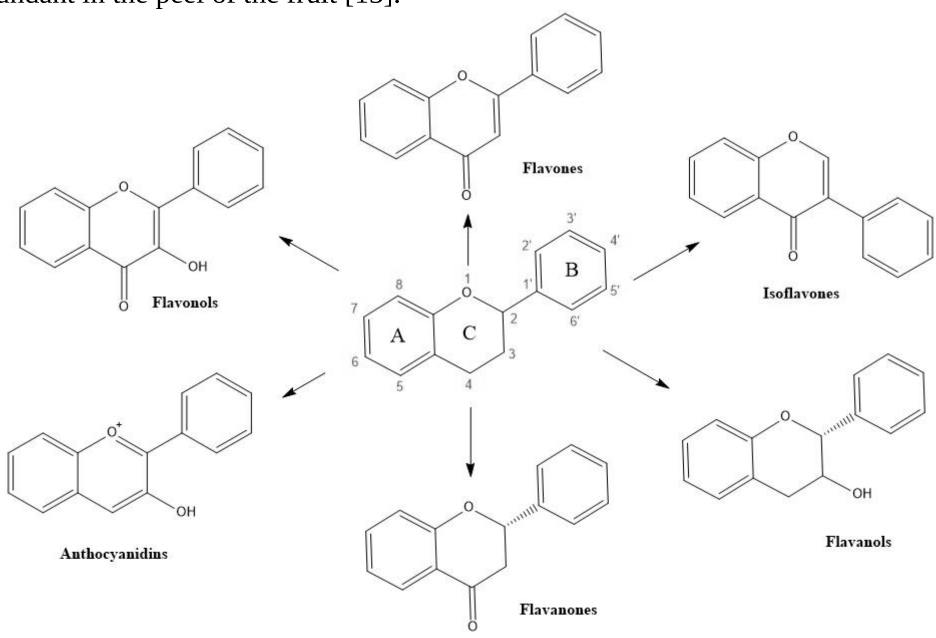

Figure 2. Basic structures of flavonoids

As with the flavones, the heterocyclic ring of the **flavonols** contain a carbonyl group and a double bond, and additionally a hydroxyl group on the C_3 carbon. The most common flavonols are kaempferol, quercetin, and myricetin [6,13,14,17].

In the structures of **flavanones**, there is a carbonyl group in the C-ring, but there is no double bond or an additional OH group [5,6]. Rings A and B can be substituted analogously to flavones. An example of a compound belonging to this group is naringenin [5,14,17].

Compounds belonging to the group of **flavanols** (flavan-3-ols) differ from the others, because in the heterocyclic C ring neither a double bond nor a carbonyl group occurs, while there is an OH group attached to the C_3 carbon. An example of a flavanol is epicatechin, that belongs to the subgroup of monomeric flavanols, as flavanols can form conjugates with gallic acid, giving compounds such as, for example, gallate epicatechins and gallate epigallocatechin [14,16].

Isoflavones, isoflavanones and neoflavones are also characterised by the C_6-C_3-C_6 structure, but in their case the B ring is in the C_3 position of heterocyclic C-ring. Representatives of this group are genistein and daidzein [6,14,16].

The basis of the **anthocyanidins** is a flavylium cation (with a heterocyclic C-ring in the form of a pyrylium cation) with an OH group attached to the C_3 position. These compounds rarely exist as free aglycones, except for a few widespread colored compounds, e.g. cyanidins [5,14,16,18]. Anthocyanidin glycosides are water-soluble anthocyanins.

Other polyphenols

The important non-flavonoid phenolic compounds are xanthones, stilbenes, lignans and tannins.

Xanthones with the C_6-C_1-C_6 skeleton belong to very stable, symmetrical *O*-heterocyclic compounds with the dibenzo-γ-pyrone structure [14].

The structure of **stilbenes** consists of 2 benzene rings connected by a two-carbon double bond (C_6-C_2-C_6 skeleton), the most common being the *trans* isomer [5,14]. The most known representative of this group is resveratrol [5,7].

Lignans are dimers or oligomers that are formed by the coupling of monolignols – *p*-coumaric alcohol, coniferous alcohol and sinapic alcohol. Most lignans are optically active compounds and there is usually only one enantiomer per plant species. Examples of lignans are (+)-pinoresinol and (–)-plicatic acid [5].

Tannins can be divided into three groups: condensed tannins, complex tannins and hydrolyzable tannins, the latter of them is additionally divided into gallotannins and ellagitannins. Condensed tannins, also known as proanthocyanidins, are oligomeric or polymeric flavonoids composed of flavan-3-ol (catechin) units. An example of condensed tannin is procyanidin B2. Gallotannins are hydrolysable tannins with a polyol core substituted with 10-12 gallic acid residues. Ellagitannins also belong to the hydrolysable tannins, however, they contain additional C-C bonds between adjacent galloyl units. Complex tannins are defined as tannins in which the catechin unit is linked glycosidically to the gallotannin or ellagitannin unit [5].

Properties of polyphenols used in the cosmetics industry

Polyphenolic compounds are currently used mainly due to their antioxidant properties, mainly in the food industry. It is estimated that the global market of polyphenolic compounds by 2025 will reach a value of approximately USD 2.08 billion, and the forecast value of the market of antioxidants intended for the cosmetics market is USD 158 million [19,20]. Consumers' awareness of the impact of polyphenols on health, that is growing every year, means that the demand for products from this sector is constantly growing. Every year there is also more and more research focusing on these relationships [21]. In the case of the cosmetics market, polyphenolic compounds have been among the most willingly and most frequently used active ingredients with anti-radical and anti-aging properties for many years [22–24]. This is due to their comprehensive, positive effect on the human body, including the skin, that is the largest organ of the human body (2 m^2), which is exposed to several adverse external factors every day, such as temperature, pollution or UV radiation [25]. Phenolic compounds can counteract the negative effects of these factors, because their most important properties include besides anti-oxidant and anti-inflammatory, are antimicrobial, anticancer, vaso-strengthening, anti-allergic, brightening, antiwrinkle, anti-DNA damage and other [23,24,26,27].

Antioxidant properties of polyphenols

The use of products rich in polyphenols on the skin supports the fight against oxidative stress caused by external factors, such as free radicals, pathogens, and UV radiation, which lead to skin aging and skin damage [28,29]. The addition of polyphenolic compounds inhibits the harmful effects of reactive oxygen species, and thus inhibits, among other, the oxidation of lipids that build epidermal cell membranes and prevents their degradation [30,31]. The action of polyphenols is based on inhibiting the formation of new radicals by neutralisation of active forms and precursors of free radicals. Polyphenols give an electron to a free radical, deactivating it, and they become stable, less reactive radicals, thus stopping the chain radical reaction [16].

It is worth to mention the beneficial effect of polyphenols on other ingredients of the cosmetic product. This is especially important in the case of ingredients that are sensitive to external factors, such as vitamin C or polyunsaturated fatty acids. It should be remembered that the antioxidant activity of plant extracts often correlates with the total content of polyphenols and their profile [32].

Protection against UV radiation

The polyphenols ability to absorb ultraviolet radiation is due to the presence of conjugated double bonds. It has been shown that these compounds can absorb UV radiation in the ranges of 240-285 nm and 300-550 nm, which is related to the presence of an aromatic ring [5,33]. The sun protection factors (SPF) of flavonoids, stilbenes and hydroxycinnamic acid derivatives defined as 7-29 SPF correspond to minimal (SPF from 2 to 12) and moderate (SPF from 12 to 30) sun protection [34,35]. However, it should be remembered that due to the low concentrations of polyphenols in cosmetics, they cannot provide sufficient protection against UV radiation, however they can support this effect. This is particularly important in the context of the prevention of neoplastic diseases, including skin cancers such as melanoma [36,37].

The anti-wrinkle activity of polyphenols

Collagen in the dermis is responsible for its firmness, while elastin fibers give it elasticity. Scientific research has proven that plant extracts rich in phenolic compounds can inhibit the activity of proteinases, that are responsible for the degradation of skin proteins, such as collagen and elastin. Excessive skin exposure to reactive oxygen species also provokes the expression of collagenase and elastase, leading to accelerated degradation of relevant proteins, which can be counteracted by preparations rich in polyphenols [35,37-40].

The influence of polyphenols on microcirculation and blood vessels

Phenolic compounds may affect microcirculation, mainly through a protective effect on the walls of blood vessels, reducing the permeability of capillaries and facilitating the free flow of blood through the capillaries as a result of inhibition of platelet aggregation [41]. This effect is due to many factors, mainly the ability of polyphenols to neutralise free radicals, and the protective properties of polyphenols in relation to vitamin C, which is necessary for the synthesis of collagen that builds vascular walls. The protective effect of polyphenols is also associated with the inhibition of the activity of hyaluronidase, the enzyme responsible for the degradation of hyaluronic acid, which is a building component of the walls of blood vessels and the dermis [33]. Moreover, polyphenols inhibit the oxidation of adrenaline to adrenochrome, what weakens blood vessels by shortening the time of their contraction. This is related to the chelation of iron and copper ions by polyphenols, which are catalysts of this process [42]. Moreover, phenolic compounds such as apigenin, catechin, rutin, quercetin, luteolin, hesperidin, and diosmin also prevent platelet aggregation by inhibiting the synthesis of fibrin, which participates in the formation of a clot (polyphenols chelate Ca^{2+} ions that are necessary for this process) [43].

Brightening properties of polyphenols

As mentioned earlier, polyphenolic compounds are characterised by the ability to chelate metal ions, which affects the activity of tyrosinase. This enzyme is catalyzing the oxidation of tyrosine to L-DOPA (L-3,4-dihydroxyphenylalanine) and then to L-dopaquinone, what is part of the melanogenesis process [33,44]. Additionally, polyphenols may limit the melanocyte proliferation process and decrease melanin production by cells, that results in lightening of discoloration and prevents the formation of new ones [33].

Antimicrobial activity of polyphenols

There is a lot of information on the antimicrobial activity of phenolic compounds and their beneficial effect on the protection of the skin against pathogenic bacteria (e.g. *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*), fungi (e.g. *Aspergillus brasiliensis*, formerly *Aspergillus niger*), yeasts (e.g. *Candida albicans*) and viruses, including those listed in the

Regulation of the Minister of Health (Journal of Laws of 2003, No. 9, item 107) on the microbiological purity of cosmetics [45]. The mechanism of this process is mainly related to the ability to inhibit the activity of proteolytic enzymes by disrupting the synthesis of nucleic acids and increasing the permeability of the cell wall to exogenous substances [46–49]. It is also worth mentioning that antimicrobial properties of polyphenols help maintaining cosmetics purity by protecting the product against contamination. They do not replace preservatives but may support their action [35].

Saponins

Saponins belong to the group of non-volatile secondary metabolites which are widespread mainly in the plant kingdom, mostly among angiosperms. However, saponins can also be found in lower plants such as ferns or algae as well as in some echinoderms, e.g. marine invertebrates, such as starfish and sea cucumbers [50–52]. The name "saponins" derives from the Latin word *sapo*, meaning "soap" and refers to the amphiphilic properties of saponins, which behave similarly to soaps in aqueous solutions [51].

In plants, saponins primarily protect them against pathogens, pests and herbivores due to antiparasitic, insecticidal, protozoicidal, nematocidal, antifungal and antibacterial properties [53-55]. For this reason, saponins are most abundant in the outer layers of cells, especially in the epidermis of the root and phloem, which is the link between the roots and shoots of plants, and in stems [55,56]. However, they are found in other plant tissues, such as flowers, leaves and fruits [50,57].

For many years, saponins have been considered anti-nutritional substances i.e. those that partially or completely limit the use of nutrients in food by the human body, or those that have a detrimental effect on it. However, recent studies indicate that some of the saponins may exhibit anticancer, antioxidant, anti-inflammatory or blood pressure regulating properties, lower blood cholesterol level and reduce the risk of cardiovascular disease, type II diabetes, osteoporosis and other chronic degenerative diseases [53].

Structure and classification of saponins

Saponins belong to the class of high molecular weight compounds (600-1500 Da) in which one part called aglycone has affinity for the hydrophobic phase, while the other part, sugar chain, is hydrophilic, and both parts are linked by a glycosidic bond (Figure 3). Due to this structure, the saponins show amphiphilic character [53,54,58,59].

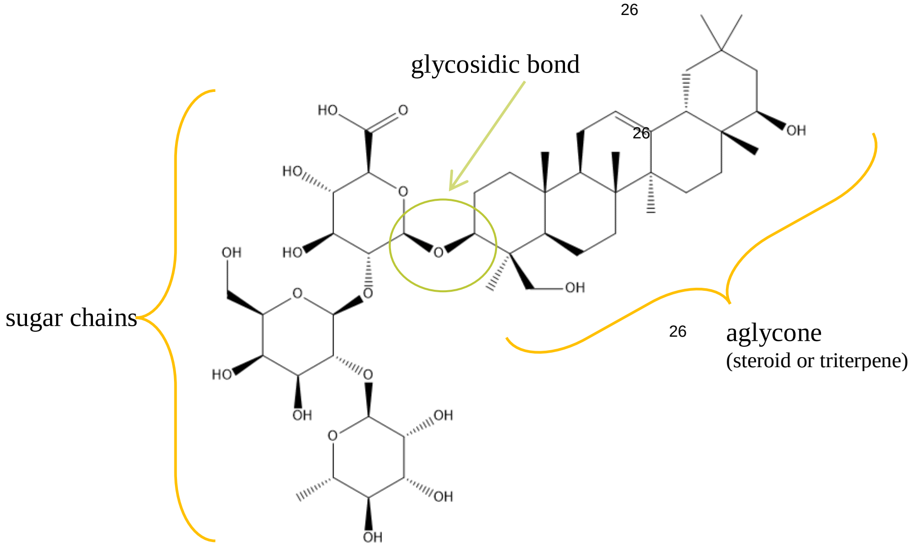

Figure 3. Basic structures of flavonoids

The hydrophobic part, called the aglycone or sapogenin, can be steroidal or triterpenic (Figures 4 and 5) [52,60]. **Steroid saponins** are characterised by a sterane skeleton that contains a side moiety at the C-17 position for a total of 27 carbon atoms. Depending on the structure of the side moiety, these compounds can be divided into two further categories: spirostan derivatives (when a six-membered pyran ring is attached at the C-22 position) and furostan derivatives (when a five-membered aliphatic chain is attached) (Figure 4) [52,54,59,61,62]. Some authors also include glycoalkaloids in steroid saponins, because their C-17 ring is similar in structure to spirostan, except for the oxygen atom, which is replaced with a nitrogen atom (Figure 4) [51,62–64].

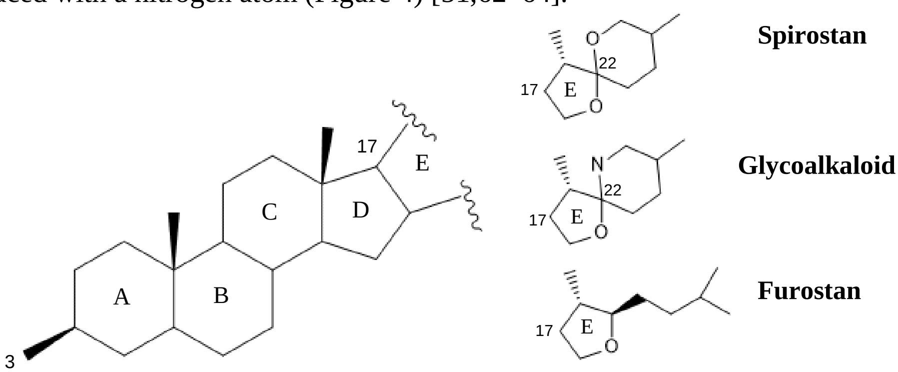

Figure 4. Structure of steroid saponin aglycones

Sapogenin of **triterpene saponins** consist of 30 carbon atoms [59,65], it is characterised by a structure derived from the cyclization of (3S)-2,3-epoxy-2,3-dihydrosqualene, which results in pentacyclic compounds, such as, for example, dammarans, ursans (α-amarin), oleanane (*β*-amarin) and lupanes/hopanes –

majority of triterpene sapogenins belong to these four basic groups (Figure 5) [54,64,66,67], and the most common of them are α- and *β*-amarin [51,65].

It should be noted that ginseng saponins – ginsenosides, are classified inconsistently as triterpene saponins, although they have steroid structure. This is due to a lack of extra furan and pyran heterocyclic rings in their skeleton [53].

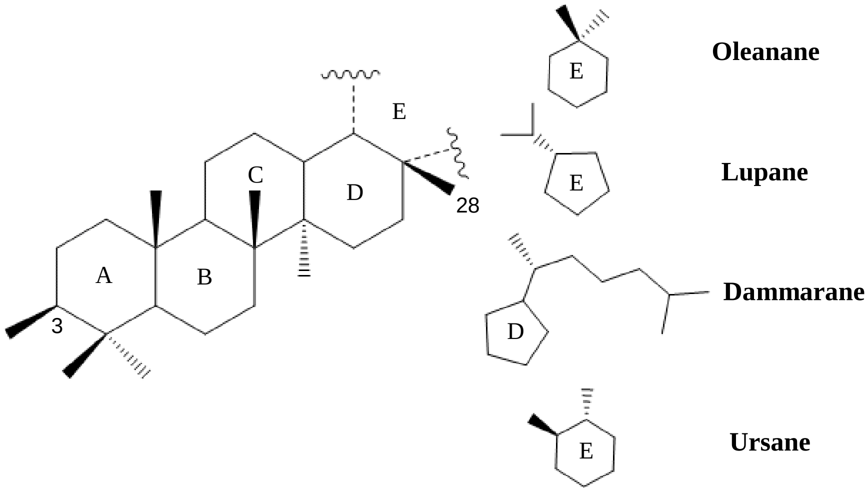

Figure 5. Structure of triterpene saponin aglycones

The hydrophilic part of a saponin moiety consists of one, two or three straight or branched chains of oligosaccharides. Each sugar chain may contain from 1 to 6 simple sugar molecules, with the total glycone usually having up to 12 simple sugar residues [52,59,65]. The most common sugars are D-glucose, D-galactose, L-arabinose, L-rhamnose, D-xylose, L-fucose, less common are D-glucuronic and D-galacturonic acids [54,57,59,61,65]. Due to the number of sugar chains attached to sapogenin, saponins can be divided into mono-, bi- and tridesmosides. Monodesmosides have a sugar chain attached to the sapogenin most often at the C-3 position, in the case of bidesmosides, sugars may additionally be attached at the C-26 position (steroid saponins) or C-28 (triterpene saponins), but it is not a rule, as there are saponins that are monodesmosides with a sugar chain at the C-28 position or otherwise attached sugars [60,62,68]. It should be noted that steroid saponins derived from spirostan occur mainly as monodesmosides, while furostan derivatives are usually bidesmosides [57,59]. Tridesmosides may have a third sugar chain linked by an ether or ester bond to one of the functional groups (OH or COOH) present in the aglycone [57]. Tridesmosides are relatively rare, and one of their examples is convallamaroside, that can be found in the herb of the lily of the valley [59].

Both steroid and triterpene sapogenins can have many differently located functional groups (-OH, -COOH, $-CH_3$), which enhances their differentiation

[57,61,64,65]. The presence of additional carboxyl groups in the aglycone or acids in the sugar part may determine the acidic nature of some saponins [52,59]. The variety of saponins is further enhanced by the number, composition and possible combinations of sugar chains. For this reason, the term "saponins" in relation to active compounds found in plants should be understood as an extremely complex mixture of glycosides [57].

Properties of saponins used in the cosmetics industry

One of the most characteristic properties of saponins is their ability to hemolysis, i.e. the breakdown of red blood cells. Substances that induce hemolysis are known to have the potential risk of causing general irritation or irritation of mucous membranes, as are many surfactants, and for this reason, the use of saponins has been avoided for a long time not only in the food industry but also in cosmetics [69]. However, studies conducted for many years show that these compounds are not harmful to human skin, on the contrary, their use may result in several beneficial effects, without negative consequences for mucous membranes and delicate skin [69]. Saponins are only toxic to humans when injected directly into a vein. When administered orally, they can cause vomiting, but only if ingested in large amounts, as they are poorly absorbed. With oral ingestion of saponins, they break down into sugars and sapogenins, that are excreted in the urine [52,53,66,70,71]. It is also worth noting that monodesmosides have a greater capacity for hemolysis than bi- or tridesmosides [52,66].

The most commonly used in cosmetics are triterpene saponins belonging to oleanane derivatives. In the production of cosmetic preparations, both plant extracts and isolated single saponin compounds are applicable. These compounds are used in cosmetic technology both as active ingredients and as auxiliary substances [72].

Surface activity of saponins

The most frequently used property of saponins in the cosmetics industry is their ability to behave in aqueous solutions like surfactants. It is the effect of the amphiphilic structure of these compounds. Due to such properties, saponins tend to lower the surface tension, and therefore can be an alternative to synthetic surfactants, emulsifiers and solubilisers. [52,73-75]. It should be noted, that saponins differ in their affinity for both phases in which they dissolve [72]. It is related to the diverse structures of saponins, more specifically, to the variable number of sugar residues attached to the aglycone, that are responsible for the affinity for the hydrophilic phase. For this reason, bi- and tridesmosides dissolve in water better than monodesmosides. The presence of bidesmosides in the solution can help to solubilise both other compounds and saponins less soluble in water and help in the transport of active ingredients [53,76]. The presence of additional functional groups, such as a carboxyl group, can also affect the surface activity of saponins, reducing or increasing their water solubility, depending on whether they are attached to an aglycone or a sugar chain [73].

Saponins can be both a standalone washing agent and an auxiliary agent. The use of extracts rich in saponins helps to stabilise the foam of washing preparations, e.g. shampoos [53,60,68,77,78], but also emulsions [79]. Properly selected saponins can act as an emulsifier, provided that the content of the oil phase in the product is relatively low [80,81]. Saponins obtained, for example, from the soap bark tree (*Quillaja saponaria* Molina) are a natural, effective emulsifier stabilizing O/W (oil in water) emulsions, with suspended oil droplets of very small diameter (below 200 nm), which is extremely desirable in cosmetic products because it guarantees the homogeneity and stability of the emulsion. These saponins are stable in a wide range of environmental parameters (pH, temperature), which makes them extremely attractive raw materials [82].

It is worth noting that saponins, when their concentration exceeds the critical concentration of micellisation (CMC), can form micelles in aqueous solutions, the size and structure of which depend on the type of compounds present in the mixture [50] – saponins obtained from soapwort (*Saponaria officinalis* L.) can create a micelle from just two molecules, while the compounds from the soap bark tree need 50 molecules [73]. The formation of micelles from saponins is also significantly influenced by factors such as temperature, pH and addition to the salt solution [50].

Antimicrobial activity of saponins

The second of the most important properties of saponins used in the cosmetics industry is their activity against microorganisms, including those that are pathogenic to the human body [71,76]. The antibacterial properties of saponins are described as quite weak, while a significant antifungal activity has been observed, although it is strongly dependent on the type of saponin [73,76]. The basic mechanism of action of saponins on fungi involves the rearrangement of membrane lipids, pore formation and loss of membrane integrity, and hence cell lysis, which is associated with the hemolytic activity of saponins [83,84]. Additionally, antiviral activity has been proven for some saponins, including inhibiting the replication of HIV and the antiprotozoal effect [52,71,85].

Thanks to their antimicrobial properties, saponins can support action of preservatives in protecting cosmetic products against microbial contamination. On the other hand, they can also inhibit the growth of pathogens present on human skin. Saponins, despite their relatively weak antibacterial activity, can fight *Cutibacterium acnes* that reside on human skin that is responsible for acne lesions [86–88]. For this reason, saponins can be successfully used, especially in the treatment of rosacea, because they gently slow the action of bacteria, while not irritating the sensitive skin affected by pathological changes.

Other properties of saponins

Some saponins have the ability to seal capillaries and tighten and strengthen the surrounding connective tissue. The best known is escin obtained from horse chestnut (*Aesculus hippocastanum* L.), that has been used for this purpose for many years not only in the cosmetics industry but also in medicine [69]. Moreover, saponins may exhibit antiallergic and anti-inflammatory properties as well as aid in the treatment of minor wounds [52,83,85,87,89]. Saponins can act against free radicals, soothe the irritating effect of basic surfactants used in cleansing products, brighten and promote skin hydration [52,86–88,90], and increase the permeability of cell membranes [91]. All the listed properties of saponins make these compounds extremely attractive for the cosmetics industry, although they are still little used [92]. Scientific research also confirms the anti-cancer effect of saponins, which is particularly devoted to this day [52,85,93].

Summary

Plant extracts can be a source of many extremely valuable ingredients for the cosmetics industry, including compounds as valuable as polyphenols and saponins. The former are known primarily for their antioxidant properties, the latter due to their surface activity. However, it is worth remembering that these are only a few of the numerous properties of these compounds. Due to their multidirectional, comprehensive action, polyphenols and saponins have a beneficial effect on the human body, including its largest organ, i.e. the skin. It is also worth emphasising how diverse these groups of compounds are and how, in fact, we still know little about them, as is shown every year by research on newly discovered compounds or their new properties and effects on the human body. This creates many opportunities for the cosmetics industry, thanks to which it can constantly develop and meet the growing expectations of consumers.

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