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REVIEW ARTICLE

Surfactin as an ingredient in cosmetic industry: Benefits and trends

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Abstract

Surfactin is a natural surfactant almost exclusively produced by *Bacillus* species with excellent physical-chemical, and biological properties. Among innovative applications, surfactin has been recently used as an ingredient in formulations. The antibacterial and anti-acne activities, as well as the anti-wrinkle, moisturizing, and cleansing features, are some of the reasons this lipopeptide is used in cosmetics. Considering the importance of biosurfactants in the world economy and sustainability, their potential properties for cosmetic and dermatological products, and the importance of patents for technological advancement in a circular bioeconomy system, the present study aims to review all patents involving surfactin as an ingredient in cosmetic formulas. This review was conducted through Espacenet, wherein patents containing the terms "cosmetic" and "surfactin" in their titles, abstracts, or claims were examined. Those patents that detailed a specific surfactin dosage within their formulations were selected for analysis. All patents, irrespective of their publication date, from October 1989 to December 2022, were considered. Additionally, a comprehensive search was performed in the MEDLINE and EMBASE databases, spanning from their inception until the year 2023. This complementary search aimed to enrich the understanding derived from patents, with a specific emphasis on surfactin, encompassing its associated advantages, efficacy, mechanisms of action on the skin, as well as aspects related to sustainability and its merits in cosmetic formulations. From the 105 patents analysed, 75% belong to Japan (54), China (14), and Korea (9). Most of them were submitted by Asian companies such as Showa Denko (15), Kaneka (11) and Kao Corporation (5). The formulations described are mainly emulsions, skincare, cleansing, and haircare, and the surfactin dose does not exceed 5%. Surfactin appears in different types of formulas worldwide and has a high tendency to be used. Surfactin and other biosurfactants are a promising alternative to chemical ingredients in cosmetic formulations, guaranteeing skin health benefits and minimizing the impact on the environment.

KEYWORDS
biosurfactant, emulsions, formulation, hair growth, lipopeptide, skin barrier, stability

Résumé

Objectif: La surfactine est un agent tensioactif naturel presque exclusivement produit par les espèces de Bacillus, qui présente d'excellentes propriétés physico-chimiques et biologiques. Parmi les applications innovantes, la surfactine a été récemment utilisée comme ingrédient dans les formulations. Les activités anti-bactériennes et anti-acnéiques, ainsi que les propriétés antirides, hydratantes et nettoyantes, sont quelques-unes des raisons pour lesquelles ce lipopeptide est utilisé dans les cosmétiques. Compte tenu de l'importance des biosurfactants pour l'économie mondiale et la durabilité, de leurs propriétés potentielles pour les produits cosmétiques et dermatologiques, et de l'importance des brevets pour les progrès technologiques dans un système de bioéconomie circulaire, la présente étude vise à passer en revue tous les brevets impliquant la surfactine en tant qu'ingrédient dans les formules cosmétiques.

Méthodes: Cet examen a été mené en utilisant Espacenet, dans lequel les brevets contenant les termes «cosmétique» et «surfactine» dans leurs titres, résumés ou revendications ont été examinés. Les brevets détaillant un dosage spécifique de surfactine dans leurs formulations ont été sélectionnés pour l'analyse. Tous les brevets, quelle que soit leur date de publication, d'octobre 1989 à décembre 2022, ont été pris en compte. En outre, une recherche complète a été effectuée dans les bases de données MEDLINE et EMBASE, depuis leur création jusqu'à l'année 2023. Cette recherche complémentaire visait à enrichir la compréhension dérivée de brevets, en mettant l'accent sur la surfactine, ses avantages associés, son efficacité, ses mécanismes d'action sur la peau, ainsi que les aspects liés à la durabilité et ses mérites dans les formulations cosmétiques.

Résultats: Sur les 105 brevets analysés, 75% appartiennent au Japon (54), à la Chine (14) et à la Corée (9). La plupart d'entre eux ont été soumis par des sociétés asiatiques telles que Showa Denko (15), Kaneka (11) et Kao Corporation (5). Les formulations décrites sont principalement des émulsions, des soins de la peau, des nettoyants et des soins capillaires, et la dose de surfactine n'excède pas 5%.

Conclusions: La surfactine apparaît dans différents types de formules dans le monde et conserve une forte tendance à l'utilisation. La surfactine et d'autres biosurfactants sont une alternative prometteuse aux ingrédients chimiques dans les formulations cosmétiques, garantissant des bénéfices pour la santé de la peau et minimisant l'impact sur l'environnement.

INTRODUCTION

Surfactants are amphipathic molecules with both hydrophilic and hydrophobic (generally hydrocarbon) fractions that partition preferentially at the interface between fluid phases, with different degrees of polarity and hydrogen bonding, reducing surface and interfacial tension and forming microemulsion [1]. According to their origin, they can be classified into two large groups: (i) synthetic surfactants, produced by chemical synthesis, and (ii) biosurfactants from natural origin, including microbial biosurfactants produced by bacteria, fungi, and yeasts [2].

Due to their wide and diverse applications, there is a growing need to reduce the use of synthetic surfactants, whose adverse environmental effects endure, as they persist as pollutants due to their resistance to (bio)degradation.

Biosurfactants emerged as an equally efficient but environmentally friendly alternative to synthetic surfactants [3]. For a decade, some authors have described and classified the properties applied to the cosmetic sector of various subgroups of biosurfactants [4], such as lipopeptides [5] and glycolipids [6–8]. We reviewed surfactin properties using databases like MEDLINE and EMBASE, spanning from their inception up to 2023. This review encompassed surfactin's advantages, effectiveness, skin-related mechanisms of action, sustainability considerations, and merits in cosmetic formulations, providing complementary insights to the information found in patents.

SURFACTIN STATUS QUO. BENEFITS AND MECHANISM OF ACTION

One of the most studied lipopeptide biosurfactants is surfactin, a cyclic lipopeptide composed of 7 amino acids with a 11–15 carbon hydrophobic tail. The structure of surfactin is depicted in Figure 1. It is a biosurfactant produced mainly by *Bacillus subtilis* through submerged fermentation. It is considered a very versatile biosurfactant, with excellent interfacial properties, as well as functional properties, making it ideal for its integration in formulations of personal care products, detergents, and food, among others [9].

The increasing interest in surfactin is a consequence of the great evidence of its properties: potential use as a therapeutic molecule for health applications, high biodegradability, low toxicity, high stability as an emulsifier, foaming capacity in a wide range of temperatures, and absence of skin irritation. The results from skin irritability and oral toxicity tests firmly confirmed the low toxicity of the molecule when acting as an ingredient in detergent formulas [11–13].

Over recent years, researchers have studied surfactin-based formulations for skin rejuvenation, especially to attenuate wrinkles appearing in the natural ageing process. Evidence has revealed that surfactin exhibits remarkable cosmetic efficacies in smoothening wrinkles. Furthermore, some studies have indicated that surfactin enhances the expression of the longevity gene, sirtuin 1, in mouse embryo fibroblasts. This fact could affect the process of ageing by regulating the gene activity of the cell and repairing DNA breakage. Sirtuins play a key role in epigenetic modifications of histones and controlling the expression of genes involved in the regulation of the oxidative stress response and apoptosis. When the DNA is damaged as a result of UV light or free radical exposure, sirtuins will assist the repair mechanism in the damaged areas [14]. The addition of 50 and 75 μg of surfactin to a culture of embryonic fibroblast cells caused a significant increase in expression of the sirtuin 1 gene, in contrast with resveratrol and palmitoyl pentapeptide-3, ingredients used by the cosmetic industry in anti-wrinkle products. In the same work, collagen concentration was measured. Surfactin at micromolar concentrations showed great effects in increasing collagen proliferation, and among the concentrations used in that experiment, 100 μM presented the best results. Moreover, a previous study reported that UV-A may induce the synthesis of matrix metalloproteinases in human skin fibroblasts, degrading collagen,

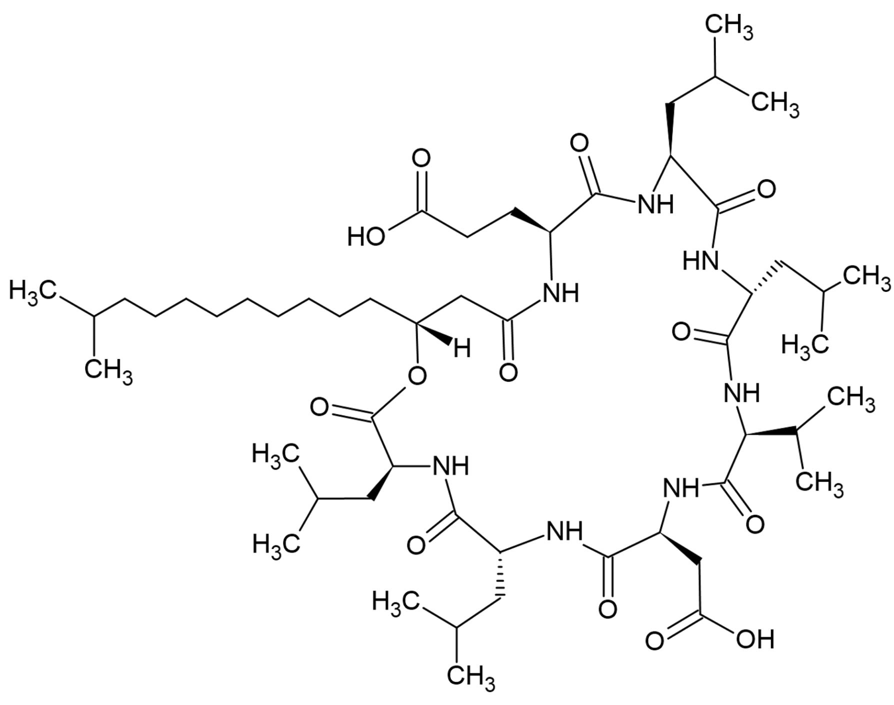

FIGURE 1 Surfactin molecule structure (modified from Ref. [10]).

elastin, and other substances in the intracellular matrix, resulting in ageing. Surfactin can inhibit the activity of matrix metallopeptidase at the concentrations mentioned above [15].

The incidence of light is another important factor related to the appearance of facial wrinkles, commonly known by the term photo-ageing. UV radiation harms skin mainly through the production of reactive oxygen species, which can damage the extracellular matrix components and affect both the structure and function of cells. Acute exposure to UV radiation may cause sunburns, resulting in a large inflammatory response that causes characteristic redness, swelling, and heat. In addition, altered pigmentation, immune suppression, and dermal extracellular matrix damage can occur. Surfactin molecules can absorb UV radiation, acting as a physical barrier when topically applied. The addition of surfactin in fibroblast cultures favoured cell survival after subjecting the culture to ultraviolet radiation [15].

Abdollahi et al. [16] corroborated the antioxidant capacity of the surfactin. It was concluded that it presents antioxidant activity and lipid peroxidation inhibition capacities, showing greater antioxidant capacities than other microbial-derived surfactants and similar efficacy to synthetic antioxidants such as butylhydroxyanisole [16]. In other experiments, surfactin increased cell survival of embryonic fibroblasts after subjecting the culture to hydrogen peroxide [15], increased the inhibition of oxidative deterioration of membrane lipids [17] and 2,2-diphenyl-1-picrylhydrazyl reducing power when its concentration increased [18].

Its healing quality was another studied property. Surfactin in gel was applied to wounds in murine models, demonstrating a remarkable improvement in healing time. A total epidermis re-epithelialization with the correct organization of fibroblasts and collagen fibrils was attained, avoiding hypertrophy of the scar. A decrease in inflammation, increased neovascularization, and better correction of the connective tissue were observed in the gel application area. The best wound recovery result was achieved at 15 mg/mL [17]. Yan et al. in 2020 described a similar healing speed, using the same model but applying gel at 100 μg/mL and reaching even higher values than their positive control, containing epidermal growth factor at the same concentration [19].

Surfactin has also been shown to possess anti-inflammatory features. The amphiphilic structural characteristics of surfactin allow its interaction with cell membranes and macromolecules, such as lipopolysaccharides (LPS) and enzymes. It is capable of inhibiting the expression of LPS induced by interleukin 1β and the nitric oxide synthase enzyme. It reduces the levels of plasmatic endotoxin, tumoral necrosis factor, and nitric oxide in rats that have suffered septic shock, and suppresses the interaction of lipid A with LPS-binding protein [20]. Referring to the immunologic system cell, 60 μg/mL of surfactin caused a change in the structure of macrophages, making them larger than their usual size. The anti-inflammatory effect of surfactin lies in its ability to negatively regulate inflammatory cytokines by inhibiting the NF-κβ cell signalling pathway, the MAP kinase pathway, and phosphatidylinositol-3-kinase [21].

Surfactin's antibacterial mechanism encompasses disrupting the cell membrane of pathogenic bacteria, leading to membrane disintegration or osmotic pressure imbalance, hindering protein synthesis, which prevents cell replication, and suppressing enzyme activity, thereby disrupting normal cell metabolism [22]. LPS adhesion and lipid membrane disturbance mechanisms make surfactin an ideal molecule for the treatment of acne-producing bacteria. The oily formula with integrated surfactin effectively ameliorated the *Propionibacterium acnes*-induced epidermis swelling and erythema, reduced the epidermis thickness to 48.5% compared to the model control group, and decreased *P. acnes* in the epidermis to 1 log CFU/mL. Furthermore, surfactin-oleogel attenuated oxidative stress in the epidermis by increasing the activities of superoxide dismutase, catalase, and glutathione peroxidase. Moreover, the expression of inducible nitric oxide synthase, nitric oxide, cyclooxygenase-2, pro-inflammatory cytokines (e.g., tumoral necrosis factor-α and interleukin-1β), and nuclear factor kappa-B in the epidermis was reduced [23, 24].

Surfactin demonstrates versatile antifungal properties through the inhibition of glucan synthesis and callose formation in fungal cell walls such as *Candida albicans* [25]. Surfactin exhibits dual antifungal effects, including pore formation at high concentrations and apoptosis induction at lower concentrations. Surfactin interacts with mitochondrial ATPase, resulting in a reduction of its activity. It perturbs cell membranes by inserting its peptide into lipid bilayers, leading to pore formation and vesicle/membrane fusion. The presence of calcium ions can neutralize surfactin's charge, influencing its penetration. These multifaceted mechanisms collectively render surfactin an efficacious antimicrobial agent against fungal cells [26].

Opening pores in lipid membranes can be used to increase the permeability of skin cells too. Recent publications describe the use of surfactin in nanoparticle synthesis with the aim of encapsulating in its interior lipidic molecules capable of solving various types of pathology or diseases, getting the bioavailability of the active compounds increased by enhancing their permeability to deeper layers of the skin [27]. For instance, the transdermal permeability of surfactin nanoemulsion was carried out by measuring a fluorescent component, and notable permeabilization was observed versus the control 1 h after the application of the cream in the ex vivo study [28]. The formulations with surfactin and vitamins reduced discolouration, vascular lesions, and wrinkles' depth on the tested skin [29]. In vitro investigations showed that surfactin could ameliorate the cell internalization of broad-spectrum chemotherapy drugs, and the combined usage of surfactin notably improved the antitumour activity of them while having no obvious effects on normal cells. Surfactin could be applied as a potential synergist for chemotherapy drugs to reduce their treatment dose while maintaining the therapeutic effect on the treatment of skin carcinoma, providing an alternative way to minimize side effects [30]. Surfactin significantly increases infiltration of mast cells and levels of histamine, enhances levels of IgE and immune-enhancing mediators, such as interferon-γ, interleukin (IL)-2, IL-6, IL-12, and tumoral necrosis factor-α in serum and melanoma tissues, and has a significant anti-cancer effect on melanoma skin cancer through indirectly or directly inducing apoptosis of B16F10 melanoma cells [31]. Furthermore, other anticancer mechanisms have been elucidated in various studies. Surfactin, derived from *Bacillus subtilis* natto TK-1, has been shown to induce cell cycle arrest in human breast cancer MCF-7 cells, particularly during the G2/M phase. Additionally, it triggers apoptosis by increasing calcium (Ca^2+) levels. Another study has reported that surfactin generates reactive oxygen species and induces the phosphorylation of ERK 1/2 and JNK, ultimately promoting cell death through the mitochondrial/caspase apoptotic pathway [32, 33].

In this work, we review patents on cosmetic formulas that include surfactin as ingredient, which is labelled "Sodium Surfactin" according to the INCI (International Nomenclature of Cosmetic Ingredients). It is mainly used as an emulsifying agent, favouring the mixing of various substances with low miscibility. Cosmetic products use numerous ingredients of different chemical nature. The addition of surfactin ensures homogeneity in the final formula and the correct mixing of the ingredients by altering the surface tension [34]. As a surfactant, surfactin action includes cleaning surfaces, gelling (giving a gel consistency to a liquid preparation), and reducing the surface tension of cosmetics, contributing to the uniform distribution of the product when applied to the skin. Its physicochemical properties provide it with the ability to act as a penetrating agent for the skin, foaming, cleansing [15], acting as an antimicrobial agent [35], even increasing the protective effect of mineral ingredients derived from mica (like magnesium or iron) against ultraviolet rays, achieving more than 2000% sunscreen protection factor compared to formulas without this biosurfactant. Attributable to the development of a Pickering emulsion with mica, a synergistic effect augments the protective attributes of mica by establishing a fortified barrier [36].

SUSTAINABILITY APPROACH

Biodegradable constituents in cosmetics are of paramount significance as they cater to the consumer's increasing demand for natural, safe, and sustainable products while concurrently upholding principles of environmental sustainability [37]. These ingredients balance environmental responsibility with product quality. However, achieving this balance requires careful formulation to maintain texture and efficacy while addressing ingredient shelf life and packaging concerns. Biodegradable cosmetics offer a competitive edge in a sustainability-focused market and reduce aquatic hazard [38].

Surfactin emerges as an environmentally friendly ingredient in cosmetics due to several pivotal attributes. Its inherent biodegradability ensures gradual, environmentally friendly decomposition, substantially reducing ecological impact [39, 40]. Extensive research has been conducted regarding surfactin production, predominantly employing bacterial cultures, notably *Bacillus* species. These studies have prominently explored the utilization of various substrates, with particular emphasis on by-products. Some of the investigated low-cost substrates include crude glycerol from different wastes, cassava wastewater, kitchen waste, black cumin cake, and brewery waste, among others [41–45]. The global rise in waste oil production increases the carbon footprint, but harnessing microbial processes to produce biosurfactants from these waste materials can significantly mitigate greenhouse gas emissions and advance the goal of carbon neutrality [46].

Nevertheless, despite the cost-reduction potential associated with utilizing residues and by-products in ingredient production and the ecological impact, these alternatives have not yet achieved a level of economic competitiveness comparable to that of traditional surfactants. Various factors in the production process, including lower yields, increased downstream processing costs, longer processing times, and the energy requirements for disinfection and maintaining biological cultures, contribute to the elevated cost of biosurfactants [47]. For instance, the most efficient microbial biosurfactants like sophorolipids have an average market price of approximately $30 per litre, significantly higher than the $1 to $4 per kilogram cost of petro-based surfactants such as alkyl ether sulphates, linear alkylbenzene, and alkyl phenol ethoxylates [48].

ANALYSYS OF THE PATENTS WHICH INCLUDE SURFACTIN IN COSMETIC FORMULATIONS

The evolution of the number of patents that include biosurfactants since 2000 was examined. Figure 2 highlights the

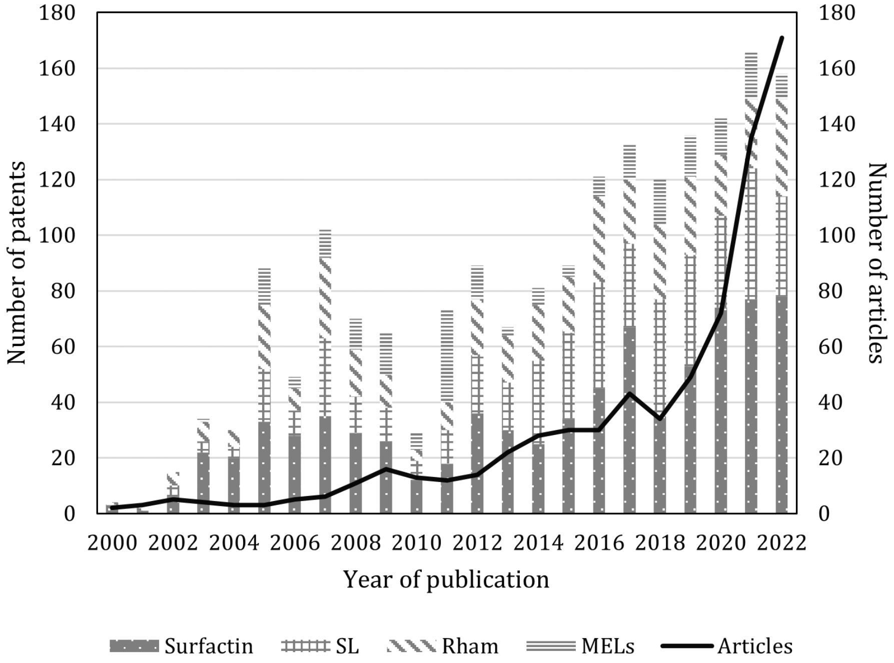

FIGURE 2 Total of patents retrieved in Espacenet database since 2000 using "cosmetic" and the corresponding biosurfactant quoted. The terms "surfactin" and "cosmetic" were used for showing the tendency of scientific articles publication in Scopus database too.

importance of surfactin as the most studied biosurfactant, followed by three glycolipid molecules: sophorolipids (SL), rhamnolipids (Rham), and lipids of mannosylerythritol (MELs). As it can be seen, the number of patents has gradually increased and preserved a continuous upward trend until nowadays. The analogue trend is also observed in the field of research through the publication of scientific articles.

The growing interest in the topic may be consequential to the discovery of the properties biosurfactants provide to the skin over the last few years, thus increasing the interest in its integration into a large number of products. Another factor is their physical-chemical properties, which make them ideal molecules for increasing the miscibility of the numerous ingredients used in cosmetics. Furthermore, the need to look for environmentally friendly ingredients has promoted the use of biosurfactants as an alternative substitute to other synthetic surfactants. Not only because of its biodegradability but also because of the possibility of being synthesized by fermentation using agro-industrial waste as nutrients sources, as for instance surfactin using *B. subtilis* [49] or sophorolipids using the yeast *S. bombicola* [50], as previously mentioned.

In 1986, the first cosmetic formula including sophorolipids as surfactant was patented in the cosmetic sector [51], but it was not until a decade later that more patents started to appear. Skincare, emulsions, exfoliants, and antimicrobial formulas have been published by companies such as IFP Energies Nouvelles, Henkel, Saraya, and L'Oréal [51–77]. By 2002, formulas including rhamnolipids and lipids of mannosylerythritol emerged, most of them describing formulations as emulsions for cosmetic preparations. Evonik is the leading owner of patents that include rhamnolipid patents [67, 78–103]. Over the last decade, patents for these three types of biosurfactants have increased, similar to surfactin, but to a lesser extent. We can no longer assume that biosurfactants are going to supersede conventional surfactants, but there is an upward trend in their use in the cosmetics market as sustainable ingredients.

MAPPING SURFACTIN COSMETIC PATENTS

In this work, the patent search was carried out using the Espacenet and other free access complementary databases such as the United States Patent and Trademark Office, the United Kingdom Intellectual Property Office, and the World Intellectual Property Organization. The key words used as descriptors in this research were "surfactin" and "cosmetic". All available patents were considered for this review since there is no other similar review of surfactin to date, covering a period from October 1989 to December 2022. As exclusion criteria, abstracts that did not include any of the descriptors were excluded from the search, as were patents that did not specifically describe a cosmetic formula and surfactin percentage. Finally, few patents were excluded due to the impossibility of translation; duplicates were also removed. The results were then stored and visualized in graphs using programming language software.

As a result of the screening, out of the hundreds of patents in the databases cited above, 104 met all the inclusion criteria for this systematic review. The resulting file allowed us to determine changes in trends regarding the type of cosmetic formula, origin of each publication, number of publications per year, main involved companies, ingredients used in the formulas, and percentage of surfactin present according to the weight percentage.

The majority of the patents belong to Asian countries. Japan stands out with 54 patents, followed by China (14), the World Intellectual Property Organization – WIPO (11), Korea (9), the United States (9), the European Patent Office – EP (7), and the Patent Office of the Republic of Poland (1). From a continental point of view, Asia leads the number of publications (84%), followed by America (11%), and Europe (5%).

Referring to the patents registered since 2011 (Figure 3), the Asian sector continues to prevail over the rest, with 75% of total representation. Japan continues to hold the lead with almost half of the patents in the present market.

Among the main applicants, eight cosmetic companies are relevant (Table 1): Showa Denko, Kaneka, Kao Corporation, Pola Chemical Industries, Kanebo, Nof, Henkel, and Evonik. The rest of them were submitted by universities or research centres. The two companies with the most published patents are Showa Denko and Kaneka. Showa Denko has the largest number of published patents, practically all of them being skincare and oil-based formulas, mostly using squalene oil. However, all of them were registered before 2006. In contrast, Kaneka remains active in the current market, describing various types of cosmetic formulas, mainly emulsifying preparations. It should be noted that Kaneka remains nowadays as one of the main suppliers of surfactin for the cosmetics industry. The rest of the companies do not follow a tendency to develop formulas with surfactin as Kaneka, but maintain diversification in the health care sector with a wide variety of products and active ingredients.

The type of cosmetic form is mainly determined by the excipients used. The distribution of the different cosmetic forms in reference to the number of total patents is illustrated in Figure 4.

The results of this search indicate that a third of all patents describe the inclusion of surfactin to produce emulsions. This category refers to oil-based moisturizing creams or stable emulsions that are reported as suitable for the formulation of cosmetic products. For example, this group englobes products such as exothermic creams for massages, skin ageing resistance, antioxidants, anti-wrinkles, skin wounds, transdermal penetration enhancers, repairing composition, and dryness, or even just describing stability formulas [109, 110, 115, 119, 122, 123, 126, 127, 129, 132, 134–137, 140, 147, 149–170]. Among the most repeated ingredients, squalene oil stands out, a light vegetable lipid from olives that is quickly absorbed into the skin without leaving a greasy residue, and glycerine, used for its high hydration and moisturizing

TABLE 1 Patents according to the top owners.

Applicant	Document count	Patents
Showa Denko	15	[104–118]
Kaneka	11	[119–129]
Kao Corporation	5	[130–134]
Pola Chemical Industries	4	[135–138]
Kanebo	3	[139–141]
Nof Corporation	3	[142–144]
Henkel	2	[145, 146]
InventionBio	1	[147]
Evonik	1	[148]

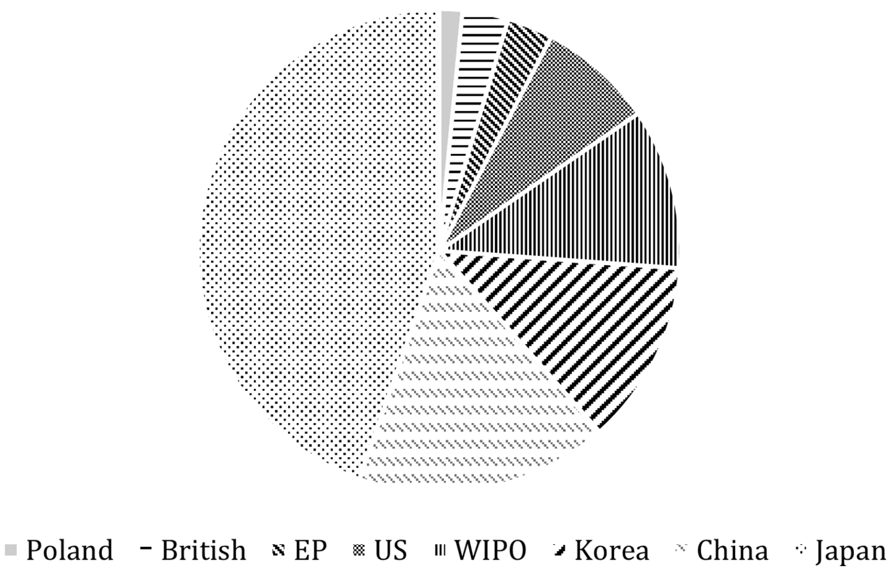

FIGURE 3 Distribution of patents by origin (2011–2022).

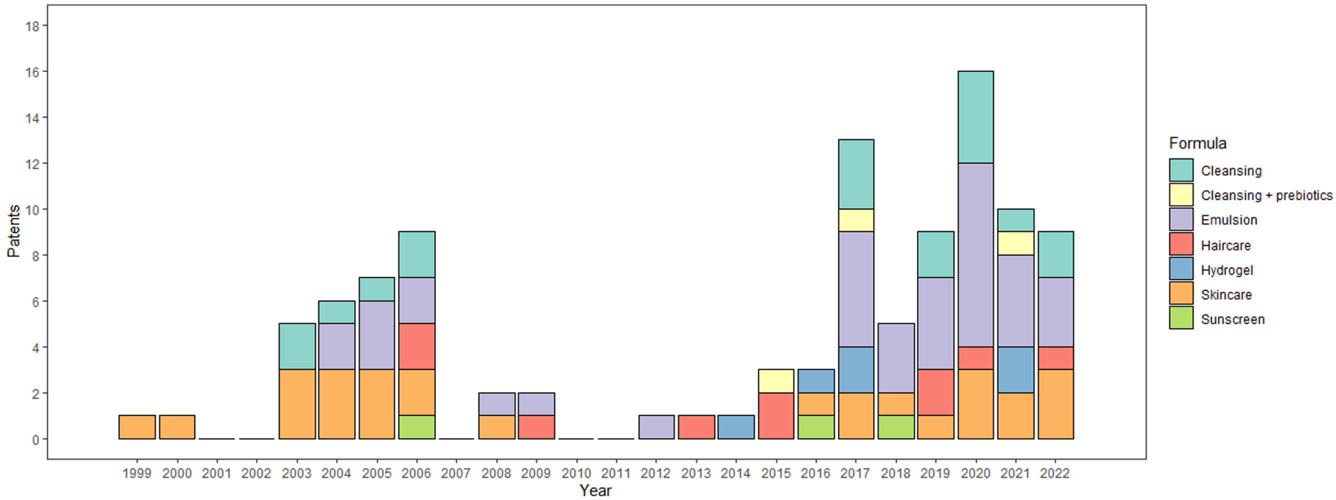

FIGURE 4 Patents according to cosmetic formula over the time.

TABLE 2 Weight percentage of surfactin in cosmetic formulations.

Cosmetic formula	Surfactin dose (%)	Number of patents	References
Emulsion	0.01–5	38	[109, 110, 115, 119, 122, 123, 126, 127, 129, 132, 134–137, 140, 147, 149–170]
Skincare	0.05–3	27	[15, 104–106, 112–114, 116–118, 120, 124, 125, 141–144, 171, 175–182, 194]
Cleansing	0.01–3	18	[111, 138, 139, 146, 195–208]
Haircare	0.1–5	10	[107, 108, 128, 185–191]
Hydrogel	0.3–1	6	[130, 131, 133, 148, 192, 193]
Sunscreen/UV filter	0.5	3	[121, 173, 174]
Cleansing + prebiotics	0.1–2	3	[145, 183, 184]

capacities [110, 112, 119, 123, 135, 171], also hyaluronic acid [130, 141, 172], quinones [118], and ascorbic acid [105, 116].

Second, skincare products are grouped, covering different formats: skin milk, skin cream, and foundation cream. Intended for the improvement of the skin, they provide greater softness, better texture, more elasticity, a good smell, a pleasant sensation, anti-flabbiness, body odour suppression, whitening, etc. [173–182].

Excellent face cleaning and good washability formulas have increased due to the appearance of more resistant and permanent makeup. The tendency of these cleansers to integrate ingredients based on natural extracts and ingredients with prebiotic capacity should be highlighted (lactic acid bacteria culture or fermented tea extracts) [145, 183, 184]. Those formulas grouped as haircare describe products intended to solve scalp issues, such as aesthetic features resulting in smooth combability after being dried, moist and glossy feeling, and flexible setting, as well as improvements in dandruff, itching, seborrheic dermatitis, and hair loss [107, 108, 128, 185–191].

Although these types of products represent the majority of patents published from 1998 to the present date, some fewer common formulations use surfactin: hydrogels (water-based) [130, 131, 133, 148, 192, 193] and sunscreens [121, 173, 174].

The concentration of surfactin varies according to the cosmetic formula. Table 2 shows the values of surfactin weight used in different patents. While some patents within the emulsion and haircare categories contain as much as 5% surfactin, the majority of them feature concentrations below 2%. Similar to the case of skincare, most patents described a concentration range from 0.05% to 2%, though a minority specified slightly higher percentages.

The quantity of surfactin present in the formula rarely surpasses 3% of the product's weight, regardless of the cosmetic formula. The ability of surfactin to produce and maintain foam is predominantly attributable to its robust surface activity. Additionally, these characteristics can be linked to the favourable mechanical and rheological properties exhibited by the film formed when surfactin adheres to surfaces. Notably, the hybrid and intermediary amphipathic structure inherent to surfactin appears to bestow particular advantages upon its foaming properties [209]. Therefore, surfactin is a low-density and high-emulsifying power molecule, as seen in previous sections [13, 29]. For this reason, the concentration of surfactin in the different products remains at low values concerning the total weight percentage. The slight variations in concentration observed within formulations of the same type may be attributed to the desired viscosity or organoleptic properties, as evidenced by certain patents that assess this attribute in relation to surfactin concentration [126, 176].

It has already been demonstrated that surfactin has surface tension properties comparable to chemical commercial surfactants (Glucopone® 215, Glucopone® 650, Findet® 1214N/23, and linear alkylbenzene sulfonates [LAS]), as well as temperature and pH stability [210]. Comparatively, sodium lauryl sulphate, another anionic surfactant extensively used in the cosmetics industry requires, 10%–25% doses for cleansing formulas, considerably more than those used in the reviewed patents [211].

When we compare these weight percentages to those of other biosurfactants, noteworthy similarities emerge. For instance, in the case of rhamnolipid patents, we observe equivalent concentrations to those documented in surfactin patents [67, 78–103]. However, despite the fact that there are fewer patents, including MELs [212–231], a highly varied weight percentage of biosurfactants is described, from <1% to more than 30%. The number of patents containing this compound is not very high and presents low diversification in terms of formulas.

CONCLUSION

The application of surfactin to prepare topical dermatological products significantly improves the physicochemical properties of the compounds and provides unique characteristics related to their anti-wrinkle, moisturizing, cleansing, antioxidant, healing, and photo-ageing potential, among others. The use of surfactin and other biosurfactants in the cosmetic sector continues to increase worldwide, likewise a wide variety of cosmetic products. Surfactin is a low-density, and high emulsifying power molecule whose concentration rarely exceeds 3% in the final formula. This biosurfactant molecule, produced by microorganisms, provides an alternative to the use of traditional surfactants for the application of different cosmetic forms.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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