Today's vision on environment, health and skin care

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Abstract

Due to an earth always more polluted and a continuous health deteriorating for the stressful way of living, consumers are looking worldwide for cosmeceuticals and nutraceuticals more effective, safe and respective of the environment. Thus a continuous increase of the food, cosmetic market and the global wellness economy evaluated USD 4.2 trillion in 2017.Consumers are further looking for natural-oriented and personalized age-agnostic products which, having an holistic approach, are able to maintain the natural skin and global microbiota, reducing the stress condition tho give emotional and physical benefits at short and long time. Thus, the research for innovative and smart cosmetics, diet supplements and services which, characterized for their high technological quality and the natural ingredients used, are able to maintain beauty and wellness of all the body, improving the general skin conditions. Use and activity of natural polymers such as chitin and lignin and their derived compounds to produce innovative cosmetics and diet supplements are reported and discussed. These natural ingredients are actually of great interest because obtainable as by-products at low cost from food and forestry waste by bionanotechnologies.

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Introduction

Personal health, wellbeing and climate change are projected to have a greater Impact in the next future. Thus, new models and new products able to bring health and wellness, safeguarding the environment and distributed at low cost and at zero waste, will represent the future global cultural stars. Scientists and consumers, in fact, are afraid of the climate changing and push industries to produce high-quality products and services, for reducing the actual air, water and land pollution. Thus, on the one hand the necessity to save water by a fast-rinse or less rinse time technology for washing skin and hair by a product, characterized for its safe and natural ingredients free of aquatic toxicity and at zero-waste for packaging also. On the other hand, the indispensable need to reduce the greenhouse gas(GHG) emissions, fundamental cause of climate changing and the worldwide disasters (1, 2). As a consequence, the necessity to pass from a linear economy of taking, making and producing waste to a circular economy of reducing, reusing and recycling. Thus, by the circular economy will be possible to obtain the 17 sustainable development goals which requested from United Nations (Fig. 1) since 2015, are fundamental to preserve the Planet' environment and reduce the worldwide extreme poverty by 2030 (1).

Fig. 1. *Linear economy versus circular economy and sustainability [by the courtesy of UN (1)].*

However, the actual global wellness industry, evaluated USD 4.2 trillion in 2017, is composed by 10 sectors. These sectors, including personal and beauty care, healthy nutrition, and fitness (Fig. 2), have shown an annual growth rate (CAGR)of 3.6% from 2015 to 2017, representing 3.3% of the global economic output (3).

Fig. 2. *Global Wellness Economy [by courtesy of GWI (3)].*

The soul, beauty and personal care market was expected to register a CAGR of 5.9 % during the forecast period 2018-2025 with a growing preference for natural/organic ingredients and an higher demand for anti-aging products (4).

Personal health and wellbeing, in fact, are the top-of-mind global concerns, so that consumers spending is massively going toward product value, healthy eating and cosmetics quality. But what are consumer expectations? They are looking for novel skincare experiences, high-value skin- and environmentally-friendly products, specifically tailored to their personal needs so that 40% of Millennial consumers (aged 18-34) and 45% of Generation Z (aged 6-24) buy products that make them to look healthier, enhancing their skin conditions (4).The skin, in fact, exchanging and sending out messages, interfaces continually with other organs and the environment, filtering the stimuli that comes from the outside to maintain its homeostasis. For these reasons, nearly half of US women aged 18-34 years have tried to enhance their appearance combining the use of oral supplements and innovative cosmeceuticals to fulfil the dream of beauty from within (Fig. 3) (5).To realize this dream, therefore, it seems possible "to ingest specific prebiotic and probiotic in order

to associate topical and general treatments for improving skin condition without falling into the drugs category" (5, 6).The food functional market, therefore, has risen from USD 8.0 billion in 1996 up to USD 16.1 in 2006, and to USD 177.7 in 2019 with a compound annual growth rate (CAGR) of 8.1% from 2019 to 2025 (7).

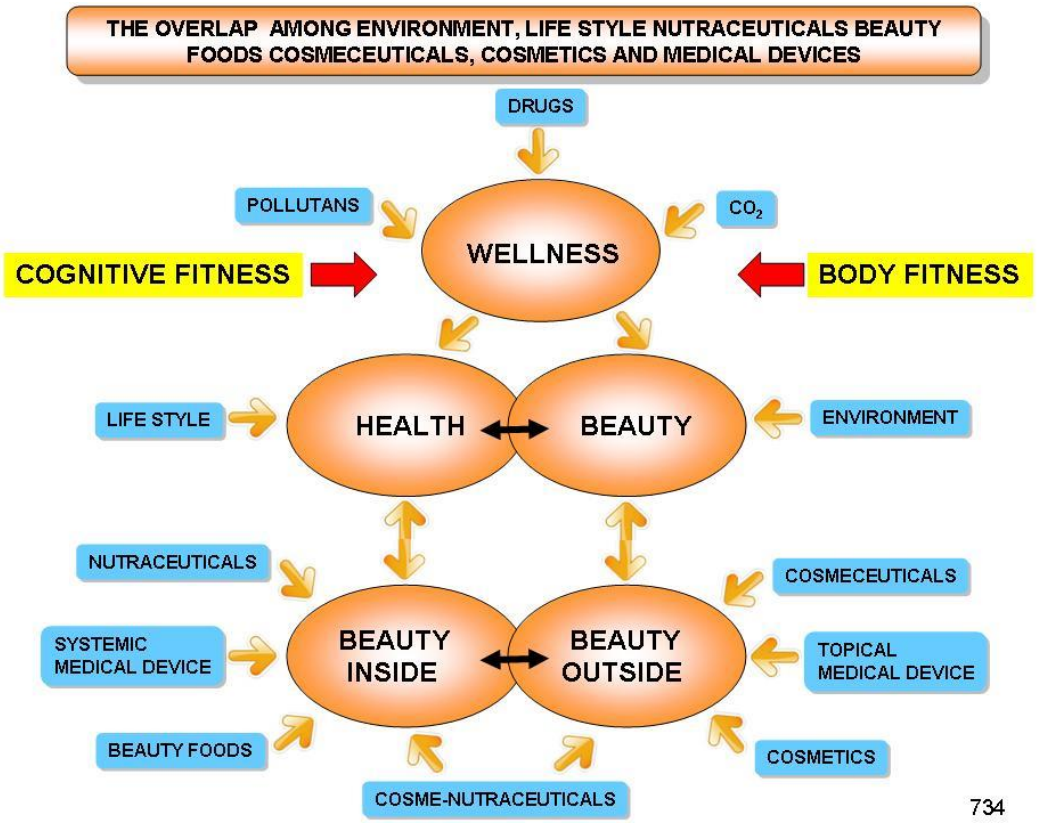

Fig. 3. *Beauty and Health Connection by Cosmeceuticals and Nutraceuticals.*

Thus, the concept of health, wellness and beauty involves not only the skin, but also the entire body. Taking everything into account, this concept is represented by a broad and segmented market, underlined by an emphasis on prevention and maintenance which involve body and cognitive fitness without use of drugs (4, 5). At this purpose it is to remember that human body host 1.5Kg of microorganisms, part of which are located on the skin and scalp surfaces or under the epidermis. Therefore, skin microbiota, represented from pathogen(disease) and saprophytic(helpful) microorganisms, changes throughout a person' lifetime, according to age, diet, environment and lifestyle. Moreover, it may vary from individual to individual and in different anatomical areas, being gender-dependent also (6, 8). It is, therefore, a major player in establishing and maintaining skin health, so that 78% of consumers agree to the necessity to maintain balanced skin and hair microflora by specializes diet supplements or cosmetics. So doing it will be possible to

avoid the bacterial and fungal dysbiosis which, exacerbated by a polluted environment, could cause for example scalp dandruff and seborrheic dermatitis (9). Moreover wellbeing could be considered the result of the many interactions between genetic and external environmental factors which, having the possibility to augment or reduce the gene impact, account 10-15% of the human health outcomes (10).

Human lifespan, in fact, determined by both genes and external influences, acts by means of genetic pathways regulating the cellular processes, cause of aging and death. Thus, the environmental conditions are of great importance for humans also, because no living organism is able to live and survive in an environment completely different from that to which is genetically adapted.

Consumer expectations

As previously reported, consumers are looking for cosmetics and diet supplements which, with a rinsing awareness regarding microbiota balance, can protect health and environment. These products would be characterized by a real clinical effectiveness and safeness, and therefore studied and verified by in vitro and in vivo methodologies (11). Unfortunately, many are the skincare products controlled only by in vitro methods and some time by in vivo ones, too often realized by a small number of subjects. Furthermore, some of these cosmetics, are sold and publicized by marketing claims attesting to possess, for example, anti-aging effectiveness, only because formulated with ingredients effective to positively modify the cell turnover. Thus, the definitions of cosmeceuticals and nutraceuticals which, coined many years ago from Albert Kligman in 1984 and Stephen De Felice in 1989 respectively, should be characterized for their effectiveness and safeness, documented, and verified by the same scientifically correct pharmaceutical methodologies used for the drugs (12).

In any case, these terminologies, while not officially recognized by the international laws governing cosmetics and diet supplements, are normally accepted from dermatologists, nutritionists, and marketing managers to define cosmetic/food products showing a pharmaceutical effectiveness (12-14). Thus, according to current EU and other international laws a cosmetic product is (15):"any substance or mixture intended to be placed in contact with the external parts of the human body.... or with the teeth and mucous membranes ...with a view exclusively or mainly to cleaning them.... changing their appearance ...and/or protecting them or keeping in good condition".

On the other hand, the diet supplements, legally recognized as foodstuffs with the indication to supplement the normal diet by concentrated source of nutrients, may claim their specific effectiveness (as slimming, anti-aging etc) showing and documenting their activity by in vitro and in vivo studies, to be successively approved by a special official EC commission (16, 17). In conclusion for consumers wellness has to be considered as the active full complement of multifaceted activities, encompassing physical, mental, emotional, social, environmental and spiritual dimensions (3, 10). Thus food, cosmetics, exercises, and all the other living activities are considered necessary means for the daily life. Therefore, it must be recognizing the impossibility

to live a full life without a healthy body, mind, and spirit because all humans, animals and plants are interconnected in a natural world. Therefore, wellness is a salutogenic approach focused on prevention and healthy lifestyle, so that longer-term physical and mental benefits are better than looking good. Consequently, in 2018 the global beauty and personal care market and the food functional market have been evaluated to reach from by 2025 USD 717, 6 billion and USD 275, 77 respectively with a CAGR of 5.9% and 7.9%, while, for example, the EU fitness market in 2018 had a growth of 1.2% with a revenue of ₁27.2 billion and a number of 61, 984 clubs, located across all the countries (18-21).

Consumers are trying to personalize both life and products, looking for cosmetics which, allowing them to express their individuality, improve the environmental sustainability eliminating the invasive and dangerous plastic waste (22-24).Therefore, their investments are oriented in high quality products, including reuse and recycling whatever possible, while the mental, spiritual and physical balanced status remain the priority (24, 25).Thus the health habits and attitudes are an important aspect of consumers' lives influencing their decisions so that Generation Z, Millennials and Baby boomers, (54-74 years old) are looking at health with a more holistic view (26, 27). However, Baby boomers, who define themselves as the forever young, have many values and priorities in common with Millennials and younger generations, focusing their life on prevention and enjoyment of life (23-25). They, in fact living much longer, don't want to feel old and may be defined age agnostic for their dream to remain active, contributing to the society progress, thus maintaining an ageless attitude towards life. Over 50% of the global consumers, however, claiming to suffer from moderate and high stress levels, wish to live by a more balanced lifestyle, simplifying their lives and spending more time on themselves (25, 26). Among the other Millennials, accounting for about 32% of the world's' population and being the largest demographic group in USA, show to prefer their "appearance", thus representing the largest potential group buying beauty and personal care products (22, 25). It is interesting to underline that, in 2019 in China also , Millennials and Generations Z, living prevalently in urban areas (60%) and accounting for almost 40% of the population, have spent more than 50% of their income for beauty and personal care cosmetics, looking for high quality products for babies and pets also (27). Moreover they have a strong attachments for smartphones used to buy products and services (27). However, it is to underline once again that global consumers demand and are willing to pay more for products which, preserving the natural resources and maintaining a long-term ecological balance, result necessary to maintain a healthier built environment (10).

Chitin nanofibrils, nano-lignin and derived-complexes

Among the natural industrial bio-ingredients useful to produce innovative cosmeceuticals, nutraceuticals, would dressings, and/or air/water purification agents, there are chitin and lignin, obtainable from waste materials at low cost (28, 29).

They are the most abundant biopolymers present in nature, having an increasing market for their

multiple use in different fields and to be easily obtained from food and forestry waste. Moreover, the possibility to make both chitin and lignin in the nano size and purity form has further increased their utilization in pharmaceutical, food and cosmetic sectors (30, 31).

Chitin

Chitin is synthesized in nature as a linear biopolymer composed of many acetyl-glucosamine units linked by 1-4 beta bonds. It may be easily produced industrially in the form of micro/nano fibrils (i.e. chitin nanofibrils) which, partially deacetylated, are characterized by the presence of 40 to 60 % of glucosamine units, the percent of which is depending from the technological process adopted(Fig. 4) (32).The totally deacetylated, chitin is named chitosan, characterized by 60 to 90% of glucosamine units (Fig. 4) (32).

Fig. 4. *Chemical structure of chitin with glucosamine and acetyl glucosamine groups (left) and chitosan group (right).*

Chitin, present as structural structure in crustaceans shells, insect cuticles and cell wall of fungi, is a biocompatible, biodegradable, and nontoxic polymer made by linear macromolecules joined by hydrogen bonds to form, ordered crystalline and amorphous structure organized by microfibrils (Fig. 5).

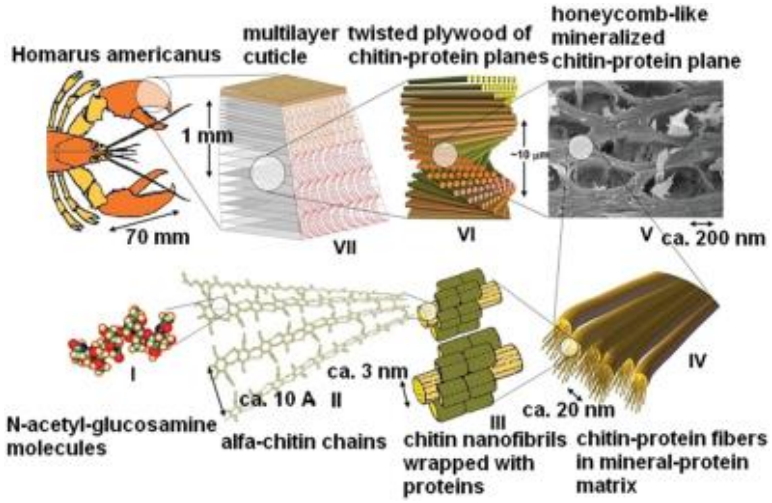

Fig. 5. *Structure organization of chitin nanofibrils in nature (by personal courtesy of D. Raabe et al)..*

The nanofibrils, industrially produced (Fig. 6), have a mean dimension of 240x 5x7nm and a crystalline structure covered by positive electrical charges on their surface. According to fibril size, micro/nano dimension and electrical charges of the carrier-nanoparticle used, CN, the derived compounds and/or micro-complexes may disrupt the skin barrier, penetrating through its layers, releasing the loaded active ingredients.

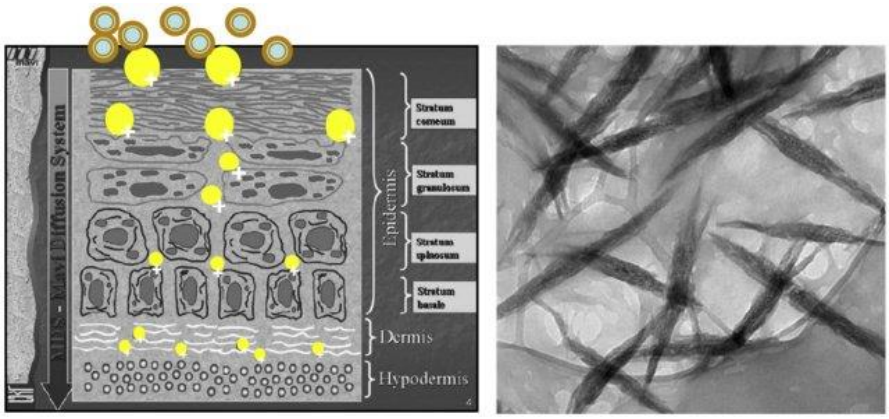

Fig. 6. *Chitin nanofibrils produced in lab at SEM (right) and their skin penetration degree (left). The Brown particles, negatively charged remain on the skin surface, while the yellow ones positively charged may penetrate less or more deeply, according to their dimension also.*

Due to the different polarities, in fact, it is possible to make a CN-nanolignin (NL)compound, complexing, for example, the electropositive CN with the electronegative hyaluronic acid (Fig. 7), which previously can be loaded with different bioactive ingredients. At this purpose it is interesting to underline that chitin: (a)when produced industrially as Chitin nanofibrils, loses not only its pro-inflammatory characteristics becoming an anti-inflammatory agent, but also its allergenic character. During the many purification steps necessary for its production process, in fact, CN loses the protein content wrapping the natural fibrils (fig 8), and it is these wrapped proteins that are responsible for seafood intolerances and allergic reactions, often recovered by dermatologists on many subjects (33, 34).

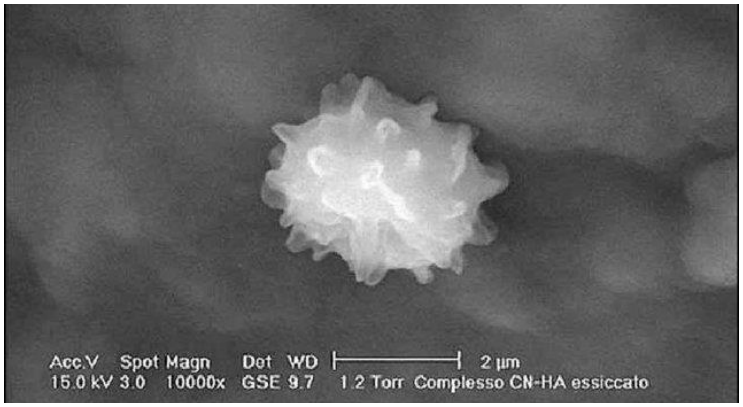

Fig. 7. *Chitin nanofibrils-hyaluronic acid complex at SEM.*

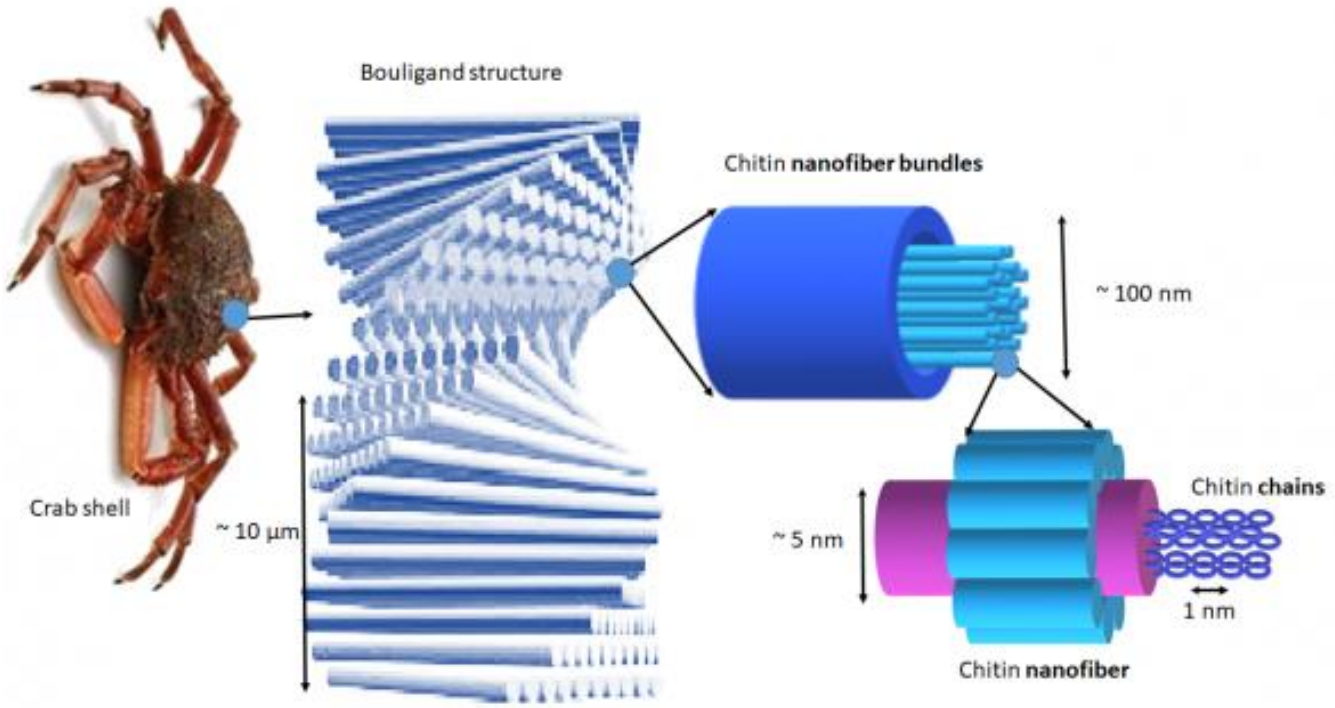

Fig. 8. *The chitin fibril wrapped by proteins*.

The minor or major presence of OH- and -NH2 groups in the chain molecular structure of both chitin and chitosan (Fig. 4) opens the door for their many industrial and biomedical applications by the obtainable derived compounds .Moreover their different use depend not only from the acetylation and polymerization' degree, but also from other important parameters such as molecular weight, crystallinity, solubility, environmental pH, surface area, etc

Additionally, and depending upon the chains' disposition and bonding, chitin may be recovered in nature in alpha, beta and gamma polymorphic form, the more frequent and used resulting the alpha ones (35).

For all the reasons previously reported, the global market of alpha chitin and chitosan evaluated USD 6.8 billion in 2019, is expected to expand at a revenue based CAGR of 24.7% between 2020-2027(36). This growth will be determined from the growing Industrial applications in water treatments, pharmaceutical, biomedical, cosmetic and food. One of the key factors steering the demand of these polymers is their easy availability from the industrial fishery waste and the increasing use as chelating, coagulating and flocculating agent to purify water. Moreover, they are massively used as antimicrobial and anti-inflammatory agents in food packaging as well as cosmetic active ingredient and carrier in the increasing cosmetic natural market .The global Cosmetic natural market size, estimated 34.12

billion in 2018 with a CAGR of 5.01% from 2019-2025 (Fig. 9) (37), has expected in fact to drive the growth of the wellness and beauty sector for the increasing request of natural-oriented, skin-friendly and environmentally -friendly products. About the worldwide involvement, Asia Pacific emerged as the largest regional market in 2019, owing to the rapid development of end-use industries in Japan, China, India and South Korea.

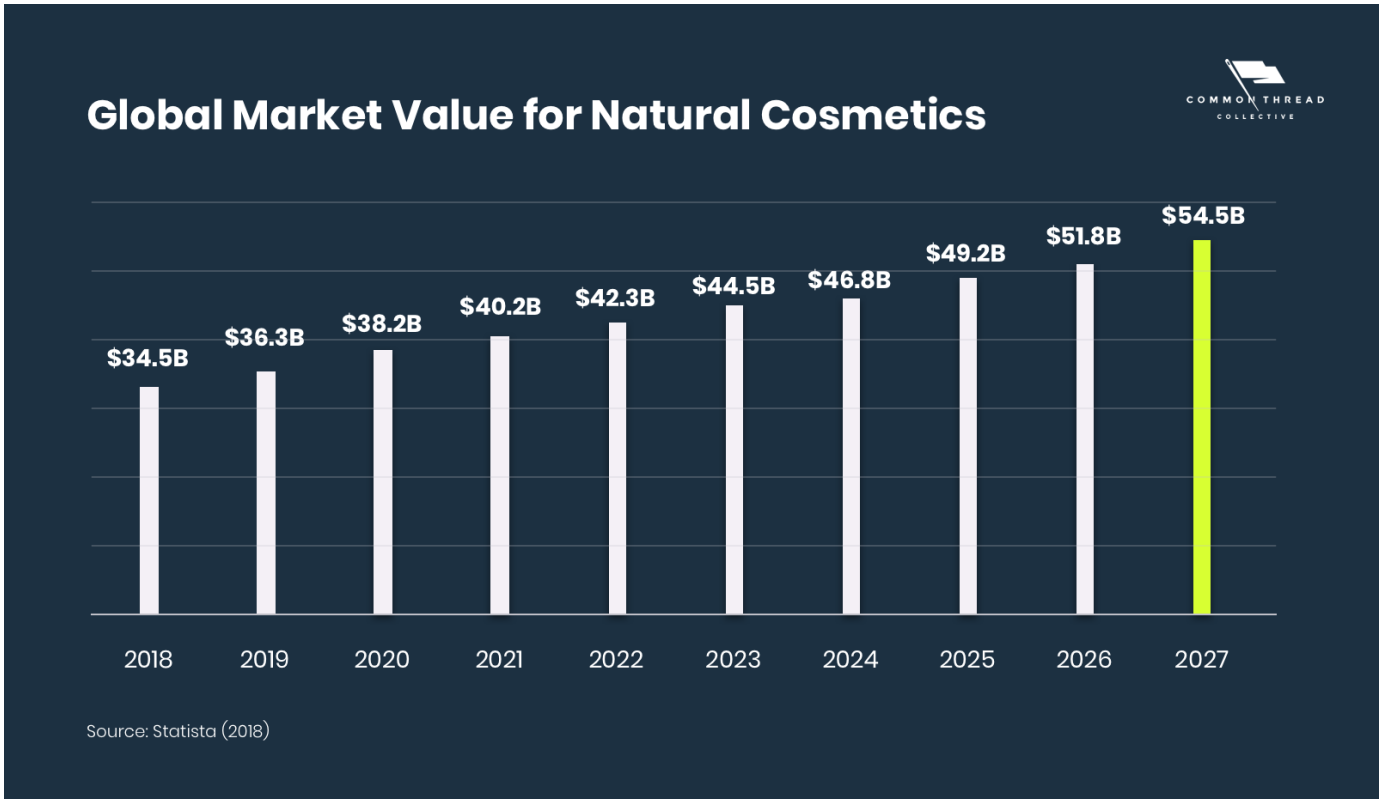

Fig. 9. *Global value of natural Cosmetic (by courtesy of Statista).*

Lignin

Lignin, constituting from 20 to 30% of the earth plant biomass, is a complex structure made of three different type of monolignols :p-coumaryl-, coniferyl- and synapil alcohol, the ratio of which depends from plant type and the extraction method used (Fig. 10) (29). This natural polymer, rich of phenolic and chromophore groups with antioxidant and UV-blocking properties respectively, represents the integral part of the secondary cell wall of living plants like trees and grasses, being one of the most abundant organic polymer in the earth (29).

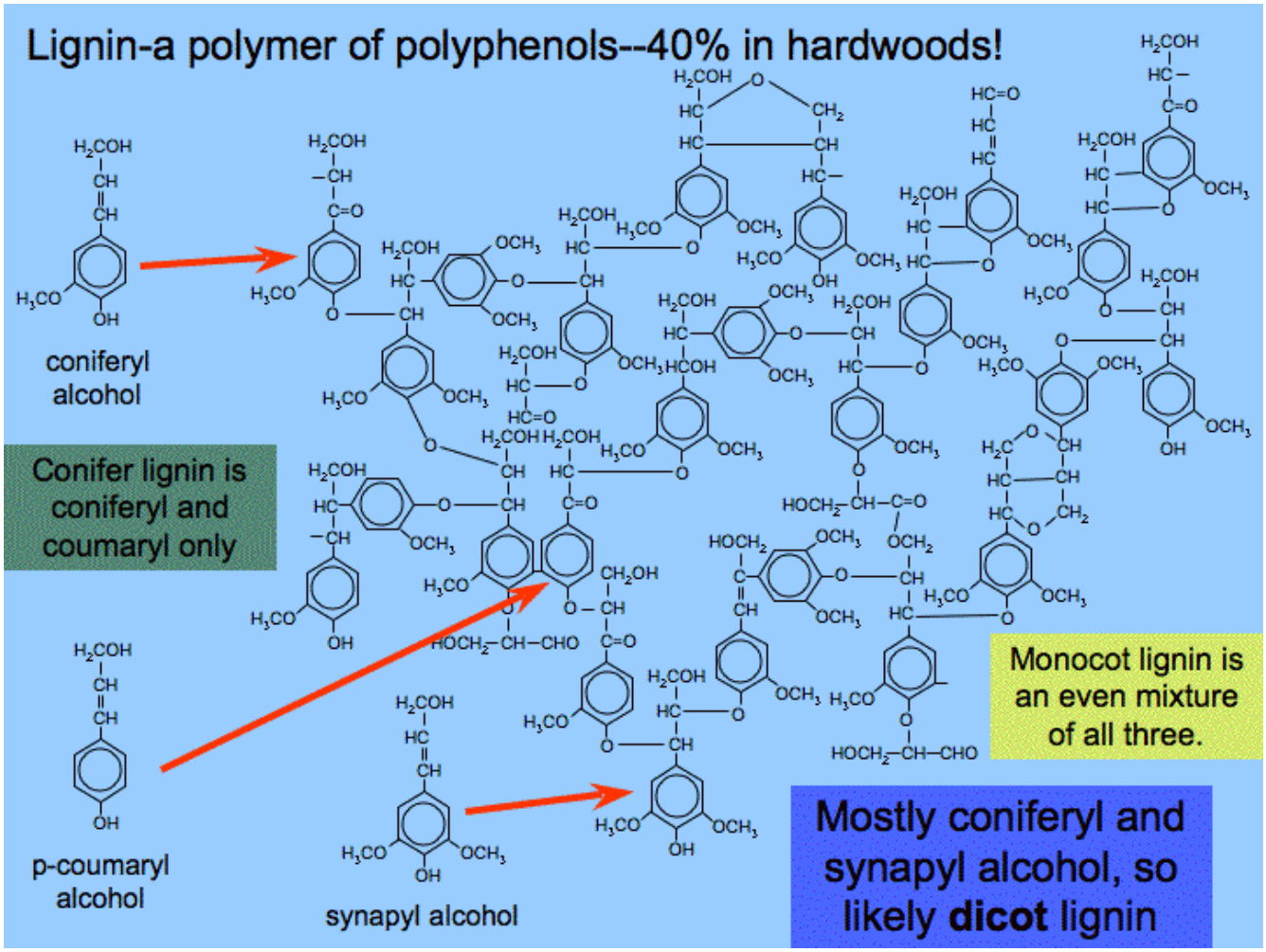

Fig. 10. *Lignin structure.*

Lignin, covalently linked to cellulose and hemicellulose and cross-linked to different plant polysaccharides to form a three-dimensional amorphous structure, acts as a glue and confers mechanical strength to the cell wall, similarly to chitin as principal structural polysaccharide of the arthropods (32). Thus, the polymer, containing a vast amount of the world's carbon and possessing a great antioxidant, antibacterial and light protective properties, may be utilized to replace many petrol chemical-based products used in the everyday life. However, depending also to its structure and purity, the polymer and its derivatives are used principally in the medical and cosmetic sectors, because of their versatility to produce wound dressings, drug and cosmetic delivery systems, and innovative materials to remove air/water toxic ingredients (29-31, 38). Lignin, in fact, modifying its native structure when extracted as a by-product from the plant biomass during the industrial pulp (70 million tons per year) and paper process, is purified before its use and may be transformed in its nano size (39). As such, it may be used as composite or complexed polymeric compound when bound to other ingredients as chitin and chitosan to make

a biomedical or cosmetic gel and tissue, used as high-performance broad-spectrum sunscreen emulsion or drug/cosmetic delivery carrier (39-41). However for a better utilization of the polymer, due to the high chemical variability of its complex molecular structure, it should be necessity to understand how the productive process could affect the reaction mechanisms and structure-properties of lignin, first of all when used in human health for its biological properties.

Thus, the global market size of this natural polymer has been estimated in 2019 at around USD 1/1.5 billion and is expected to expand at a CAGR of 2 % in term of revenue from 2020 to 2027(42).Because of the increasing demand for animal feed and macromolecules and aromatics' production, used in the development of bitumen, biofuels, pharmaceuticals and cosmetics, it is anticipated that lignin will drive the market growth, also if 2% only of the polymer is used for value-added products. About the regions involved, Asia Pacific is anticipated to witness the fastest growth over the forecast period, as a result of its rapid industrialization and rinsing demand for electronics and automobiles also. On the other hand, it has been estimated a rapid growth of the EU market because of the favourable regulatory framework facilitating the use of lignin as alternative raw material to produce biopolymers and bioplastics.

Conclusion

The Beauty and health market has been rapidly evolving with the rise of social media opening an interesting discussion around beauty products, skincare, wellness and the environment, playing an increasing role in educating consumers about the activity of this category of products. The today community is represented by new consumers 30% of which, exploring the push-off between nature and science, and looking for cosmetics effective for their needs, are fitting into the digital beauty consumer segment. However, they show a high interest on the environmental pollution and waste, being particularly worried about the health of both their skin and hair, affected by microbiota, stress and aging (6, 8, 43).

Some bacteria, in fact, providing relief for skin concern that involve a poor barrier activity, could ameliorate its function by the use of smart cosmeceuticals and nutraceuticals. But to find the wright solutions it should be necessary to better understand the condition in which microbes are beneficial or harmful to the skin, what's their unbalance and how to rebalance them (8, 9, 44). Thus, the increasing skincare sustainability is becoming a global consumer priority, pushing beauty products and apparel towards new sustainable innovations (45). Sixty percent of global consumers, in fact, are worried about climate changing and the wrong way of producing and consuming goods, so that 55% think that their purchases could have a positive contribution to ameliorate the general condition of our planet. Moreover, half of them, as previously discussed, claim to use do-it-yourself beauty products at least once a month not only to customize and personalize the products used, but also to take back control over they are putting on their own skin (22, 23). For these reasons,

the necessity to make and use nature-oriented products realized by a circular economy at almost zero waste.

A new productive method could be metabolically engineering the bacteria by biorefinery technologies, involving these microorganisms to produce bio-compounds realized by a low-carbon emissions. This is an innovative method to obtain new ingredients by a molecular machinery able to make them in a safe, inexpensive, and fast way. Moreover, it is possible to produce active ingredients and biological carriers using agro-forestry and food by-products based on the use of waste biological materials. Thus as previously reported, the possibility to produce smart emulsions and tissues (Fig. 11) by polymers such as chitin and lignin which used as active carriers, may be applied on the skin surface or taken by oral route as innovative cosmeceuticals and nutraceuticals (46-48).These smart cosme-nutraceuticals, produced indifferently by water soluble and insoluble natural polymers by innovative bionanotechnologies, are not only biodegradable, skin- and environmental-friendly, as requested from scientists and consumers, but may be also used as drug/cosmetic carriers as well as to produce one day use beauty/surgical masks and medical dresses (48).

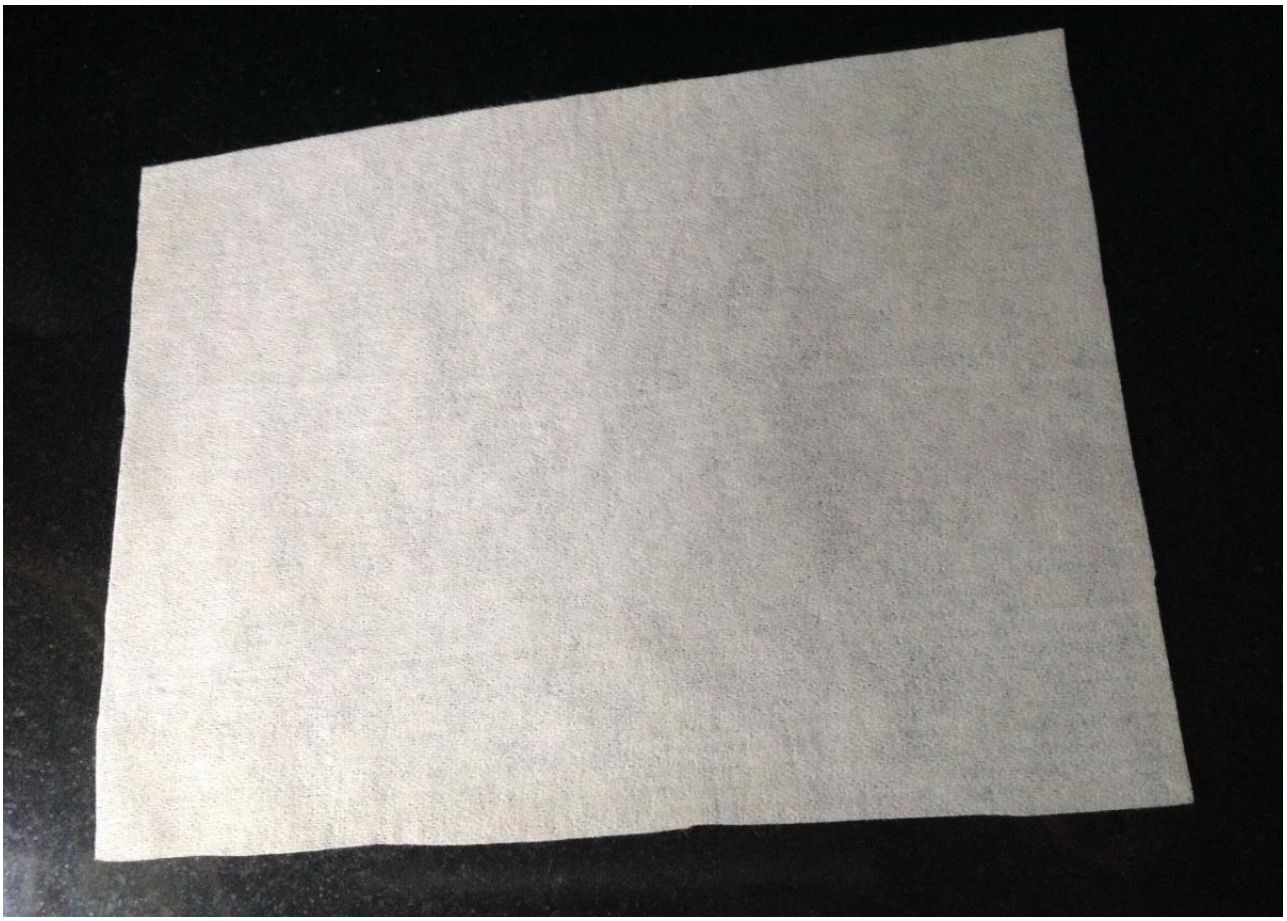

Fig. 11. *Biodegradable natural-oriented non-woven tissue made by chitin nanofibrils-lignin.*

In conclusion protecting health, beauty and the environment by the introduction of a circular economy characterized by a reduced production and consumption of plastics and production of zero waste, is the actual expectations and vision of scientists, industries and consumers. The result will be a more pleasant and living Planet with the maintenance of the natural raw materials and its important genetic, species and ecosystem biodiversity (Fig.12) (49). So doing it will be possible to improve health, food and water security, and mitigate climate changing, thus contributing to a sustainable development (1, 48, 50-52).

Fig. 12. *Global earth biodiversity.*

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