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Article

Microplastics and cosmetics: Problems and solutions

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Abstract: Plastic waste and microplastics are invading lands and oceans, creating problems for animals, human health, and the environment. Packaging, building and construction, textiles, and cosmetic sectors are the main industries that utilize these non biodegradable materials. Thus, there is a necessity to find a new way of producing and consuming skin- and eco-compatible' goods. For this purpose, it's important to remember that the cosmetic and diet supplement markets are continually increasing, due also to the introduction of "Beauty from within," based on the contemporary consumption of cosmeceuticals applied to the skin and nutraceuticals taken by oral route. Moreover, both of these products are made by emulsions or solutions based on a great consumption of water with the use of carriers rich in chemicals, which often cause allergy and sensitization problems. Thus, the proposed solution to use smart tissue carriers, which are embedded with natural ingredients, is based on the use of raw materials and biopolymers obtained from food and agroforestry waste. These new carriers, with a structure similar to the Extra Cellular Matrix, may be used to realize smart cosme-nutraceuticals useful to reduce water consumption, producing innovative products free of emulsifiers, preservatives, colors, fragrances, and other chemicals. So, it will be possible to save human health and the environment by maintaining natural raw materials and the biodiversity of the earth for future generations.

Keywords: cosmeceuticals; nutraceuticals; chitin nanofibrils; nano lignin; waste; microplastics; cosmetic market; diet supplement market; water consumption; skin and mucous barriers

1. Introduction

As known, production and consumption of cosmetics contribute to the microplastics released into the oceans as microbeads by materials used for making buildings and producing foods, cosmetics, packaging, and tissues, all impacting the environment and human health (**Figure 1**) [1]. Microplastics are defined as plastic fragments with a size lower than 5 mm. They released into the oceans have reached the number of 24.4 trillion with a weight between 82 and 578 million tons and an estimated increase of 4.8 to 12 million tonnes yearly (**Figure 1**) [2,3]. This great quantity of plastic microparticles, ingested by fish and marine mammals, enters the food chain up to the human food. In fact, microplastics have been recovered into tea cups, placentas, blood, and drinking water [4–7]. It is suspected that they can act as vectors for potentially toxic elements such as Fe, Mn, Sl, S, Pb, Cu, Ag, and Zn and contaminants, including polychlorinated bisphenols and phthalates utilized to make some kind of plastic packaging [8,9]. Textiles can be considered the primary source of microplastics because they are generated during their washing. While the presence

of plastic items in land and ocean can be limited by increased education and new technologies, the microplastics due to the textiles' use cannot be eliminated easily, hence an increased use and consumption of fashionable clothes based on biobased fibres (degradable in water) are promoted day by day [10].

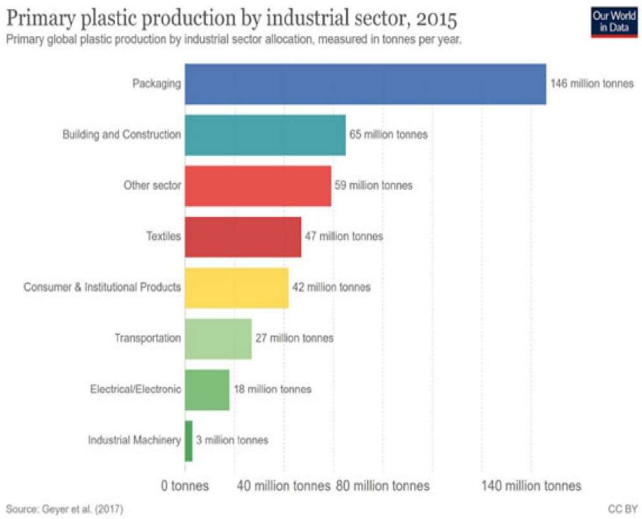


Figure 1. Plastic industrial production cause of the microplastics' release (courtesy of Richie and Roser-Our World in Data [3]).

Regarding the cosmetic products, the global market was valued at USD 375.30 billion in 2022, and it is expected to expand to USD 560.50 by 2030 with a compound annual growth rate (CAGR) of 5.1% from 2021 to 2030 (**Figure 2**) [11]. The principal key factors driving the market are the global aging population and the rapidly changing lifestyle with the adoption of skin care and personal care products by aged and young consumers, driven by social media and the increasing e-commerce [11,12].

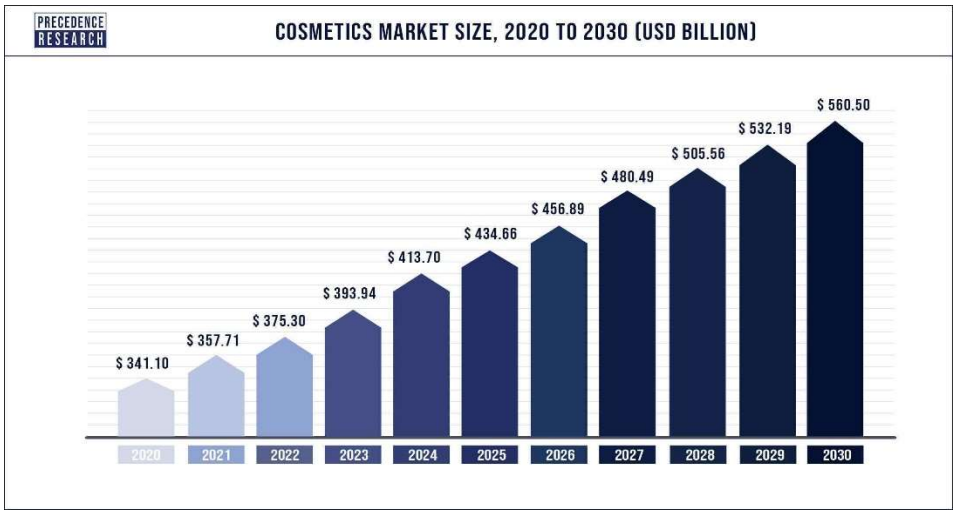


Figure 2. Global cosmetic market (courtesy of Precedence Research Company) [12].

Moreover, for maintaining the actual health and beauty, the so-called "Beauty from within" has born, based on the integration of cosmeceuticals applied to the skin with nutraceuticals (functional food) taken by oral route. Thus, it will be possible to obtain the global health and beauty of the body, acting contemporarily from inside and

outside, by the use of the so-called nutricosmetics [13]. Consequently, it could be useful to add the cosmetic market size (USD 376) to the nutraceuticals ones (USD 493) (**Figure 3**) [9] for understanding the real value of the global beauty healthy market, which, from USD 870 billion in 2022, has been valued to range from USD 1553 billion by 2030 [12,14].

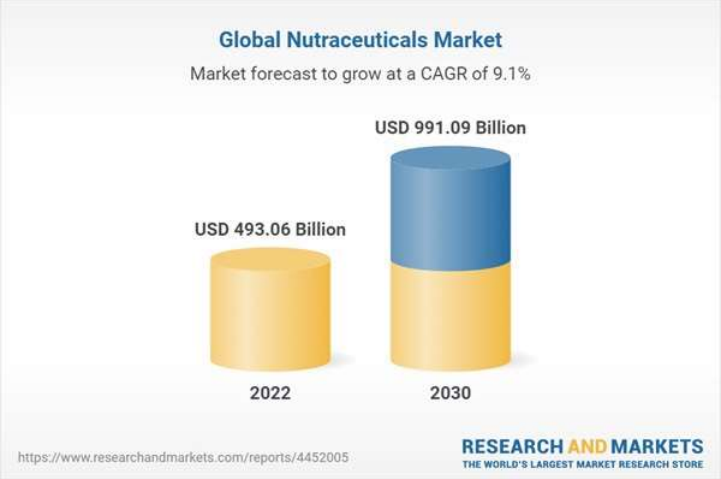


Figure 3. The global nutraceutical market (courtesy of Research and Markets [14]).

At this purpose, it is important to underline that both these products may contain and are packed by plastic polymers such as polyethylene and polypropylene, remembering that the beauty industry only produces more than 120 billion units of not recyclable plastic packaging every year [12,15].

Consequently, it has been valued that the global bottles into which cosmeceuticals and nutraceuticals are filled up will range around 480 billion units by 2029, from the actual 240 billion ones. Moreover, the bottles' fossil origin and limited recyclability due to their incineration and contamination with the product also result in further greenhouse gas emissions.

Therefore, there is the urgent necessity to increase production and use of biobased and biodegradable polymers for realizing innovative skin- and eco-friendly cosmeceuticals and nutraceuticals by sustainable productive processes, reducing the great micro nanoparticles invading the oceans also [1–3,15].

2. Cosmeceuticals & nutraceuticals needs

As a consequence, the consumer request for cosmeceuticals and nutraceuticals that are skin- and eco-friendly is continually increasing. These specific products, in fact, are considered made by natural and biodegradable ingredients, carriers, and packaging and therefore characterized for their high effectiveness and safety [16–19]. However, to be effective, both ingredients and carriers must be capable of passing throughout the keratin-lipid matrix of the skin lamellar membranes as well as the glycoproteic polymer and fibers forming the mucous barrier, possibly maintaining balance in the physiological activity of the microbes living on their surface (**Figure 4**) [19–21].At this purpose, in fact, it results of fundamental importance not only the active ingredients' selection but also the different carriers (vehicles) used because, driving the penetration of the active molecules through the skin and mucous

membrane' barriers, have the possibility to give effectiveness and texture to the final formulation [19–21].

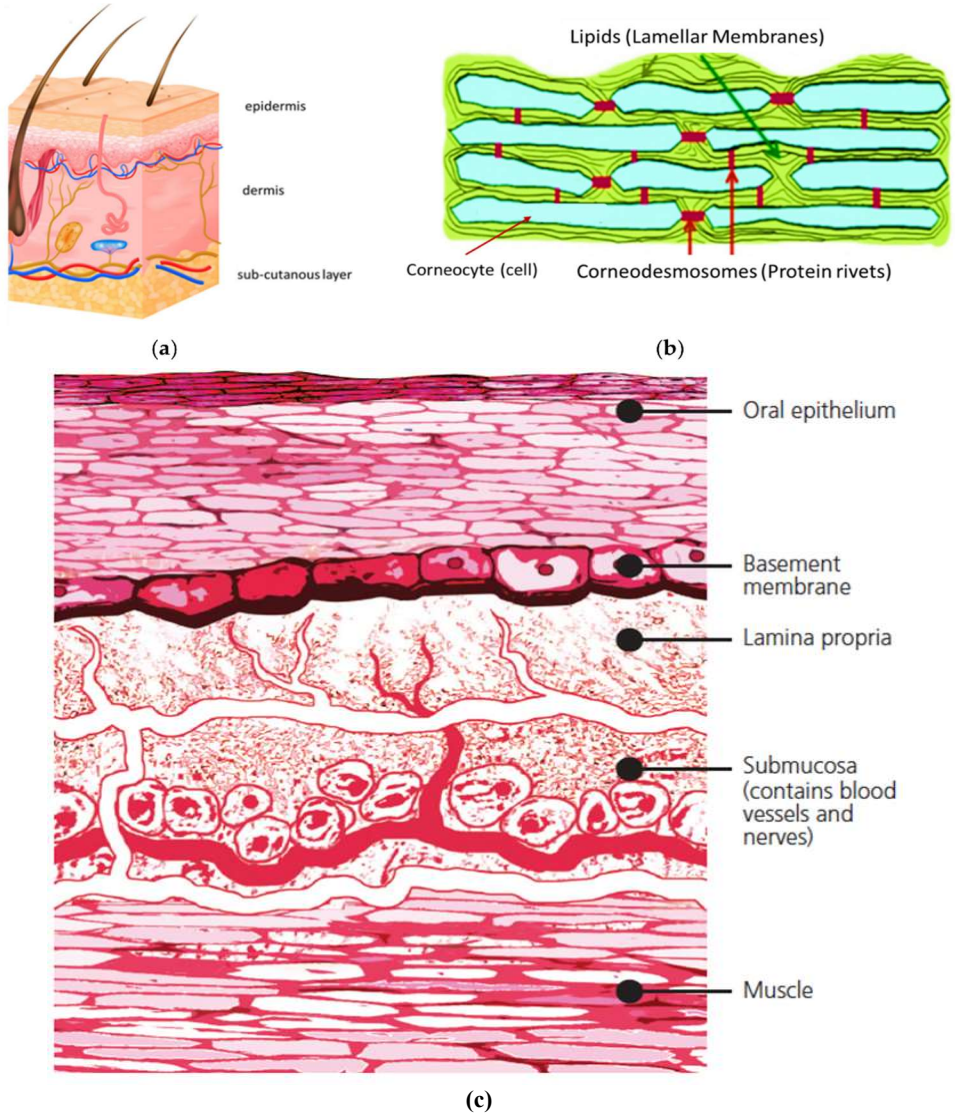


Figure 4. (a) skin structure; **(b)** corneocytes organized by lipid lamellae; and **(c)** the mucous membrane.

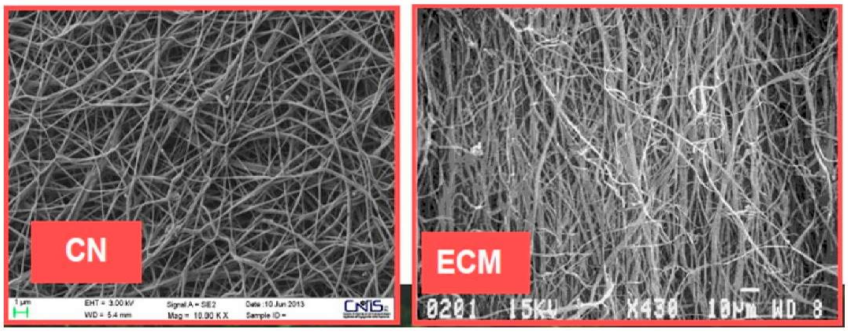
Skin lipid lamellae and oral epithelium, in fact, modulate the penetration of active ingredients depending on the carrier used naturally; all the selected ingredients have to be biodegradable and obtained possibly by food and agro-forestry waste for maintaining the natural sources and the planet's biodiversity for future generations [22].

It is important to remember, in fact, that "nature and biodiversity loss is a material risk to climate stability, economy and financial increasing and to the global development". Therefore, protection of biodiversity safeguards climate too, avoiding planet disasters [22]. Unfortunately, the great problem of the biodegradability of both cosmetics and nutraceuticals' packaging is practically not solved, and the use of non-biodegradable plastic polymers increases year by year. Consequently, polyethylene (PE) dominates the composition of plastic waste at lands and oceans, followed by

polypropylene (PP) and polystyrene (PS), contributing to the reported formation of microplastics [23]. Moreover, the many and different active ingredients, formulating the majority of all the so-called nutri- and eco-cosmetics (combined use of cosmeceuticals and nutraceuticals) carried by emulsions based on the use of preservatives, emulsifiers, fragrances, colors, and other chemicals, are often causes of allergic and sensitizing phenomena [24], being packaged in non-biodegradable plastic containers also. Thus, as previously reported, consumers are looking for the so-called "clean beauty" and "beauty from within" focusing their purchases on products that, free of common harmful ingredients and made with less plastic materials, renewable energy, and regenerative ingredients, release less waste and are skin- and environmentally friendly [12,25–28]. The majority of the nutricosmetics, in fact, are packed by plastic polymers such as polypropylene and other plastics, including PET and acrylic ingredients. By all these considerations, our proposed solution is reported soon after. It is based on the production of smart tissues as novel carriers to make innovative cosmetic and nutraceutical vehicles that, alternative to the actual emulsions, could be packaged by simply paper also [19].

3. Proposed solution

To partially solve some of these problems, our research group has proposed to substitute the carrier emulsions of the active eco-nutri-cosmetics with natural biodegradable tissues, which, made by the electrospinning technology, result characterized by the same morphology of the extracellular matrix (ECM) (**Figure 5**) [19,29–33]. Moreover, due to the natural ECM similarity of these innovative tissues, the skin layers' penetration seems to be more interesting and effective [28–33]. Finally, during the electrospinning process, the block-polymeric micro-nano particles have been bound to the polymer's fibers by a patented technology able not only to create stable micro-nanoparticles but also to encapsulate various active ingredients utilizing water as solvent only [29–33]. It is also interesting to underline that, while to produce one cosmetic product (emulsion or shampoo), it seems necessary to consume between 60 and 90 mL of water, to make a piece of the new tissue carrier, the necessary water should be around 0.5 mL. In conclusion, the quantity of water necessary to produce the supposed 120 billion units per year of cosmetic products made by the reported tissues will be around 60 tons in comparison with the normal emulsions, for which it will be necessary to consume around 9 million tons.



(a) **(b)**

Figure 5. (a) structure at the SEM of the proposed tissue (CN); **(b)** compared to the Extracellular Matrix (ECM).

By our technology, the electrospun tissues have been functionalized by embedding the fibers with chitin nanofibril-nanolignin or chitin nanofibril-yaluronan block polymeric complexes (**Figure 6**). These complexes have the possibility to encapsulate different active ingredients, necessary to characterize the final product: cosmeceutical or nutraceutical [32–34]. It is interesting to underline that these smart tissues, made by biodegradable water-soluble or water-insoluble polymers embedded by selected active bio-ingredients, may be applied on the skin and/or on oral mucous membranes, acting as tissue-regenerative products [32–35]. Moreover, the usual non-biodegradable polypropylene support, normally utilized for the non-woven tissues made by the electrospinning technology, has been substituted by a biodegradable bamboo tissue, rendering globally biodegradable the final product for both the ingredients used and the packaging materials [36,37].

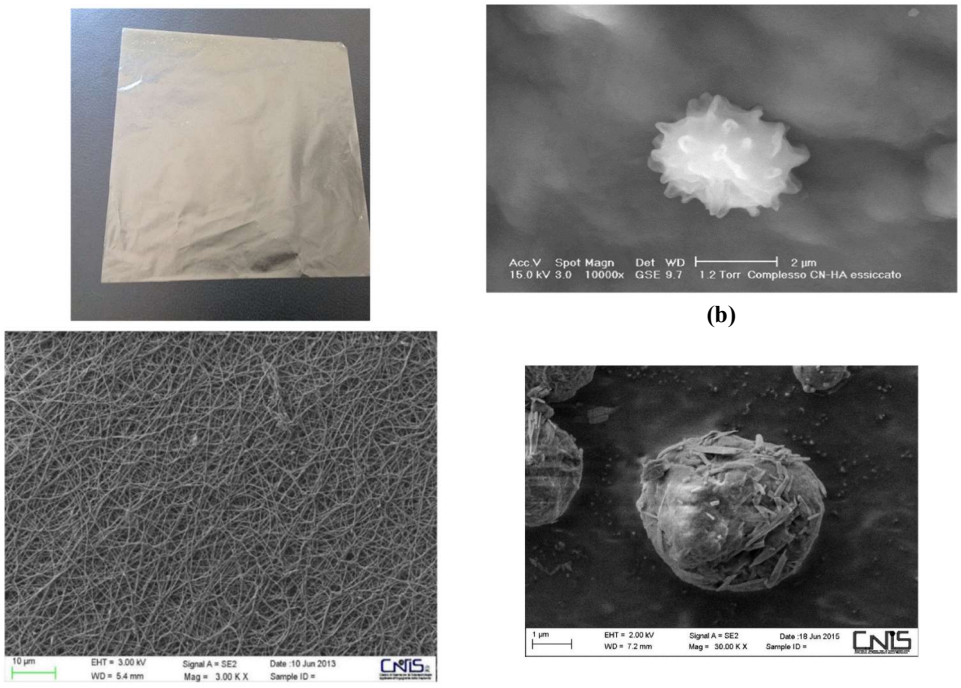


Figure 6. (a) tissue structure (up) and at SEM (down); **(b)** chitin nanofibrils yaluronan; **(c)** chitin nanofibrils-nanolignin.

4. Conclusion

As reported by many scientific papers, plastics and microplastics' invading lands and oceans became a great problem to be solved for saving human health and the environment. Thus, the necessity to change the way of living ameliorates our actual economic and social approaches, transforming the current linear model of economy based on "take-make-consume-throw away" in a circular economy. This new producing circular methodology, in fact, keeping in use products and materials of post-consumption waste rich in high-value natural resources, might achieve and facilitate a greater level of social and environmental sustainability [38–43]. Therefore, the proposed use of smart biodegradable tissues as new vehicles able to carry natural active ingredients through the skin layers and/or the mucous membranes could be useful to make innovative cosmeceuticals and nutraceuticals [19,29,30,44–47]. These

new carriers seem also able to slow down the actual worldwide side effects (i.e., allergic and sensitizing phenomena), being free of water, preservatives, emulsifiers, fragrances, colors, and other chemicals normally contained in the actual in-use emulsions. In conclusion, these natural-made tissues could be useful to realize innovative and sustainable products that are skin- and environmentally-friendly and packed in biodegradable plastic-free containers [9,19,48–50]. Moreover, by this new way of producing, it will be possible to partially reduce the great quantity of plastics and microplastics invading lands and oceans, safeguarding the natural raw materials and the planet's biodiversity for future generations.

Author contributions: Conceptualization, PM; methodology, PM; software, PM; validation, PM; formal analysis, PM; investigation, PM; resources, PM; data curation, PM; writing—original draft preparation, PM, GM and MBC; writing—review and editing, PM and MBC; visualization, PM, GM and MBC; supervision, PM, GM and MBC; project administration, PM, GM and MBC. All authors have read and agreed to the published version of the manuscript.

Conflict of interest: The authors declare no conflict of interest.

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