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Potential application of Saccharina japonica and its extracts in cosmetology

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Abstract. *Saccharina japonica (S. japonica)*, a type of brown algae widely consumed in east Asia due to its enormous health benefits, has now been greeted with great expectation in the field of cosmetics. Although many cosmetological functions of *S. japonica* extracts have been reported, there is still a lack of comprehensive review on the potential application of *S. japonica* and its extract in cosmetology. This article aims to sum up the cosmetological functions of *S. japonica* extracts, including anti-inflammation, skin whitening, anti-oxidation, and anti-bacterial activities. Moreover, the production of bioactive chemicals from *S. japonica* is explored, hoping to provide new insights into cosmetic manufacturing. Study exploration was conducted using online databases (PubMed) using the keywords *Saccharina japonica*, *Laminaria japonica*, kelp, cosmetics, anti-inflammation, skin whitening, anti-oxidation, anti-bacterial, etc., focusing on established pre-clinical trials proving relative bioactivities.

Keywords: S. japonica, cosmetic, anti-inflammation, skin whitening, anti-oxidation

1. Introduction

Recent years witnessed a sharp rise in the research of bioactive compounds derived from algae. Apart from being used as food, cosmetic preservatives and antioxidant agents, several health advantages have also been reported [1]. *Saccharina japonica (S. japonica)*, formerly known as *Laminaria japonica* (*L. japonica*) before 2006, is a familiar brown algae mainly used in food industry given its rich polysaccharides, iodine, vitamins, mannitol, mineral elements and other functional substances [2]. *S. japonica* is more often referred to as “kelp” in English. It is most widely dispersed and economically grown in various temperate coastal regions, with significant yields in east Asian nations including China, South Korea, and Japan. As was reported, about 4.8 million tons dehydrated *L. japonica* can be reaped yearly along the coast of China [3].

Due to rising consumer demand for natural ingredients, substances with marine and maritime origins are being used more frequently in skin care products. *S. japonica*, almost the most important marine commercial crop, is anticipated to play a crucial role in future cosmetology. However, there is still a lack in comprehensive reviews of how *S. japonica* and its functional chemicals can be utilized and commercialized in the cosmetology industry. This review aims to sum up the potential functions of *S. japonica* extracts and chemicals purified from *S. japonica* that can provide insights in developing novel and natural cosmetic products.

2. Anti-inflammation activity

First, we mainly focus on the anti-inflammatory activity of chemicals derive from *Saccharina japonica*.

Found in brown algae and echinoderm, fucoidan belongs to sulfated polysaccharide and contains high ratios of L-fucose and a fraction of other types of sugars like galactose, glucuronic acids, mannose and xylose [4]. Former reasearch has shown that fucoidan exhibits a variety of bioactivities, including antioxidant, anticoagulant, and bacterial homeostasis, with the bioactive effects mostly determined by the its molecular weight(MW) [5].

Ni et al. tested the physicochemical properties of LJSF4, a fucoidan purified from Saccharina j.. They measured its anti-inflammatory activity and study the molecular mechanisms behind, with both in vitro and in vivo models tested for the first time. It is well wroth mentioning that zebrafish model was opted for in vivo tests, which is generally regarded as the most suitable model for effective measurement of anti-inflammatory activity [6]. They found that when conducted on RAW 264.7 cells for the invitro test, LJSF4 exhibited excellent anti-inflammatory activity, where reduced the production of pro-inflammatory cytokines (TNF-, IL-1, and IL-6) and nitric oxide (NO) was noticed in a dose-dependent way. Also, by lowering cell death and the formation of ROS and NO, LJSF4 had protective effects in zebrafish under exposure to LPS. When it comes to practical production in cosmetic industries, future development and application of LJSF4 could be facilitated thanks to its comparatively simple structure. Moreover, *S. japonica* is broadly cultured with abundant production and industial supply. These two factors together make it feasible for massive production of *S. japonica* fucoidan, a highly potential anti-inflammatory chemical expected to be applied in the functional food and cosmetic industries [5].

3. Skin-whitening effect

The skin-whitening effect is also what people want to include in an ideal cosmetic. To deal with darkened skin and dark spots on the skin, Tyrosinase (TYR), which is the core rate limiting enzyme in melanogenesis, is usually targeted for inhibition to reduce melanin production and treat skin hyperpigmentation [7]. Due to the mild reaction conditions and preservation of sulfate radicals, it has already been a established method to degrade fucoidan with the help of fucoidanase derived from Flavobacterium RC2-3, a fucoidan-degrading bacterium [8]. Using such purified fucoidanase, Chen et al. found that in the MW range above 5 kDa, the smaller MW of fucoidan tended to exhibit enhanced whitening activity. When it comes to fucoidan of molecular weight within the range of 5-10 kDa, highest tyrosine inhibitory activity as well as antioxidant activity and prominent anti-melanogenesis ability were verified in B16 cell models [9]. This study fundamentally revealed the relationship between MW and whitening activity of fucoidan, providing an insight for further transforming fucoidan into a new applicational chemical in skin-whitening products.

4. Anti-oxidation activity

Oxidative damage is also what draws people's concerns in cosmetology, because it has a significant part in skin aging process, both intrinsically and even more so extrinsically. Meanwhile, in the skin, reactive oxygen species are responsible for the aging process to a greater extent than they are in any other organ [10].

A balance between oxidants and antioxidants in the body can be maintained by increasing dietary antioxidant intake or consumption of foods rich in antioxidants [11]. Phlorotannins are a group of major polyphenol secondary metabolites found only in brown algae, including *S. japonica* [12]. Phlorotannins have a wide range of bioactivities and health advantages, including antibacterial, anti-inflammatory, antioxidant, antidiabetic, anti-HIV, and anticancer properties. Bai et al. found that the phlorotannins encapsulated by polyvinylpyrrolidone nanoparticles (PPNPS) showed a slow and steady kinetic release of phlorotannin in simulated gastrointestinal fluid. Also, the encapsulated phlorotannins were proved non-cytotoxic in HaCaT keratinocytes and could diminish the production of endogenous reactive oxygen species (ROS). Because of this, PPNPS may provide an effective platform for the application of phlorotannin in the pharmaceutical and cosmetics fields [13].

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5. Anti-bacterial effect

When it comes to anti-bacterial effects, the *L. japonica* essential oil (LJEO), an inexpensive but favorable resource extracted by microwave-hydrodistillation, is reported to manifest strong antibacterial activity. Free radical scavenging and antioxidant activity were also discovered in the oil, making it promising for application in the food, cosmetics, and pharmaceutical industries [14].

Extracts of *S. japonica* and Rosmarinus officinalis also display antimicrobial effects against oral pathogens [15]. When one of the two extracts were applied jointly with other anti-microbial chemicals like chlorhexidine digluconate or Protamine sulfate, enhanced anti-bacterial effect could be attained at certain concentrations of both counterparts compared to their respective activities [16]. Hameury et al. saw the lack in ex vivo tests, so they performed a thorough assessment of the activity on the skin of combined ingredients from marine and maritime origins. Using label-free quantitative proteomic analysis, the clinical benefits was predicted when applied in a skin care product. Compared to untreated control groups, 64 proteins were evidently regulated after treatment. Assisted with computer data processing, they found that in epidermis and dermis tissues, these evidently regulated proteins are involved in gene expression, cell survival and metabolism, inflammatory processes, dermal extracellular matrix synthesis, melanogenesis and keratinocyte proliferation, migration, and differentiation. Their results suggested that the ingredients tested could help maintain epidermis and dermis health, expected to minimize the noticeable signs of skin aging [17].

6. Enhancement of kelp polysaccharide extraction process

After talking about the potential applications of *S. japonica* in cosmetology, how the producers are going to extract and purify these functional ingredients but still preserves their activity may be rather significant and difficult, which are likely to require loads of trials. Currently, hot-water, alkline solution, acidic solution, enzymatic and microwave extraction have been used in kelp polysaccharide extraction. As may be an inspiriation, Statistics-based response surface methodology (RSM) was adopted by Yu & Chao to magnify the productivity of kelp polysaccharide extraction process. They found out that the optimal conditions were as follows: pH 3.4, temperature 83◦C, extraction time 3.95 h and ratio of water to kelp 1:23. Under the above conditions, the production of kelp polysaccharide was 1.26%, with high scavenging percentages of free radicals. Also, an increase in the biosynthetic activity of collagen can be realized at certain kelp polysaccharide concentration. The results above pointed out that kelp polysaccharide is expected to make a good candidate for future use in cosmetics given its high effectivity plus relatively easy production [18]. However, these factors require further verification before being applied in real production due to an amplification in industrial extraction and purification systems.7. Insights in kelp blanching water polysaccharides

Nowadays, seaweeds contribute to half of all mariculture worldwide and are now a major participant in bio-based businesses [19, 20]. Hot water blanching, which is often the first step in the seaweed processing, reduces postharvest quality decline but also produces a significant amount of hydrothermal waste. Notwithstanding the recent realizations that it is likely to contain beneficial chemicals, the blanching waste is still largely untapped for bioactive molecules [21, 22].

Using Saccharina j. blanching water as example, 2.9 g/L of polymeric substances were efficiently isolated by ultrafiltration, implying biopolymer coproduction potential of ~5.8 kt from blanching wastewater of current kelp industry. After purified by anion exchange chromatography, the remainings of blanching water polymers mainly consisted of acidic polysaccharide. The biopolymers manifested different yet overlapping structural features with polysaccharides extracted by hot water, in possession of high levels of fucose, uronic acids and sulfate. Additionally, the polysaccharides were proved to be compatible with cosmetic creams, adding to the cohesion and freshness, which suggested the potential cosmetic values for such natural biopolymers from the seaweed blanching water untapped [23]. This deserves further research and development to discover practical strategies and mature techniques to reutilize the valuable ingredients in the kelp blanching water, which used to be treated as wastes.

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7. Conclusion

From what is introduced above, *S. japonica* extracts exhibit ideal cosmetic effects like anti-inflammation, skin-whitening, antioxidation, and anti-bacteria, with all these proven activities supported by pre-clinical experiments. What's more, when used in combination, these bioactive components purified from *S. japonica* are likely to provide multiple efficacies or even new unexpected effects.

However, before being commercialized and industrialized, these chemicals still require ample verifications, like clinical trials, which are of the utmost significance and most time-consuming. The final dose applied to cosmetic products should be carefully determined by weighing both safety and efficacy. Moreover, when it comes to the research and development stage of cosmetic products, the preservation of the bioactivities of functional components deserves fine experiments to optimize the effectiveness of *S. japonica* extracts. The form of how manufacturers make their cosmetic products can no longer be limited to applicational products like face cream and lotion; oral preparation and injection may well be taken into consideration, with the phlorotannin nanoparticle mentioned above as a good example.

To answer the call for resource saving and sustainable development, during the processing of raw kelps, it is desirable that the efficiency of extraction be elevated while the energy consumed and the waste produced be lowered as much as possible. Apart from the increasing demand for technology development, reconsidering where the raw materials come from may provide new insights, with kelp blanching water—an initial industrial waste—as a possible new source of raw materials in cosmetics.

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