*J. Cosmet. Sci.*, 74, 63–80 (January/February 2023)

# Natural Active Ingredients and Skin Hydration: A Systematic Review

NUR SHADIAH BINTI ZULKIFLI, SHARIZA BINTI SAHUDIN AND NORSAVINA KAHARUDIN
*Puncak Alam, Selangor, Malaysia (N.S.B.Z., S.B.S.)*
*Senawang, Negeri Sembilan, Malaysia (N.K.)*

*Accepted for publication March 02, 2023.*

**Synopsis**

The skin can reflect the origin, lifestyle, age, and health status of a person. Skin hydration is one of the fundamental elements that influences skin health. The prevalence of psychiatric disorders in patients with skin conditions is in the range of 25% to 43%. Therefore, having good, healthy skin helps to boost a person's confidence and self-worth. Moisturizers are the most prescribed products in dermatology. They increase hydration by improving the barrier function of the stratum corneum and also by reducing water loss. The global natural cosmetics market was estimated at $34.12 billion in 2018 and rising at a compound annual growth rate of 5.01% from 2019 to 2025. This study systematically looks at published literature on various natural ingredients that can be used to promote skin hydration. Search engines used include ScienceDirect, PubMed, National Center for Biotechnology Information databases, and ResearchGate. Results obtained give insight into the use of natural active ingredients as cosmetic formulations for skin hydration. Natural active ingredients from plants, animals, and marine sources contain vitamins, humectants, emollients, peptides, and collagens that can promote skin hydration. This review concludes by identifying the natural active ingredients that can be used in cosmetic formulations to promote skin hydration.

## INTRODUCTION

Skin can reflect origin, lifestyle, age, and state of health (1). Skin consists of three different layers: the epidermis, dermis, and subcutaneous layers. The epidermis is the outermost layer of the skin that provides a waterproof barrier and produces color and tone. The epidermis is made up of four distinct layers: the stratum corneum (SC), stratum spinosum, stratum granulosum, and stratum basale (Figure 1).

Brick-and-mortar structures are mainly responsible for the effectiveness of the SC (Figure 2). The protein-enriched corneocytes (bricks) impart a high degree of tortuosity to the path of water or any other molecule that crosses the SC. The hydrophobic lipids, organized into tight lamellar structures (mortar), provide a watertight barrier property (2). Meanwhile, the dermis, which is located beneath the epidermis, is made up of connective tissues, collagen, elastin, and glycoaminoglycans, which are jointly termed the extracellular matrix (2). The

Address all correspondence to Shariza Binti Sahudin, shariza22802280@uitm.edu.my



Purchased for the exclusive use of nofirst nolast (unknown)
From: SCC Media Library & Resource Center (library.scconline.org)

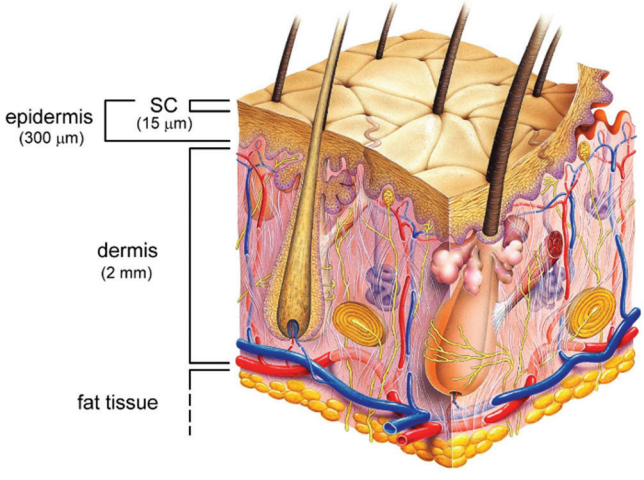


**Figure 1.** Schematic overview of skin layers. (Adapted from Benjamin Cummings, Pearson Education Inc.)

important function of the skin is to protect the body from microorganisms and unwanted elements in the surrounding environment. The main barrier of the skin is the outermost layer (the SC).

Skin moisture is one of the fundamental elements that influences skin health. Moisturizers are the most prescribed products in dermatology and help to sustain skin integrity and well-being, creating a healthy appearance. The main actions of moisturizers are to smoothen the skin's surface and to enhance water content in the SC to moisten the skin (3). Traditionally, moisturizers have been considered to hold back transepidermal water loss

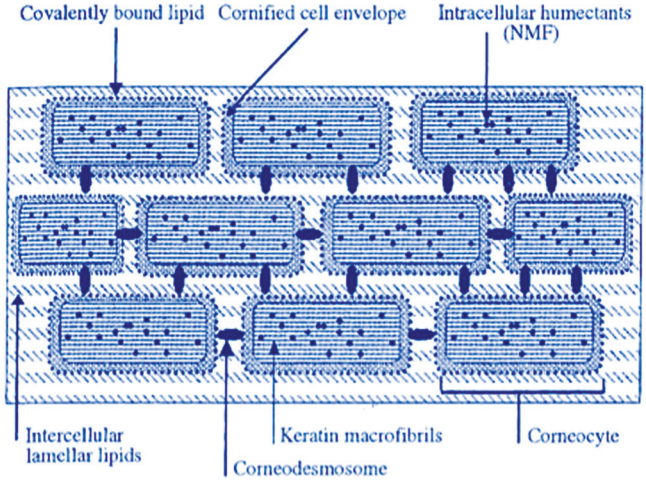


**Figure 2.** The SC morphology. Adapted with permission from reference 1. Copyright 2019 Open Scientific Publishers.

Purchased for the exclusive use of nofirst nolast (unknown)
From: SCC Media Library & Resource Center (library.scconline.org)

(TEWL) by occlusion (4). Water maintains the elasticity and softness of the SC. Moisturizers are used to improve skin barrier function by influencing the structure of SC and skin barrier homeostasis through reduction of TEWL, boosting skin hydration, and reducing proliferation activity of the epidermis (5). Buraczewska stated that moisturizers have also been shown to regulate skin barrier recovery after exposure to irritants (6).

Moisturizers are formulated primarily as oil-in-water emulsions, where oil droplets are dispersed in water and stabilized by emulsifiers (3). Emulsions can be categorized into creams, lotions, gels, ointments, and suspensions. Creams are the most widely used moisturizers to treat dry skin conditions, as they are cosmetic and pharmaceutical products that are produced to soothe, restore, reinforce, protect, and treat the skin. They therefore keep skin in "good condition" (1). Moisturizers may either have simple contents and consist of several ingredients or be a complex mixture of many materials (3). Natural active ingredients used in cosmetic formulations have been found to provide a number of beneficial effects such as good moisturization, skin smoothening and rejuvenation, healing, anti-aging properties, and anti-inflammatory properties. According to Corley and Matthews, the Natural Products Association recognizes a product as natural if 95% or more of its ingredients come from natural sources (7,8).

According to a Grand View Research market analysis report from 2022, the global natural cosmetics market size was estimated at $34.12 billion in 2018, and it is projected to register a compound annual growth rate of 5.01% from 2019 to 2025. The market demand for natural personal care products is being driven by the population increase in various countries. For example, a large market exists in the United Kingdom for products that focus on the aging population. These consumers possess higher disposal income and demand products that can fulfill their skincare needs. The rising population of millennials in the Asia-Pacific region and other regions is also driving global demand. Consumers are willing to spend more money on natural products due to increasing disposable incomes and more of a consciousness regarding appearance (9).

Natural sources may consist of vitamins, fatty acids, polyphenols, and terpenes that may improve certain endogenous bioactivities and can be used in cosmetic products. They also show characteristics as emollients and skin moisturizers and can be used for hair protection and softening (10). Plants are considered the most influential sources of active ingredients in the cosmetic industry. Examples of plant sources that are currently used as natural active ingredients in cosmetic formulations include: papaya peel, cucumber, sweet potato, shea butter, mango butter, cocoa butter, aloe vera, palm oil, avocado oil, sweet almond oil, pumpkin seeds, *Centella asiatica, Calendula* flowers, jojoba oil, sunflower seed oil, argan oil, coconut oil, and comfrey roots. Palm oil is also included as one of the natural source active ingredients used in cosmetic formulations. Active ingredients from natural sources, especially plants, normally exhibit emollient properties. Emollients are agents that are mainly oils and lipids and function to soften and smooth the SC by increasing hydration (4). Emollients also contain humectants and hygroscopic compounds that serve to hydrate the SC (11). Humectants possess good moisturizing properties because they increase TEWL by strengthening water absorption from the dermis into the epidermis, where water is easily lost to the surroundings (4). There are also active ingredients obtained from animals and marine sources used in the cosmetic industry. These include sea cucumber, algae, snails, shark fish liver oil, hydras, jellyfish, cuttlefish, starfish, sea urchins, and fish scales, along with animal bone, cartilage, and/or muscle.

Purchased for the exclusive use of nofirst nolast (unknown)
From: SCC Media Library & Resource Center (library.scconline.org)

## MATERIALS AND METHODS

### SEARCH STRATEGY

For this review, the published articles and reviews on the use of natural active ingredients in cosmetic formulations were retrieved from electronic databases including ScienceDirect, PubMed, National Center for Biotechnology Information databases, and ResearchGate. Some of the keywords included "natural cosmetics," "active ingredients," "skin hydration," "moisturizing effect," and "formulations."

### DATA EXTRACTION

From articles searched, the inclusion and exclusion criteria were used in the extraction of data. The included criteria consisted of publications from various database sites, such as English language articles, abstract articles, review articles, full text articles, and experimental studies. These were about natural active ingredients used in cosmetic formulations for skin hydration, and articles published in languages other than English were excluded from the search. Data extracted included information on basic details and functions of the natural active ingredients used in cosmetic formulations on therapeutic values, such as hydrating and moisturizing effects on the skin. This review collected all of the data related to the efficiency of the natural sources on skin hydrating levels and compiled them into one review article. Some of the studies also analyzed the biological and pharmacological activities of the natural resources that have good hydrating effects; those data were also included in this review.

## RESULTS

A total of 75 studies from ScienceDirect, 35 studies from PubMed, 45 studies from the National Center for Biotechnology Information, and 20 studies from ResearchGate were selected. After removing duplicates, 115 studies remained. After reviewing their titles and abstracts, 20 studies were excluded. The remaining 105 articles were assessed in more detail for eligibility by examining the full texts. Among them, 9 were excluded due to lack of relevant outcome measurements, and 11 were excluded due to lack of detailed information. Finally, 75 studies were used for the data extraction. The flowchart of the literature search is presented in Figure 3. Data extracted from the final studied articles are presented in table format to understand and identify different types of active ingredients commonly found and used in cosmetic formulations to date. Table I displays different plant-based sources used in cosmetic formulations. Meanwhile, Table II shows several animal and marine sources used as the active ingredients in cosmetic formulations.

## DISCUSSION

It is widely known that moisturization is the first step toward skin health. It helps to maintain the skin's appearance, strengthen skin elasticity, and play a role as a barrier against harmful environmental factors (12,13). Moisturization also helps to prevent skin aging. To

Purchased for the exclusive use of nofirst nolast (unknown)
From: SCC Media Library & Resource Center (library.scconline.org)

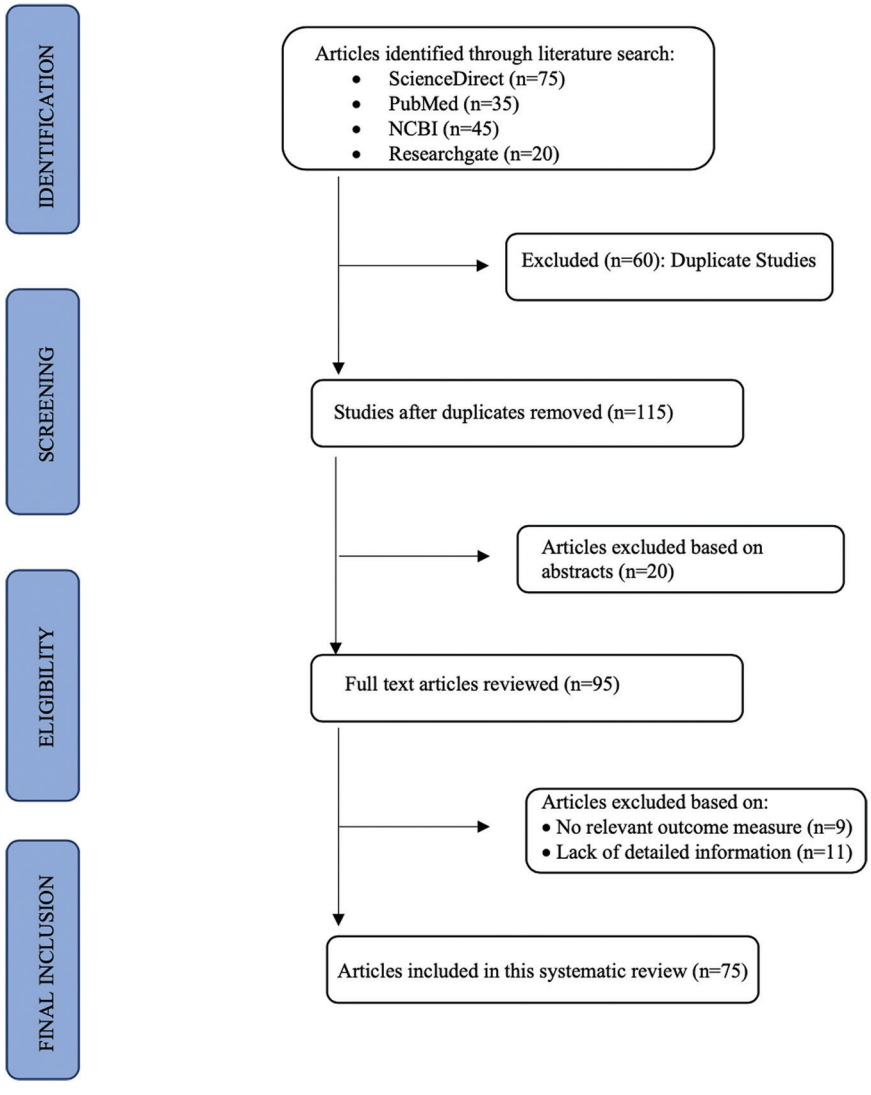


**Figure 3.** Flow diagram of the study selection process.

achieved maximum effects of skin hydration and consumer acceptability, a moisturizer should be able to reduce and prevent water loss in the skin; help restore the lipid barrier properties of the skin by enhancing its moisture retention mechanisms; provide immediate hydration; be immediately absorbed into the skin; be nonsensitizing; and be cosmetically acceptable and affordable for a consumer to purchase (4). Studies on the influence of moisturizers on the skin's barrier properties have shown that they are able to enhance skin hydration, reduce skin roughness and scaling of the skin, and help improve dry skin conditions (10). The functions and uses of natural sources and the properties of their active ingredients are further discussed in this review.

Purchased for the exclusive use of nofirst nolast (unknown)
From: SCC Media Library & Resource Center (library.scconline.org)

**Table I**
Plant-Based Sources Used in Cosmetics

| Sources | Bioactive ingredients | Therapeutic value/s | Reference |
|---|---|---|---|
| **Turmeric** | Curcuminoids | Moisturizing<br>Antioxidant | (83) |
| **Aloe vera** | Phenolic<br>Vitamins<br>Sugars<br>Anthraquinones | Moisturizing<br>Anti-inflammatory | **(88)**<br>**(87)** |
| **Papaya peel** | Vitamin A | Moisturizing<br>Smoothness<br>Lightening, restore, rebuild damage skin | (105) |
| **Palm oil** | Tocopherol<br>Tocotrienol<br>Vitamin E | Antioxidant<br>Emollient<br>Moisturizing | (32)<br>(31)<br>(86) |
| **Shea butter** | Vitamin A<br>Vitamin E<br>Vitamin F | Moisturizing<br>Emollient<br>Anti-inflammatory<br>Restore skin | (24)<br>(11). |
| **Mango butter** | Tocopherol<br>Triterpenes<br>Phytosterol<br>Vitamin E | Moisturizing<br>Anti-inflammatory<br>Skin rejuvenating | (85) |
| **Cocoa butter** | Vitamin E<br>Vitamin F<br>Palmitic acid<br>Linoleic acid | Antioxidant<br>Anti-inflammatory moisturizing<br>Smoothness | (32,66)<br>(89,109)<br>(108) |
| **Avocado oil** | Phytosterols | Moisturizing | (90) |
| **Pumpkin seeds** | Fatty acids | Antioxidant<br>Anti-inflammatory | (66)<br>(89) |
| **Comfrey root** | Allantoin | Moisturizing Keratolytic | (91) |
| **Sweet potato** | Hyaluronic acid | Moisturizing<br>Skin rejuvenating | (17)<br>(16) |
| **Cucumber** | Vitamin C<br>Cucurbitacin | Moisturizing<br>Skin rejuvenating | (92)<br>(93)<br>(94)<br>(95) |
| **Sweet almond oil** | α-tocopherol<br>Vitamin A<br>Vitamin E<br>Unsaturated fatty acids | Moisturizing<br>Smoothness | (38)<br>(39)<br>(37)<br>(97)<br>(96) |
| ***C asiatica*** | Centelloid<br>Flavonoid<br>Phytosterols | Moisturizing<br>Anti-inflammatory<br>Skin regeneration | (98) |
| ***Calendula* flowers** | Essential oil<br>Fatty acids<br>Tocopherol | Moisturizing<br>Skin regeneration | (99)<br>(100) |
| **Jojoba oil** | Fatty acids | Moisturizing | (101) |
| **Sunflower seed oil**<br>**Argan oil** | Linoleic acid | Antioxidant | (90) |

Purchased for the exclusive use of nofirst nolast (unknown)
From: SCC Media Library & Resource Center (library.scconline.org)

**Table II**
Animal- and Marine-Based Sources Used in Cosmetics

| Sources | Bioactive ingredients | Therapeutic value/s | Reference |
|---|---|---|---|
| **Snail secretion** | Hyaluronic acid | Moisturizing | (17) |
| | | Skin rejuvenating | (16) |
| **Algae** | Marine polysaccharides | Moisturizing | (3) |
| | Vitamins | Antioxidant | (63) |
| | Alginates | Restore damaged skin | (49) |
| | Unsaturated fatty acids | | |
| **Microalgae** | Hyaluronic acid | | (65) |
| | Exopolysachharides | | (19) |
| | Biopolymers | | (64) |
| | | | (67) |
| **Shark fish (oil and cartilage)** | Fatty acids | Moisturizing | (74) |
| | Squalene | Anti-inflammatory | (68) |
| | Squalene Collagen | Antioxidant | (69) |
| | Peptides | | (73) |
| | | | (63) |
| **Hydras** | Vitamin C | Antioxidant | (63) |
| | Vitamin E | Emollient | |
| **Fish (scales/bone/ cartilage/muscle)** | Collagen | Skin regeneration | (75) |
| | Peptides | Improve skin barriers | (102) |
| | Antioxidant | Antioxidant | (106) |
| | Chondroitin | | (76) |
| | Sulphate | | (77) |
| **Sea cucumber** | Collagen | Moisturizing | (107) |
| **Jellyfish** | | Rebuild damaged skin | (58) |
| **Cuttlefish** | | Improve skin barriers | (103) |
| **Sea urchin** | | | (104) |
| **Starfish** | Collagen | Moisturizing | (57) |
| | | Antioxidant | |
| | | Anti-aging | |

## HYALURONIC ACID IN COSMETIC FORMULATIONS AND SKIN HYDRATION

Hyaluronic acid (HA) is an anionic, nonsulfated glycosaminoglycan scattered widely throughout epithelial, connective, and neutral tissues (14). HA can be found in plants and animals (15). HA is also a main component of the skin, where it is involved in tissue repair. HA is abundant in the extracellular matrices of skin. Cosmetic formulations containing HA have been found to moisturize the skin (15). HA is the active ingredient for many moisturizing, protecting, and anti-aging products (16). It was reported that Estée Lauder™ (The Estée Lauder Companies Inc., New York) was the first to apply animal HA in cosmetics. The effectiveness of using HA in cosmetics is further supported in the *Journal of Drugs in Dermatology*, which indicates that formulations containing 0.1% HA resulted in significant improvement of skin hydration and elasticity (17). A study by Olejnik et al. (16) stated that HA acts by forming a film on the surface of the epidermis (the SC), and it prevents TEWL. In cosmetic formulations, HA also works as a potent humectant, or a moisturizing agent. This is a category of skin-care ingredients that attracts water to the skin, increases the water content of the SC, and keeps the cosmetic formulation from becoming dry (11). *C asiatica* extract also was found to inhibit the enzymatic action of hyaluronidase; it demonstrated potent inhibitory effects for elastase and hyaluronidase (12). A study by Milani and Sparavigna (12) showed that the inhibition activity for

Purchased for the exclusive use of nofirst nolast (unknown)
From: SCC Media Library & Resource Center (library.scconline.org)

hyaluronidase can prolong the hydrating action of HA and increase the long-lasting effects of moisturizing the skin.

Several studies have concluded that microalgae have high antioxidant activity and that microalgal extracts or bioactive compounds derived from microalgae have significant potential to be accessional new biobased products like cosmetics, pharmaceuticals, nutraceuticals, bioplastics, and biopolymers (18–20). It has been shown that the level of skin moisturization is related to the frequency of washing with tensioactive supplies or defensive potential from any irritant agent. HA has been used in cosmetic products for moisturizing the skin in accordance with these two mentioned mechanisms. Hydroxy acids can be produced by plants, but there are restrictions of HA production from plants. Therefore, interest in algal polysaccharides has increased.

Studies have shown that *Pediastrum duplex* extract contains significant quantities of polysaccharides and can be evaluated for skin moisturization and protection (20). HA can be classified as alpha-HA, beta-HA, and salicylic acid. Alpha-HA is also known as 2-hydroxy acid because of its hydroxyl group attached to the carbon atom next to the carboxyl group. The most popular 2-hydroxy acids used in cosmetics are glycolic acid and lactic acid. In addition, beta-HA is named 3-hydroxy acid because of its hydroxyl group attached to the carbon atom that is situated in the second place when counted starting from the carboxyl group. The most well-known 3-hydroxy acid used in cosmetic formulations is citric acid (21). Other microalgae species that have been reported to have moisturizing properties include *Anabaena variabilis, Anacystis nidulans, Chlorella pyrenoidosa, Chlamydomonas reinhardtii, Cyanidium caldarium, Phormidium foveolarum*, and *Oscillatoria* spp. They produce 2-hydroxy acids and 3-hydroxy acids, and their extracts can serve as promising candidates as cosmetic ingredients (22,23).

## VITAMINS IN COSMETIC FORMULATIONS AND MOISTURIZING PROPERTIES

Palm oil is one of the primary sources of vitamin E that has abundant quantities of tocopherols and tocotrienols. Because of its abundant amounts of tocotrienols and tocopherols, palm oil has shown great capability as a skin penetration enhancer because of intercalation within the lipid bilayer region of the SC (17). This has resulted in modification of the membrane, impacting permeability.

Shea butter is known for its high content of vitamin A, which is effective in soothing the skin and promoting healing. Shea butter also contains vitamin F, which has the ability to act as a rejuvenator for soothing and healing rough and chapped skin (24). Shea butter is rich in vitamins A and E, which makes it a good moisturizer for the skin and hair (9). Mango butter and cocoa butter contain high amounts of vitamin E; it exhibits the same properties as shea butter in terms of effectiveness in healing and soothing the skin. Vitamin E from mango butter helps with water retention in the skin and can significantly reduce the roughness of skin upon multiple applications.

In cosmetics, cucumber has exhibited an excellent ability for skin soothing and cooling, and cucumber extract is sometimes used as an antioxidant. Cucumber extracts are rich in vitamins, especially vitamins A and C, which display several cosmetic benefits for the skin (25). Vitamin C is known to increase collagen fibers in the dermis. Increase in collagen fibers helps improve the hydration state of the skin (25). In studies by Naveed A et al., the studies

Purchased for the exclusive use of nofirst nolast (unknown)
From: SCC Media Library & Resource Center (library.scconline.org)

found that TEWL values increased after the use of formulation with cucumber extracts. They caused disruption of the skin, thus increasing the rate of water evaporation from the SC and leading to reduction of skin moisture. However, these effects were statistically insignificant ($p > 0.05$) (25). In addition, studies of *C asiatica* have shown effectiveness in skin hydration that has resulted from improvement in elasticity and firmness of the skin (14). A total of 20 healthy women, with a mean age of 40 years old, were enrolled in an intrasubject (right versus left), randomized, assessor-blinded, controlled, 1-day trial. The primary end points were the skin hydration and TEWL, evaluated at the volar surface of the forearm and in standardized conditions (temperature- and humidity-controlled room: 23°C and 30% of humidity). The author found that a single application of the fluid containing *C asiatica* extract, HA, and glycerin, significantly improved skin hydration for up to 24 hours while improving skin barrier function. In addition, a study by Vaughn et al. (15) stated that almond oil is rich in vitamin E and has been shown to have occlusive properties, thus improving skin hydration. The author conducted a multicenter randomized, clinical study of the effects of natural oils on xerosis and skin barrier properties. The study outcome showed that almond oil, jojoba oil, and coconut oil significantly increased hydration after 2 weeks and are as effective as white petrolatum as daily moisturizers for xerosis. The participants also preferred natural oils over white petrolatum, which indicates that these moisturizer options may improve patient compliance.

### EMOLLIENTS AND HUMECTANTS IN COSMETIC FORMULATIONS ON SKIN CONDITION

The emollient action of some ingredients is a consequence of skin softening, smoothing, and moisturizing capacity (26). These compounds have the ability to maintain almost 25% of the water in corneocytes and protect the skin barrier (27,28). The main functions of emollients are to protect and help maintain skin sebum and lipid levels (28). The topical application of these compounds improves skin hydration and prevents the appearance of dry skin (29). In physiological terms, emollients create a thin layer on the skin's surface that is able to prevent water evaporation (28). Compounds such as ceramide, cholesterol, and free fatty acid may be included in cosmetic and medical skin-care formulations to improve barrier homeostasis and, consequently, hydration and sebum levels (30).

Palm oil is a natural oil that has emollient properties and does not create any irritation effects on the skin (31). In addition, palm oil has moisturizing properties by reducing the level of dryness and roughness of skin. It works by strengthening the water-binding capacity of the SC (11). According to Fluhr et al., palm oil works by forming an occlusive film that inhibits water evaporation from beneath the skin. Palm oil contains tocotrienols, with the highest levels among all vegetable oils, and tocopherols (32,33) Shea butter also exhibits emollient properties, protecting the skin by stimulating the production of structural proteins by specialized skin cells (10).

A study by Nandal et al. (34) found that aloe vera is useful for maintaining skin moisture and helping to sooth the skin to prevent dryness due to harsh weather. Aloe vera can also be used as a moisturizer for oily skin. It acts by improving the skin's ability to hydrate itself, helps in removal of dead keratin cells, and has an effective penetrating ability that aids in transporting healthy materials through the skin barrier (34). Development of aloe sugar with a combination of selected essential oils makes it an excellent moisturizing agent that helps to smoothen the skin. A study by Sajjad et al. (35) stated that aloe vera extracts act

Purchased for the exclusive use of nofirst nolast (unknown)
From: SCC Media Library & Resource Center (library.scconline.org)

as humectants; they attract water from the deeper parts of skin and help keep the water bound in the SC. The humectant mechanism of aloe vera improves skin hydration. These factors make aloe vera an ideal ingredient in cosmetic and dermatological products.

A study by Vaughn et al. (36) stated that argan oil was found to have good emollient properties and was effective in reducing dryness of skin; thus, it helped to enhance the skin condition. Almond oil contains highly active natural humectants and emollients, which possess excellent moisturizing abilities, to prevent the skin from drying out, thus avoiding peeling or chapping. Almond oil has properties that nourish, sooth, protect, and calm the skin by helping the epidermis maintain optimum moisture levels (37–39).

Jin et al. (40) evaluated the nutritional composition of *Actinidia arguta* (kiwi berry), reporting the presence of palmitic acid (a saturated fatty acid) and α-linoleic acid (an unsaturated fatty acid). Fatty acids—such as lauric acid, linoleic acid, palmitic acid, stearic acid, linolenic acid, myristic acid, oleic acid, and isostearic acid—are known as skin penetration enhancers in topical and transdermal formulations (41). Linoleic and α-linoleic acids have influence on the skin physiology and can be oxidized to eicosanoids, which are extremely important compounds in cell signaling (42). Similarly, linoleic acid is described as a topical treatment for skin inflammation (43). Fluhr et al. (44) applied free fatty acids—such as palmitic acid, stearic acid, and linoleic acid in murine skin surfaces—concluding that they play an important role in acidification, integrity, and cohesion of the SC. In addition, topical application of polyunsaturated fatty acid was shown to induce the hyperproliferation in guinea pig skin (45). Furthermore, fatty acids are easily incorporated in cell membrane lipids, improving the epidermis lipid barrier and softening the SC (26). Barcelos et al. (46) administered daily omega-3 fish oils (FOs) to rats and observed the changes in dermal responses to skin irritation after 30, 60, and 90 days of supplementation. After 60 days of supplementation, both irritation and TEWL were significantly reduced in response to acetone exposure. After 90 days, TEWL had gone down by 50% compared with the control group without FO. Cutaneous hydration significantly increased by 30% after 60 days of FO treatment, which was maintained after 90 days compared with the control group. This supports previous claims that dietary fatty acids are transported to the SC (47,48) and are able to improve cutaneous health through oral administration.

## MARINE SOURCES IN COSMETIC FORMULATIONS AND SKIN HYDRATION

The expanding market and increasing demand for skin-care products and continual studies on new ingredients in cosmetic formulations have led to a revolution in cosmetic products based on marine constituents (49). According to a study by Silvipriya et al., marine sources were found to be the safest sources of collagen. Collagen is the major structural protein constituting the extracellular matrix of connective tissues and is widely used in various industries such as medical tissue regeneration (50), pharmaceuticals, food, and cosmetics. Collagen is biocompatible and biodegradable, which enables superior cell accommodation with a relatively low immunogenicity compared with other biomaterials (51). Hydrolyzed collagens, or small-molecular-weight peptides, have been found to penetrate deep layers of the skin easily compared with high-molecular weight native collagens. They play an important role in fibroblast growth (52), collagen expression (53), and strong collagen fiber formation in the epidermis (54). In addition, they are important molecular components in improving the functionality of the skin layer by increasing the water content of the SC (55).

Purchased for the exclusive use of nofirst nolast (unknown)
From: SCC Media Library & Resource Center (library.scconline.org)

Therefore, they are widely used in cosmetic applications to maintain skin homeostasis and to restore disrupted skin layers (56). Seong-Beom Han et al. studied *Asterina pectinifera*, a marine species of starfish found mainly in Korea, eastern Russia, Japan, and China. Collagen peptides were isolated from *A pectinifera* starfish with a lower molecular weight. These were then encapsulated into elastic liposomes with high efficiency to overcome the low absorption rate of collagen peptides into the skin. In conclusion, they demonstrated this combination to be superior as a cosmetic ingredient by measuring the reduction of matrix metalloproteinase expression in photoaged cells (57).

Collagens are found in cosmetic applications acting as moisturizers and natural humectants with anti-aging properties (58). Most marine organisms contain active ingredients such as polysaccharides, fatty acids, and collagens that possess excellent moisturizing properties for the skin (59). In a study by Li et al. (60), collagen extracted from sea cucumber contained a significant composition of moisture content. Sea cucumber collagen shows strong moisture absorption and high moisture retention ability, which determined the moisturizing properties for the skin. The author compared this collagen with those from the skins of tilapia and pigs. The three collagens that were extracted exhibited better moisture-retention and moisture-absorption capacity than glycerol. This showed that the collagen molecules were rich in hydrophilic groups, which have potential applications in cosmetic formulations. Another study suggested that the moisture absorption and retention potential of collagen in sea cucumber extract was excellent compared with glycerol. Therefore, the extracted collagen could be utilized as a moisturizer in the cosmetic industry (15). Studies by Wang et al. (3) concluded that extracts from algae or other marine organisms can be used for skin moisturization, as they are promising substances that can boost collagen synthesis, helping to promoting skin tissue, which eventually helps in reducing wrinkles. Another study by Brunt and Burgess (61) found that collagen extracted from jellyfish had a notable moisturizing effect on skin. Swatschek et al. (62) reported the successful extraction of collagen from the marine sponge *Chondrosia reniformis*. A total of a 30% yield of freeze-dried collagen was obtained, and two cosmetic formulae were trialed on human skin. They found no significant difference in skin hydration between the sponge collagen treatments and the existing collagen product control; however, there was a significant increase in skin lipid content of 140–180 lg $cm^{-2}$ 1 hour after treatment.

A review by Uppala (63) stated that hydras can be used as a moisturizer, as it contains vitamin C, which helps to increase collagen production in the dermis, and vitamin E, which helps in enhancing the skin's barrier properties. Hydras are also rich in olive oil, which has emollient properties. Shark fish liver oil is highly rich in fatty acids and squalene, which have moisturizing properties. The application of seaweed as a cosmetic ingredient was also found to be effective as a moisturizing agent. This was supported by a study from Wang et al. (3), which showed that polysaccharides extracted from brown algae absorbed and retained more moisture than those from four other species of algae. The abundance of polysaccharides in red algae species also have hydrating, therapeutic, and moisturizing effects (15). An extract from green algae was also found to be efficient in regulating water distribution in the skin, thus protecting the skin from becoming dry, particularly in arid environments (15).

In addition to producing HA, exopolysaccharides (EPS) are also produced by microalgae and can be considered significant moisturizing products. EPS involve several significant high molecular weight biopolymers. Microalgae produce these biopolymers and secrete them to a medium size during their cultivation (64,65). Glucuronic acid is one of the

Purchased for the exclusive use of nofirst nolast (unknown)
From: SCC Media Library & Resource Center (library.scconline.org)

biopolymers that can be utilized to protect the skin from dry environmental conditions and can help regulate the water content in the skin (64,66). EPS produced by microalgae show variability as a result of changes in the biosynthesis mechanism according to nutrients, culture conditions, and strains. *C pyrenoidosa* FACHB-9, *Chlorococcum* sp., *Porphyridium cruentum, Spirulina platensis*, and *Scenedesmus* sp. are known as EPS producers. Their cell-free cultivation mediums might be evaluated as cosmetics because of their glucuronic acid content (64,67). It has also been shown that cell-free cultivation mediums of *P cruentum* and *S platensis* might be good candidates for cosmetic ingredients because of their glucuronic acid content.

Research on the bioactivity of fish collagen Type II (C-II) is in its beginning stages. The information that exists is limited almost entirely to shark C-II and is separated into three categories. First, because of its terrestrial sources, C-II from the blue shark (*Prionace glauca*) and the whale shark (*Rhincodon typus*) cartilage has anti-inflammatory activity (6,69). Chen et al. (70) showed that oral administration of C-II from the blue shark suppresses rheumatoid arthritis in experimentally induced rheumatoid arthritis model rats. Second, whale shark C-II stimulates osteogenesis and suppresses osteoclastogenesis when used as cellular scaffolds (71), and blue shark C-II scaffold promotes osteoblast cell formation (72). Third, whale shark C-II has antioxidant activity (73). Three peptides isolated from shark (*Mustelus griseus*) cartilage hydrolysate scavenge radicals were shown to inhibit lipid peroxidation and provide protection to $H_2O_2$-stressed HepG2 cells (74). Antioxidant peptides that help to improve the skin barrier from two skate species, *Raja porosa and Rostanga pulchra* cartilage, have also been reported (75,76). Other studies have reported antioxidant activities from salmon cartilage chondroitin sulphate (77,78). Puścion-Jakubik et al. (79) studied the consumption of certain ingredients (vitamins A, C, D, and E, and Cu, Mn, and Zn) on 172 young women. The study was assessed using the Diet 6.0 program, body composition was assessed using electrical bioimpedance, and skin hydration and lubrication were assessed using the corneometric and sebumetric methods, respectively. The results indicated that one-third of students showed insufficient consumption of vitamin C, vitamin E, and Zn, while approximately 99% showed insufficient vitamin D levels. The highest degree of hydration was observed in the areas of the eyelids, neckline, and chin. The greatest amount of sebum was found in the area of the nose and forehead. Low positive correlations were observed between hydration or lubrication and Cu, vitamin A, and vitamin E. The author concluded that in order to properly moisturize and lubricate the skin, young women should eat products that are rich in ingredients with antioxidant properties, particularly fat-soluble vitamins A and E and copper (79). Vitamin A and its derivatives contribute to the proper exfoliation of the SC, which improves its protective function and reduces TEWL (80). By penetrating deep into the lipid barrier of skin cells, vitamin E seals and strengthens the cell membrane, which results in water retention (81).

## CONCLUSION

To date, the use of natural resources has been beneficial to consumers for healthier skin conditions and eventually a healthier lifestyle. In our review, natural sources from plants or marine sources were shown to provide hydration properties that warrant their use as cosmetic ingredients. The natural cosmetics sectors show encouraging development worldwide and are likely to keep growing and expanding alongside the increasing interest and demand among consumers.

Purchased for the exclusive use of nofirst nolast (unknown)
From: SCC Media Library & Resource Center (library.scconline.org)

**ACKNOWLEDGMENTS**

The authors involved in this research would like to thank Pharmaceutical Department Faculty of Pharmacy, UiTM, Puncak Alam Campus for providing facilities. This research was supported by the VNI Scientific (100-TNCPI/PRI 16/6/2(056/2022) fund.

## CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest on this manuscript.

## REFERENCES

(1) A.K. Mohiuddin, Skin care creams : formulation and use, *American Journal of Dermatological Research and Reviews*, **2**(8), 1–45 (2019).

(2) G.K. Menon, New insights into skin structure: scratching the surface, *Adv. Drug Delivery Rev.*, **54**(Supplement), 3–17 (2002).

(3) H.-M. D. Wang, C.-C. Chen, P. Huynh, and J.-S. Chang, Exploring the potential of using algae in cosmetics—a review, *Bioresour. Technol.*, **184**, 355–362 (2015).

(4) A. Sethi, T. Kaur, S.K. Malhotra, and M.L. Gambhir, Moisturizers: the slippery road, *Indian J. Dermatol.*, **61**(3), 279–287 (2016).

(5) R.S. Sivamani, J. Jagdeo, P. Elsner, and H.I. Maibach, *Cosmeceuticals and Active Cosmetics*, 3rd Ed. (CSC Press, Taylor & Francis Group, Boca Raton, FL, 2016), p. 443.

(6) I. Buraczewska, Skin barrier responses to moisturizers, *Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Medicine*, **381**(66), 1–47 (2008).

(7) J.W. Corley, "Natural and organic: the emerging revolution," in *Natural and Organics in Cosmetics: From R and D to the Marketplace*, B.M. Lawrence. Ed. (Allured Publishing Corporation, Carol Stream, IL, 2008), pp. 55–66.

(8) I. Matthews, "Naturals hit mainstream," in *Natural and Organics in Cosmetics: From R and D to the Marketplace*, B.M. Lawrence. Ed. (Allured Publishing Corporation, Carol Stream, IL, 2008), pp. 17–20.

(9) Grand View Research, accessed August 20, 2022, https://www.grandviewresearch.com/industry-analysis/cosmetics-market.

(10) M.N. Dennie, Medical benefits of the shea nut tree, *Biology Student Research*, **1**(1), 1–10 (2012).

(11) M. Lodén, Role of topical emollients and moisturizers in the treatment of dry skin barrier disorders, *Am. J. Clin. Dermatol.*, **4**(11), 771–788 (2003).

(12) A.V. Rawlings and C.R. Harding, Moisturization and skin barrier function, *Dermatol. Ther.*, **17**(1), 43–48 (2004).

(13) Ç. Yarkent, C. Gürlek, and S.S. Once, Potential of microalgal compounds in trending natural cosmetics: a review, *Sustainable Chem. Pharm.*, **17**, 100304 (2020).

(14) M. Milani and A. Sparavigna, The 24-hour skin hydration and barrier function effects of a hyaluronic 1%, glycerin 5%, and *Centella asiatica* stem cells extract moisturizing fluid: an intra-subject, randomized, assessor-blinded study, *Clin. Cosmet. Investig. Dermatol.*, **10**(1), 311–315 (2017).

(15) A.R. Vaughn, M. Nguyen, M. Maarouf, M. Van Skiver, K. Tran, I. Rybak, R. Sivamani, and V.Y. Shi, Pilot study on the effects of natural oils on skin barrier function in xerosis skin, *Journal of Cutaneus Medicine*, **2**(5), 269–272 (2018).

(16) A. Olejnik, J. Gościańska, and I. Nowak, Significance of hyaluronic acid in cosmetic industry and aesthetic medicine, *Chemik*, **66**(2), 129–135 (2012).

(17) T. Pavicic, G.G. Gauglitz, and M. Farwick, Efficacy of cream-based novel formulations of hyaluronic acid of dfferent molecular weights in anti-wrinkle treatment, *J. Drugs Dermatol.*, **10**(9), 990–1000 (2011).

Purchased for the exclusive use of nofirst nolast (unknown)
From: SCC Media Library & Resource Center (library.scconline.org)

(18) M.B. Ariede, T.M. Candido, A.L.M. Jacome, M.V.R Velasco, J.C.M. de Carvalho, and A.R. Baby, Cosmetic attributes of algae—a review, *Algal Res.*, **25**, 483–487 (2017).

(19) S. Khanra, M. Mondal, G. Halder, O.N. Tiwari, K. Gayen, and T. Kumar, Downstream processing of microalgae for pigments, protein and carbohydrate in industrial application: a review, *Food Bioprod. Process.*, **110**, 60–84 (2018).

(20) H.D. Wang, C. Chen, P. Huynh, and J. Chang, Exploring the potential of using algae in cosmetics, *Bioresour. Technol.*, **184**, 355–362 (2015b).

(21) A. Kornhauser, S.G. Coelho, and V.J. Hearing, Effects of cosmetic formulations containing hydroxyacids on sun-exposed skin: current applications and future developments, *Dermatol. Res. Pract.*, 1–6 (2012).

(22) G.I. Matsumoto and H. Nagashima, Occurrence of 3-hydroxy acids in microalgae and cyanobacteria and their geochemical significance, *Geochem. Cosmochim. Acta*, **48**(8), 1683–1687 (1984).

(23) G.I. Matsumoto, M. Shioya, and H. Nagashima, Occurrence of 2-hydroxy acids in microalgae, *Phytochemistry*, **23**(7), 1421–1423 (1984).

(24) P.M.I. Maanikuu and K. Peker, Medicinal and nutritional benefits from the shea tree- (Vitellaria paradoxa), *Journal of Biology, Agriculture and Healthcare*, **7**(22), 51–57 (2011).

(25) A. Naveed, A. Mehmood, B.A. Khan, T. Mahmood, H. Muhammad, H.M.S. Khan, T. Saeed, and A. Barkat, Exploring cucumber extract for skin rejuvenation, *Afr. J. of Biotechnol.*, **10**(7), 1206–1216 (2011).

(26) M.A. Nunes, F. Rodrigues, and M.B.P.P. Oliveira, "Grape processing by-products as active ingredients for cosmetic proposes," in *Handbook of Grape Processing By-Products*, C. Galanakis. Ed. (Academic Press, Elsevier, Rochester, NY, 2017), pp. 267–292.

(27) F. Rodrigues, M.A. Nunes, and M.B.P.B. Oliveira, "Applications of recovered bioactive compounds in cosmetics and health care products," in *Olive Mill Waste: Recent Advances for Sustainable Management*, C. Galanakis. Ed. (Academic Press, Elsevier, Rochester, NY, 2017), pp. 255–274.

(28) K. Sakamoto, R. Lochhead, H. Maibach, and Y. Yamashita, *Cosmetic Science and Technology: Theoretical Principles and Applications.* (Elsevier, Rochester, NY, 2017).

(29) C. Faria-Silva, A. Ascenso, A.M. Costa, J. Marto, M. Carvalheiro, H.M. Ribeiro, and S. Simões, Feeding the skin: a new trend in food and cosmetics convergence, *Trends Food Sci. & Technol.*, **95**, 21–32 (2020).

(30) M. Mao-Qiang, K.R. Feingold, C.R. Thornfeldt, and P.M. Elias, Optimization of physiological lipid mixtures for barrier repair, *J. Invest. Dermatol.*, **106**(5), 1096–1101 (1996).

(31) J.S. Trivedi, S.L. Krill, and J.J. Fort, Vitamin E as a human skin penetration enhancer, *Eur. J. of Pharm. Sci.*, **3**(4), 241–243 (1995).

(32) G. Scapagnini, S. Davinelli, L. Di Renzo, A. De Lorenzo, H.H. Olarte, G. Micali, A.F. Cicero, and S. Gonzalez, Cocoa bioactive compounds: significance and potential for the maintenance of skin health, *Nutrients*, **6**(8), 3202–3213 (2014).

(33) J.W. Fluhr, C. Cavallotti, and E. Berardesca, Emollients, moisturizers, and keratolytic agents in psoriasis, *Clin. Dermatol.*, **26**(4), 380–386 (2008).

(34) U. Nandal, R.L. Bhardwaj, and K.V. Kendra, Aloe vera for human nutrition, health and cosmetic use—a review, *International Research Journal of Plant Science*, **3**(3), 38–46 (2012).

(35) A. Sajjad and S.S. Sajjad, Aloe vera: an ancient herb for modern dentistry—a literature review, *Journal of Dental Surgery*, 1–6 (2014).

(36) A.R. Vaughn, A.K. Clark, R.K. Sivamani, and V.Y. Shi, Natural oils for skin-barrier repair: ancient compounds now backed by modern science, *Am. J. Clin. Dermatol.*, **19**(1), 103–117 (2018).

(37) M. Ouzir, S. El Bernoussi, M. Tabyaoui, and K. Taghzouti, Almond oil: a comprehensive review of chemical composition, extraction methods, preservation conditions, potential health benefits, and safety, *Compr. Rev. Food Sci. Food Saf.*, **20**(4), 3344–3387 (2021).

(38) K.M.M. Koriem and M.A. El-Attar, Almond oil restores blood parameters, liver function, blood and liver antioxidants and DNA, and liver histology more efficiently than olive oil in favism, *J. Complementary Integr. Med.*, **19**(3), 599–606 (2022).

Purchased for the exclusive use of nofirst nolast (unknown)
From: SCC Media Library & Resource Center (library.scconline.org)

(39) H. Kara, H. Filiz Ayyıldız, İ. Tarhan, F. Erci, and M. Raşit Bakır, "Bioactive phytochemicals from almond (*Prunus dulcis*) oil processing by-products," in *Bioactive Phytochemicals from Vegetable Oil and Oilseed Processing By-Products*, M.F.R.H. Ed. (Springer, New York, 2022), pp. 1–25

(40) D.E. Jin, S.K. Park, C.H. Park, T.W. Seung, and H.J. Heo, Nutritional compositions of three traditional Actinidia (Actinidia arguta) cultivars improved in Korea, *J. Korean Soc. Food Sci. Nutr.*, **43**(12), 1942–1947 (2014).

(41) M.E. Lane, Skin penetration enhancers, *Int. J. Pharm.*, **447**(1–2), 12–21 (2013).

(42) P.C. Anderson and J.G. Dinulos, Are the new moisturizers more effective? *Curr. Opin. in Pediatr.*, **21**(4), 486–490 (2009).

(43) R. Sarkar, I. Podder, N. Gokhale, S. Jagadeesan, and V.K. Garg, Use of vegetable oils in dermatology: an overview, *Int. J. Dermatol.*, **56**(11), 1080–1086 (2017).

(44) J.W. Fluhr, J. Kao, S.K. Ahn, K.R. Feingold, P.M. Elias, and M. Jain, Generation of free fatty acids from phospholipids regulates stratum corneum acidification and integrity, *J. Invest. Dermatol.*, **117**(1), 44–51 (2001).

(45) C.C. Miller and V.A. Ziboh, Induction of epidermal hyperproliferation by topical n-3 polyunsaturated fatty acids on guinea pig skin linked to decreased levels of 13- hydroxyoctadecadienoic acid (13-hode), *J. Invest. Dermatol.*, **94**(3), 353–358 (1990).

(46) R.C. Barcelos, C. de Mello-Sampayo, C.T. Antoniazzi, H.J. Segat, H. Silva, J.C. Veit, J. Piccolo, T. Emanuelli, M.E. Bürger, B. Silva-Lima, and L.M. Rodrigues, Oral supplementation with fish oil reduces dryness and pruritus in the acetone-induced dry skin rat model, *J. Dermatol. Sci.*, **79**(3), 298–304 (2015).

(47) G.K. Menon, K.R. Feingold, A.H. Moser, B.E. Brown, and P.M. Elias, De novo sterologenesis in the skin, II. Regulation by cutaneous barrier requirements, *J. Lipid Res.*, **26**(4), 418–427 (1985).

(48) G. Grubauer, K.R. Feingold, and P.M. Elias, Relationship of epidermal lipogenesis to cutaneous barrier function, *J. Lipid Res.*, **28**(6), 746–752 (1987).

(49) S. Agatonovic-Kustrin and D.W. Morton, Cosmeceuticals derived from bioactive substances found in marine algae, *Journal of Oceanography and Marine Research*, **1**(2), 106 (2013).

(50) Y. Koo, E.-J. Choi, J. Lee, H.-J. Kim, G. Kim, and S.H. Do, 3D printed cell-laden collagen and hybrid scaffolds for in vivo articular cartilage tissue regeneration, *J. Ind. Eng. Chem.*, **66**, 343–355 (2018).

(51) H. Hong, H. Fan, M. Chalamaiah, and J. Wu, Preparation of low-molecular-weight, collagen hydrolysates (peptides): current progress, challenges, and future perspectives, *Food Chem.*, **301**, 125222 (2019).

(52) Y. Shigemura, K. Iwai, F. Morimatsu, T. Iwamoto, T. Mori, C. Oda, T. Taira, E.Y., Park, Y. Nakamura, and K. Sato, Effect of prolyl-hydroxyproline (pro-hyp), a food-derived collagen peptide in human blood, on growth of fibroblasts from mouse skin, *J. Agric. Food Chem.*, **57**(2), 444–449 (2009).

(53) V. Zague, V. de Freitas, M. da Costa Rosa, G.Á. de Castro, R.G. Jaeger, and G.M. Machado-Santelli, Collagen hydrolysate intake increases skin collagen expression and suppresses matrix metalloproteinase 2 activity, *J. Med. Food.*, **14**(6), 618–624 (2011).

(54) N. Matsuda, Y.-i. Koyama, Y. Hosaka, H. Ueda, T. Watanabe, T. Araya, S. Irie, and K. Takehana, Effects of ingestion of collagen peptide on collagen fibrils and glycosaminoglycans in the dermis, *J. Nutr. Sci. Vitaminol.*, **52**(3), 211–215 (2006).

(55) J. Shimizu, N. Asami, A. Kataoka, F. Sugihara, N. Inoue, Y. Kimira, M. Wada, and H. Mano, Oral collagen-derived dipeptides, prolyl-hydroxyproline and hydroxyprolyl-glycine, ameliorate skin barrier dysfunction and alter gene expression profiles in the skin, *Biochem. Biophys. Res. Commun.*, **456**(2), 626–630 (2015).

(56) A. León-López, A. Morales-Peñaloza, V.M. Martínez-Juárez, A. Vargas-Torres, D.I. Zeugolis, and G. Aguirre-Álvarez, Hydrolyzed collagen—sources and applications, *Molecules*, **24**(22), 4031 (2019).

(57) S.-B. Han, B. Won, S.-C. Yang, and D.-H. Kim, Asterias pectinifera derived collagen peptide-encapsulating elastic nanoliposomes for the cosmetic application, *J. Ind. Eng. Chem.*, **98**, 289–297 (2021).

(58) K. S. Silvipriya, K. Krishna Kumar, A.R. Bhat, B. Dinesh Kumar, A. John, and P. Lakshmanan, Collagen: animal sources and biomedical application, *J. Appl. Pharma. Sci.*, **5**(3),123–127 (2015).

Purchased for the exclusive use of nofirst nolast (unknown)
From: SCC Media Library & Resource Center (library.scconline.org)

(59) J.B. Guillerme, C. Couteau, and L. Coiffard, Applications for marine resources in cosmetics, *Cosmetics*, 4(3), 1–15 (2017).

(60) P.H. Li, W.C. Lu, Y.J. Chan, W.C. Ko, C.C. Jung, D.T. Le Huynh, and Y.-X. Ji, Extraction and characterization of collagen from sea cucumber (*Holothuria cinerascens*) and its potential application in moisturizing cosmetics, *Aquaculture*, **515**(168), 1–8 (2020).

(61) E.G. Brunt and J.G. Burgess, The promise of marine molecules as cosmetic active ingredients, *Int. J. Cosmet. Sci.*, **40**(1), 1–15 (2018).

(62) D. Swatschek, W. Schatton, J. Kellermann, W.E.G Müller, and J. Kreuter, Marine sponge collagen: isolation, characterization and effects on the skin parameters surface-pH, moisture and sebum, *Eur. J. Pharm. Biopharm.*, **53**(1), 107–113 (2002).

(63) L. Uppala, A review on active ingredients from marine sources used in cosmetics, *SOJ Pharmacy & Pharmaceutical Sciences*, **2**(3), 1–3 (2015).

(64) L. Liu, G. Pohnert, and D. Wei, Extracellular metabolites from industrial microalgae and their biotechnological potential, *Mar. Drugs*, **14**(10), 1–19 (2016).

(65) W. Levasseur, P. Perré, and V. Pozzobon, A review of high value-added molecules production by microalgae in light of the classification, *Biotechnol. Adv.*, **41**, 107545 (2020).

(66) S.K. Kim, Y.D. Ravichandran, S.B. Khan, and Y.T. Kim, Prospective of the cosmeceuticals derived from marine organisms, *Biotechnol. Bioproc. Eng.*, **13**, 511–523 (2008).

(67) R.P. Rastogi and A., Incharoensakdi, Characterization of UV-screening compounds, mycosporine-like amino acids, and scytonemin in the cyanobacterium Lyngbya sp. CU2555, *FEMS Microbiol. Ecol.*, **87**(1), 244–256 (2014).

(68) Y. Bu, J. Elango, J. Zhang, B. Bao, R. Guo, K. Palaniyandi, J.S. Rohinson, J. Geevaretuam, J.M. Regenstein, and W. Wu, Immunological effects of collagen and collagen peptide from blue shark cartilage on 6T-CEM cells, *Process Biochem.*, **57**, 219–227 (2017).

(69) E. Jeevithan, J. Zhang, B. Bao, W. Shujun, R. JeyaShakila, and W.H. Wu, Biocompatibility assessment of type-II collagen and its polypeptide for tissue engineering: effect of collagen's molecular weight and glycoprotein content on tumor necrosis factor (Fas/Apo-1) receptor activation in human acute T-lymphocyte leukemia cell line, *RSC Adv.*, **6**(17), 14236–14246 (2016b).

(70) L. Chen, B. Bao, N. Wang, J. Xie, and W. Wu, Oral administration of shark type II collagen suppresses complete Freund's adjuvant-induced rheumatoid arthritis in rats, *Pharmaceuticals*, **5**(4), 339–352 (2012).

(71) E. Jeevithan, C. Sanchez, J.E.M.S. de Val, Y. Henrotin, S. Wang, K.S.C.M. Motaung, R. Guo, C. Wang, J. Robinson, J.M. Regenstein, B. Bao, and W. Wu, Cross-talk between primary osteocytes and bone marrow macrophages for osteoclastogenesis upon collagen treatment, *Sci. Rep.*, **8**(1), 5318 (2018).

(72) E. Jeevithan, J. Zhang, B. Bao, K. Palaniyandi, S. Wang, W. Wenhui, and J.S. Robinson, Rheological, biocompatibility and osteogenesis assessment of fish collagen scaffold for bone tissue engineering, *Int. J. Biol. Macromol.*, **91**, 51–59 (2016a).

(73) E. Jeevithan, J. Zhang, N. Wang, L. He, B. Bao, and W. Wu, Physico-chemical, antioxidant and intestinal absorption properties of whale shark type-II collagen based on its solubility with acid and pepsin, *Process Biochem.*, **50**(3), 463–472 (2015).

(74) J. Tao, Y.Q. Zhao, C.F. Chi, and B. Wang, Bioactive peptides from cartilage protein hydrolysate of spotless smoothhound and their antioxidant activity in vitro, *Mar. Drugs*, **16**(4), 100–118 (2018).

(75) W. Li, N. Terauchi, D. Meng, N. Miyamoto, N. Tsutsumi, K. Ura, and Y. Takagi, Antioxidant and fibroblast-activating activities of the by-product of skate chondroitin extractive production, *Sust. Chem. Ph.*, **23**, 100499 (2021b).

(76) X. Pan, Y.Q. Zhao, F.Y. Hu, and B. Wang, Preparation and identification of antioxidant peptides from protein hydrolysate of skate (*Raja porosa*) cartilage, *J. Funct. Foods*, **25**, 220–230 (2016).

(77) K. Ajisaka, Y. Oyanagi, T. Miyazaki, and Y. Suzuki, Effect of the chelation of metal cation on the antioxidant activity of chondroitin sulfates, *Biosci. Biotechnol. Biochem.*, **80**(6), 1179–1185 (2016).

Purchased for the exclusive use of nofirst nolast (unknown)
From: SCC Media Library & Resource Center (library.scconline.org)

(78) H. Uchisawa, B.I. Okuzaki, J. Ichita, and H. Matsue, Binding between calcium ions and chondroitin sulfate chains of salmon nasal cartilage glycosaminoglycan, *Int. Congr.*, **1223**, 205–220 (2001).

(79) A. Puścion-Jakubik, R. Markiewicz-Zukowska, S.K. Naliwajko, K.J. Gromkowska-Kępka, J. Moskwa, M. Grabia , A. Mielech, J. Bielecka, E. Karpińska, K. Mielcarek, P. Nowakowski, and K. Socha. Intake of antioxidant vitamins and minerals in relation to body composition, skin hydration and lubrication in young women, *Antioxidants*, **10**(7), 1110, 1–16 (2021).

(80) M. Dumoulin, D. Gaudout, and B. Lemaire, Clinical effects of an oral supplement rich in antioxidants on skin radiance in women, *Clin. Cosmet. Investig. Dermatol.*, **9**, 315–324 (2016).

(81) M. Bost, S. Houdart, M. Oberli, E. Kalonji, J.-F. Huneau, and I. Margaritis, Dietary copper and human health: current evidence and unresolved issues, *J. Trace Elem. Med. Biol.*, **35**, 107–115 (2016).

(82) J.-Y. Berthon, R. Nachat-Kappes, M. Bey, J.-P. Cadoret, I. Renimel, and E. Filaire, Marine algae as attractive source to skin care, *Free Radical Res.*, **51**(6), 555–567 (2017).

(83) I. B. Allemann and L. Baumann, Botanicals in skin care products, *Int. J. Dermatol.*, **48**(9), 923–934 (2009).

(84) I. Göllner, W. Voss, U. von Hehn, and S. Kammerer, Ingestion of an oral hyaluronan solution improves skin hydration, wrinkle reduction, elasticity, and skin roughness: results of a clinical study, *J. Evidence-Based Complementary Altern. Med.*, **22**(4), 816–823 (2017).

(85) K. Bhattacharya and V.K.S. Shukla, Mango butter in cosmetic formulations, *International Cosmetic Science Centre*, **117**(6), 65–70 (2002).

(86) D.O. Edem, Palm oil: biochemical, physiological, nutritional, hematological, and toxicological aspects: a review, *Plant Foods Hum. Nutr.*, **57**(3–4), 319–341 (2002).

(87) M. Zagórska-Dziok, D. Furman-Toczek, M. Dudra-Jastrzębska, K. Zygo, A. Stanisławek, and L. Kapka-Skrzypczak, Evaluation of clinical effectiveness of aloe vera—a review, *J. Pre-Clini. Clin. Res.*, **11**(1), 86–93 (2017).

(88) S. Javed and A. Ur-Rahman, Chapter 9: aloe vera in health, food and cosmetics industry, *Stud. Nat. Prod. Chem.*, **41**, 261–285 (2014).

(89) E. Park, H. Ok Kim, M. Shon, J. Song, and G. Kim, Antioxidant activity and personal satisfaction of avocado oil as cosmetic material, *Kor. J. Aesthet. Cosmetol.*, **12**(2), 241–247 (2014).

(90) T.K. Karagounis, J.K. Gittler, V. Rotemberg, and K.D. Morel, Use of "natural" oils for moisturization: review of olive, coconut, and sunflower seed oil, *Pediatr. Dermatol.*, **36**(1), 9–15 (2019).

(91) M. Andreassi, E. Stanghellini, A. Ettorre, A.D. Stefano, and L. Andreassi, Antioxidant activity of topically applied lycopene, *J. Eur. Acad. Dermatol. Venereol.*, **18**(1), 52–55 (2004).

(92) C. Lintas, Nutritional aspects of fruit and vegetable consumption, *Ciheam-Options Mediterranean*, 79–87 (1992), accessed June 21, 2023, https://om.ciheam.org/om/pdf/a19/CI920812.pdf.

(93) S.J. Padayatty and M. Levine, New insights into the physiology and pharmacology of vitamin C, *J. Can. Med. Assoc.*, **164**(3), 353–355 (2001).

(94) Y, Gaofeng, L.W. Mark, H. Guoqing, Y. Min, and L. Duo, Natural products and anti-inflammatory activity, *Asia Pacific. J. Clin. Nutr.*, **15**, 143–152 (2006).

(95) N. Akhtar, A. Mehmood, B.A. Khan, T. Mahmood, H.M.S. Khan, and T. Saeed, Exploring cucumber extract for skin rejuvenation, *Afr. J. Biotechnol.*, **10**(14), 1206–1216 (2011).

(96) B. Özdemir, S. Sevil Yücel, and Y. Okay, Health properties of almond—a review, *Journal of Hygienic Engineering and Design*, **3**(1), 28–33 (2015).

(97) A.N. Yildirim, F. Akinci-Yildirim, B. San, and Y. Sesli, Total oil content and fatty acid profile of some almond (Amygdalus communis L.) cultivars, *Pol. J. Food and Nutr. Sci.*, **66**(3), 173–178 (2016).

(98) W. Bylka, P. Znajdek-Awiżeń, E. Studzińska-Sroka, and M. Brzezińska, Centella asiatica in cosmetology, *Postępy Dermatol. Alergol.*, **30**(1), 46–49 (2013).

(99) S. Mukul, K. Surabhi, and N. Atul, Cosmeceuticals for the skin: an overview, *Asian J. Pharm. Clin. Res.*, 4(2), 16 (2011).

Purchased for the exclusive use of nofirst nolast (unknown)
From: SCC Media Library & Resource Center (library.scconline.org)

(100) F.A. Andersen, W.F. Bergfeld, D.V. Belsito, R.A. Hill, C.D. Klaassen, D.C. Liebler, J.G. Marks, R.C. Shank, T.J. Slaga, and P.W. Snyder, Final report of the cosmetic ingredient review expert panel amended safety assessment of Calendula officinalis—derived cosmetic ingredients, *Int. J. Toxicol.*, **29**(6), suppl.221S–305S (2010).

(101) A.R. Vaugh, A.K. Clark, R.K. Sivamani, and V.Y. Shi, Natural oils for skin-barrier repair: ancient compounds now backed by modern science, *Am. J. Clin. Dermatol.*, **19**, 103–117 (2018).

(102) A.K. Mishra and A. Mishra, Cosmetics for dermal care from marine origin, *Mathews Journal of Dermatology*, **2**(1), 1–3 (2017).

(103) B. Hoyer, A. Bernhardt, A. Lode, S. Heinemann, J. Sewing, M. Klinger, H. Notbohm, and M. Gelinsky, Jellyfish collagen scaffolds for cartilage tissue engineering, *Acta Biomater.*, **10**(2), 883–892 (2014).

(104) V. Shanmugam, P. Ramasamy, N. Subhapradha, S. Sudharsan, P. Seedevi, M. Moovendhan, J. Krishnamoorthy, A. Shanmugam, and A. Srinivasan, Extraction, structural and physical characterization of type I collagen from the outer skin of Sepiella inermis (Orbigny, 1848), *Afr. J. Biotechnol.*, **11**(78), 14326–14337 (2012).

(105) V. Yogiraj, P.K. Goyal, C.S. Chauhan, A. Goyal, and B. Vyas, Carica papaya Linn: an overview, *Int. J. Herb. Med.*, **2**(5), 01–08 (2014).

(106) X.R. Li, C.F. Chi, L. Li, and B. Wang, Purification and identification of antioxidant peptides from protein hydrolysate of scalloped hammerhead (Sphyrna lewini) cartilage, *Mar. Drugs*, **15**(3), 61–77 (2017).

(107) P.-H. Li, W.-C. Lu, Y.-J. Chan, W.-C. Ko, C.-C. Jung, D.T. L. Huynh, and Y.-X. Ji, Extraction and characterization of collagen from sea cucumber (*Holothuria cinerascens*) and its potential application in moisturizing cosmetics, *Aquaculture*, **515**, 734590 (2020).

(108) N. Ionescu (Bordei), G.C. Ivopol, M. Neagu, M. Popescu, and A. Meghea, Fatty acids and antioxidant activity in vegetable oils used in cosmetic formulations, *U.P.B. Sci. Bull. Series B*, **77**(3), 39–48 (2015).

(109) J.Y. Jung, H.H. Kwon, J.S. Hong, J.Y. Yoon, M.S. Park, M.Y. Jang, and D.H. Suh, Effect of dietary supplementation with omega-3 fatty acid and gamma-linolenic acid on acne vulgaris: a randomised, double blind, controlled trial, *Acta Derm.-Venereol.*, **94**(5), 521–525 (2014).

Purchased for the exclusive use of nofirst nolast (unknown)
From: SCC Media Library & Resource Center (library.scconline.org)