Open Access

Advances in Environmental and Engineering Research

LIDSEN Publishing Inc.

Original Research

Non-Woven Tissues as Novel Cosmetic Carriers for a Green Beauty

Pierfrancesco Morganti [1,*], Gianluca Morganti [2], Maria Beatrice Coltelli [3], Wladimir E Yudin [4], Hong-Duo Chen [5], Alessandro Gagliardini [6]

1. R&D Unit, Academy of History of Healthcare Art, Rome, Italy and Department of Dermatology, China Medical Q University, Shenyang, China; E-Mail: pierfrancesco.morganti@iscd.it
2. ISCD Nanoscience Center, Rome, Italy; E-Mail: Lucamorgan@libero.it
3. Department of Civil and Industrial Engineering, University of Pisa, Pisa, Italy; E-Mail: mb.coltelli@ing.unipi.it
4. Institute of Macromolecular Compounds, Russian Academy of Science, Saint Petersburg, Russia; E-Mail: Yudinve@gmail.com
5. Department of Dermatology, the First Hospital of China Medical University, Key Lab of Immunodermatology, National Health Commission, Ministry of Education, Shenyang, China; E-Mail: honduochem@hotmail.com
6. R&D Unit, Texol Srl, Alanno (Pescara), Italy; E-Mail: Alessandro. gagliardini@texol.it

* **Correspondence:** Pierfrancesco Morganti; E-Mail: pierfrancesco. morganti@iscd.it

Academic Editor: Wendy M. Purcell

Special Issue: Sustainable Development and the Environment

Adv Environ Eng Res
2022, volume 3, issue 2
doi:10.21926/aeer.2202021

Received: March 16, 2022
Accepted: May 04, 2022
Published: May 23, 2022

Abstract

Approximately 75% of textile waste is generated annually worldwide, as there is a dearth of viable recycling strategies. It has been estimated that textile industries can be responsible for approximately 20% of global water pollution. As a consequence, if not properly managed, the cost of waste management of textile waste will be trillions of dollars annually. Moreover, the generated wastes are detrimental to the environment and public health. On the other hand, there is a possibility that the majority of the waste can be recycled to obtain, for example, natural polysaccharides that can be used to produce biodegradable tissues, films, and goods.

These innovative tissues, constituted by chitin nanofibrils (CN) complexed with nanolignin (LG) bound to natural polysaccharide-based polymers, may be used as innovative cosmetic green carriers and novel biodegradable food packaging in line with the consumers requests. Consumers, in fact, are looking for biodegradable apparel, footwear, and natural cosmetics for the betterment of health and the environment, and thus, there is a demand for green cosmetics.

Keywords
Dressings; surgical masks; textiles; cosmetics; polysaccharides; polymers; chitin nanofibrils; nanolignin; green economy; greenhouse gas; skin aging

1. Introduction

"Textile & Fashion industry releases in the environment about the same quantity of Green House Gas (GHG) emissions per year as the entire economies of France, Germany, and the UK combined", accounting for 10% of the global emissions. The amount of GHG released into the environment by the textile industries exceeds the combined amount of GHG emitted by international flights and maritime ships (Figure 1) [1, 2]. Moreover, this industry is responsible for approximately 20% of global water pollution as it releases harmful components into the water bodies in the form of dyes and plastic microfibers [2].

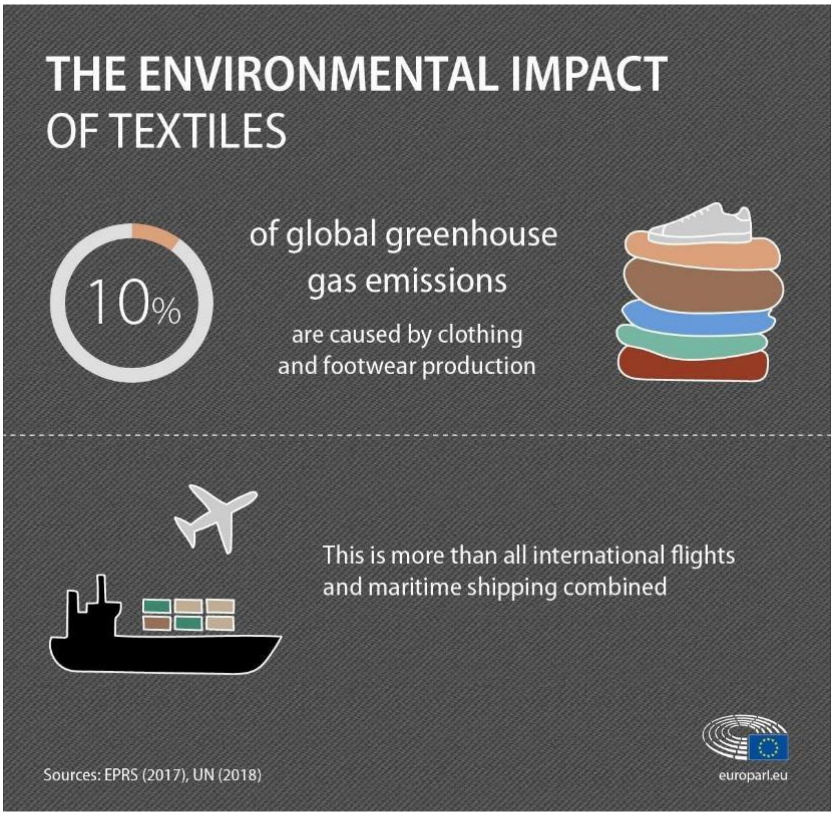

Figure 1 Green House Gas (GHG) emissions caused by the textile & fashion industries (courtesy: EU).

It has been estimated that 2. 7 billion metric tons of carbon emissions will be generated by 2030 if nothing changes. The scenario, in fact, will remain the same even if the apparel and footwear sectors will decrease their selling quantity by 27 to 30% in 2020 [2-5]. Another problem is represented from the reported waste.

Approximately 73% of the clothing items produced is sent to landfill or incinerated, and less than 1% of the material used comes from recycled sources [2-5]. As a consequence, 0. 5 million tons of textile microfibers are released into the ocean, generating a negative impacts on the natural sea environment, the health of marine animals, and the health of humans [6]. This problem can be attributed to the difficulties faced during the process of recycling textiles because, while it is technically feasible to conduct the mechanical methodologies, it is difficult to execute the chemical methods (which are used to separate the different polymers) due to a lack of funds [7-9]. However, apparel/footwear products [10, 11] and cosmetics [12, 13] constitute a large part of consumers' purchases. It is estimated that the turnaround will be approximately USD 1. 5 trillion and USD 483 billion by 2020, respectively [12, 13]. The estimated profit will be approximately USD 1. 39 trillion in the health and wellness-food sector in the 2021-2025 period [14]. This will contribute to the global wellness economy valued at USD 4. 4 trillion in 2020 (Figure 2) [15].

Figure 2 Global wellness Economy in 2020 (courtesy: GWI [15]).

These products exert high global pressure on the waste management system as plastic materials are used for packaging these products [10-14]. Moreover, other plastic-based tissues are used in the medical field. For example, one-day dressings and masks are used in hospitals to protect doctors and patients from infections [16]. Unfortunately, the majority of these products has increased during the COVID-19 pandemic, going into landfills as non-biodegradable waste after one day use only [17]. On the other hand, consumers worldwide wish to make the world a better and plastic-free place to live in, making life more convenient and safe [18]. Thus, the need to modify the current productive linear system in a circular ones, using biodegradable and recyclable materials, for exerting a positive impact on the environment [19]. As a consequence, it is important to produce biodegradable tissues and films from natural polymers extracted from waste materials. These polymers can be used as basic materials to make textiles [20], cosmetic carriers [21], containers, and food-packagings [22]. It is expected that these polymers will be more effective and less harmless for all the Planet's health. There is, in fact, a growing worldwide awareness of the responsibility of the human race toward the world in which we all are living together with an increasing concern for the preservation of health and the environment.

2. Natural Polysaccharides as Carriers and Packaging Materials

Polysaccharides, present in 99% of the plants, are composed of long chains of monosaccharide units joined by glycosidic bonds. The chains contain aldehydes, ketones, and numerous hydroxyl groups (Figure 3), while the natural polymers are of various types. They, in fact, exhibit different properties, differing for molecular weight, molecules organization (branched or linear), and the types of functional hydrophilic groups, such as hydroxyl, carboxyl, amide, and sulfate [23].

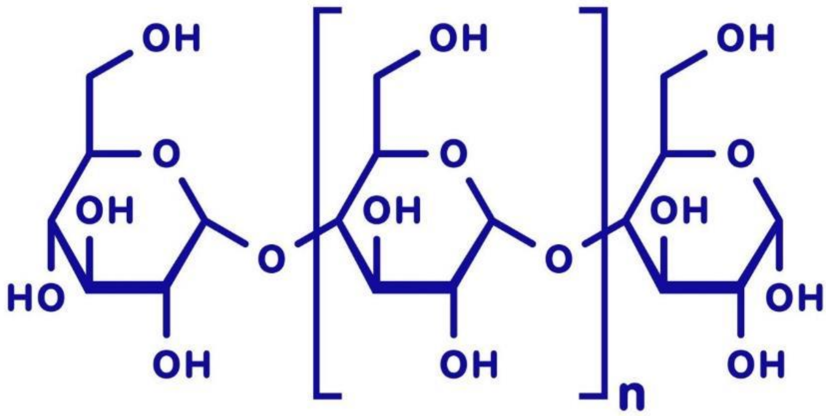

Figure 3 Structure of polysaccharides.

Therefore, polysaccharides can entrap and load different active ingredients, showing an interesting mucous-adhesiveness. This can be attributed to the presence of the different functional groups easily bound to the mucous membranes via hydrogen bonds and hydrophobic or electrostatic interactions [23-25]. Thus mucoadhesion allows prolonged retention at the site of action and helps maintain the process of controlled release. It also helps to increase the availability of active ingredients.

3. Pharmaceutical and Cosmetic Applications

As a consequence of these specific characteristics polysaccharides may be used as natural carriers, and scaffolds for both tissue and mucous regeneration. They, in fact, are non-toxic, hydrophilic, and biodegradable molecules with cell specificity, having the same structure of the natural extracellular matrix (ECM) [26, 27].

However, these natural polymers are ideally utilized as micro-nano composites that are generally formed by the incorporation of nano-sized molecules inside the bulk materials, such as non-woven tissues and films [28, 29]. While on the one hand to verify the size of these materials is a challenge, on the other hand its control is necessary to reach the nano dimension. The higher reactivity of the system, in fact, seems to be attributable to the greater surface area per mass [23]. It is interesting to underline the use of chitin at this juncture. Chitin, the second most abundant natural polymer after cellulose, can be easily obtained in its nano-size form (chitin nanofibrils (CN)). It can be easily blended with other polymers as fillers to improve the mechanical properties of the obtained composites. CN, in fact, acts as a binder and allows the polymers to form a highly dense, durable structure [26-28]. Chitin, as a natural, nano-sized polymer, may be used to make micro-nano particles that, encapsulating and protecting different active ingredients, may be used in the medical and cosmetic industry. The obtained micro-nano capsules can be embedded into emulsions or entrapped into the fibers of tissues and films which, made respectively by the electrospinnig or casting technology, may be used [29-31] to produce antioxidant cosmeceuticals. Thus, for example, nanofibril-nanolignin(CN-LG) particles might encapsulate vitamins A, E, and C, entrapped int. They can also be used for the fabrication of anti-inflammatory, antibacterial, and skin-repairing medical devices by encapsulating glycyrrhizic acid or nanostructured silver [32-34]. In this case, the antibacterial effectiveness of the electrospun tissues can be attributed to the CN activity that increases significantly when Ag+ ions are linked to their fibers (Figure 4). The anti-inflammatory, immunomodulating, and skin-repairing activity recovered, can be attributed to the vitamins A, E, and C encapsulated into CN-LG systems [30-33]. On the other hand LG increases the skin antioxidant system, thanks to the network of polyphenols, as components of the polymer. Naturally, the presence of the different encapsulated active ingredients, the release of the targets at skin level [34, 35], and the cell compatibility and thermal stability (Figure 5) were controlled as well as the mechanical and biocompatible nature of the realized final tissues [29, 36-39].

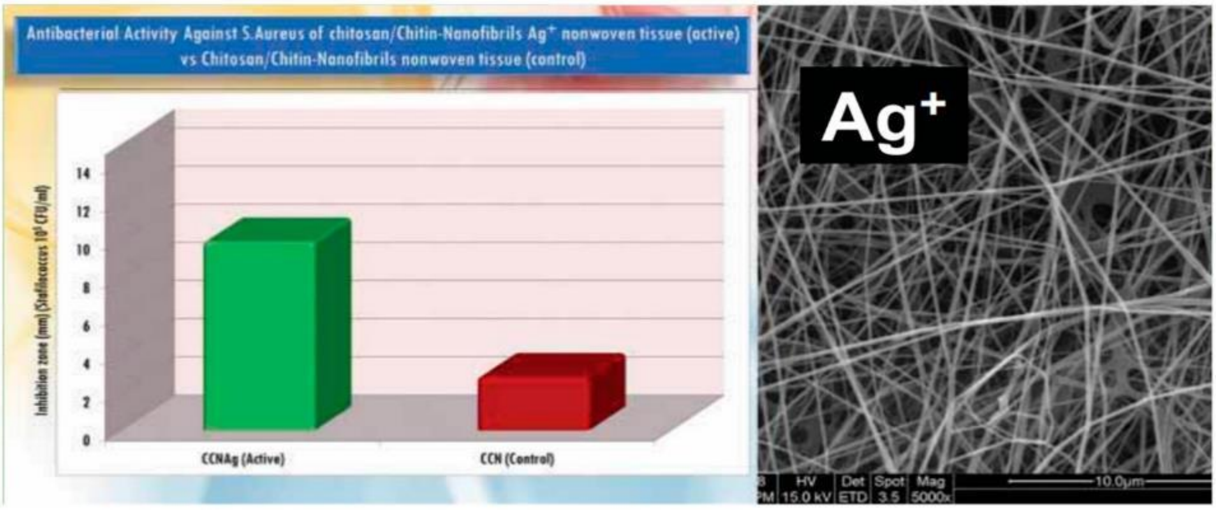

Figure 4 Activity of the non-woven tissue entrapping Chitin nanofibrils bound to nanostructured silver (courtesy:[40]).

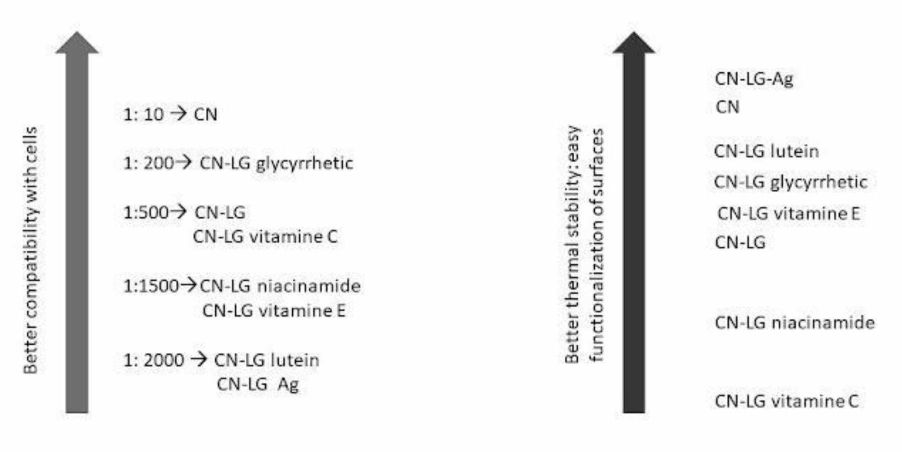

Figure 5 Thermal stability and biocompatibility of different active ingredients encapsulated into the CN-LG complex (courtesy: [39]).

Therefore, depending on the designed particles bound on the fibers and the natural polymers selected, these smart tissue/films can be potentially used to prepare innovative biological carriers or biodegradable, sustainable packages [20-22].

4. Packaging Applications

There is a growing interest in utilizing the biopolymers and biodegradable natural composites, such as polysaccharides, polylactic acid, and polyhydroxyalkanoates, for the production of green packaging to prepare soft and rigid bioplastic containers [41]. The use of these innovative materials allows us to save the petrol resources and valorize the byproducts obtained from agricultural feedstock and food & textile waste [41]. Unfortunately, the production process of biopolymers is more costly than the conventional fossil fuel-based ones. Thus, the need of further research studies to improve the mechanical properties of the actual systems and facilitate the relative processing methods [22, 41-45]

However the recycled fibers, obtained from textile and food waste, can be potentially used to make biodegradable products and packaging, indispensable to reduce the global pollution also. Their derived byproducts, in fact, exert a high impact on the air and water conditions, as they release numerous toxic compounds during their life cycle [41-45].

Therefore the biological use of these biopolymers is of great interest because CN is not only a nano-sized polymer but, as previously reported, is also made of a backbone similar to that present in natural hyaluronic acid, an important component of ECM [36, 37] (Figure 6z). ECM forms a three-dimensional network composed of macromolecules, such as collagen, hyaluronic acid, and other reticular fibers, which help generate signals and regulate the processes of cell adhesion, cell functions, and differentiation. Therefore, it is an indispensable component for skin regeneration [46-48]. For these reasons, CN has been used to make scaffold tissues for biomedical and cosmetic applications as it exhibits the ability to mimic the skin's biological and mechanical properties, while LG reinforce the skin antioxidant defenses [20, 21, 39, 49-51]. On the other hand, chitin nanofibrils and nanolignin may be also used to make biodegradable and sustainable packaging [52] in the form of soft films (Figure 7) [40, 53] or rigid containers as both impart tensile strength and thermal resistance to the composites when used as fillers [54].

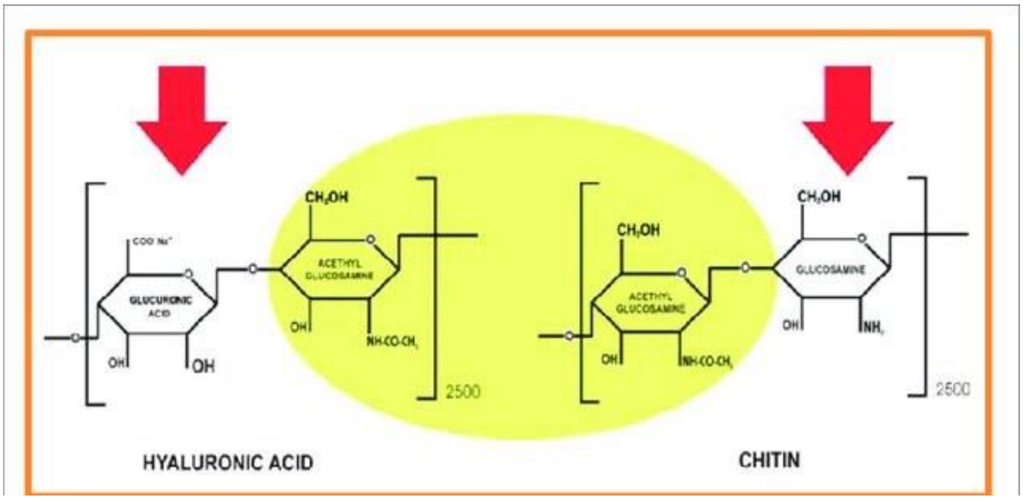

Figure 6 Backbone of CN is similar to the backbone of hyaluronic acid (Courtesy:[52]).

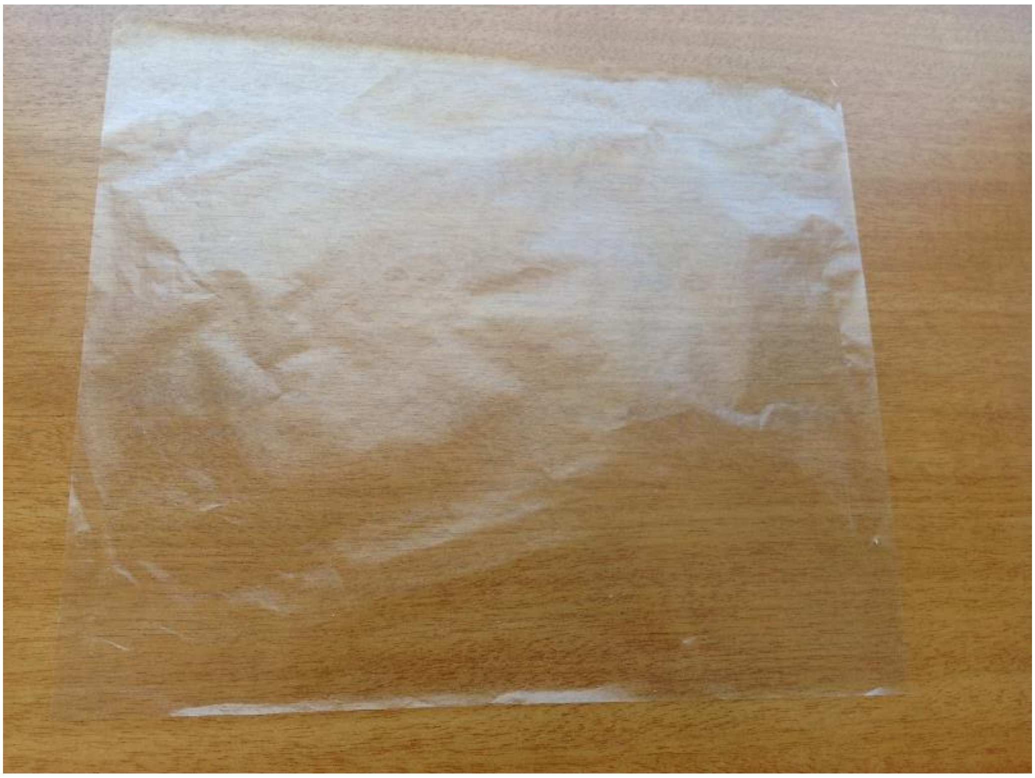

Figure 7 Soft film made of Chitin nanofibrils (courtesy: [52]).

Analysis of the physicochemical and electropositive characteristics of CN reveals that this polymer can be readily complexed following the gelation ionotropic method using other electronegative polymers, such as hyaluronic acid(HA) and nano-lignin (LG), to form nano-microparticles (PNs)(Figure 8)[54-56]. As previously discussed, these PNs may be embedded into emulsions or bound to fibers of tissues and films for making innovative carriers [20, 31, 33, 36, 57]. The particles may encapsulate active ingredients, making the tissue/films useful as medical devices or cosmeceuticals. Naturally, the applications of the tissues/films depend on the molecules bound to the fibers or the surface [57, 58]. Thus CN, complexed with LG or HA, can potentially act as "active" carriers. This can be attributed to the capacity to load, transport, and release the ingredients. The functions also rely on the ability of the system to function as active compounds that exhibit antioxidant, immunomodulant, and protective properties versus the ultraviolet rays (UV) [56-58].

These innovative carriers functionalized by active ingredients, such as hyaluronic acid, collagen peptides, and other selected molecules might act as *effective* scaffolds that promote the generation of specific signals. For example, hyaluronic acid may regulate the process of cell reproduction and differentiation [59-61]. It can help regenerate burned, wounded, or prematurely aged skin [53, 55, 60-62]. It can also help in repairing aged hair [63, 64].

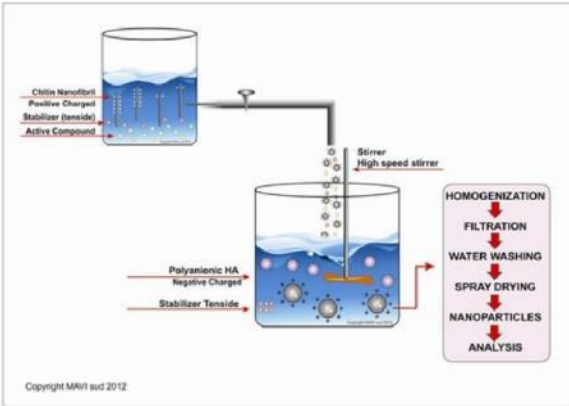

Figure 8 Gelation method used for the fabrication the complexes as the CN-HA complex reported (courtesy:[52]).

In conclusion, polysaccharide-polymers can be potentially used as chitin to make biodegradable tissues and goods that can substitute petrol-derived systems [65-67]. It is also interesting to underline that these natural polymers may be obtained from food waste, the treatment of which is a huge problem worldwide. The cost of treating waste is approximately USD 836 billion per year [68]. It should also be highlighted that CN-LG complexes can be obtained from food and agricultural wastes, and these can also function as *active* carriers. They can be metabolized using human and environmental enzymes to form glucosamine, acetyl glucosamine, glucose, and polyphenols, that are used in cells as food and energy [22, 30, 45]

5. Conclusions

Tissues and cosmetics form a huge part of the consumer-purchase sector. The production of these materials puts high pressure on the waste management system globally as plastic polymers are used as raw material for the production of these items and packaging. These polymers are formed from non-biodegradable [6] micronanoparticles. These pollute lands and oceans, releasing toxic compounds [68-70]. On the other hand, the global population wants to age well. People are more focused on their wealth and appearance [6, 71]. Consumers are also concerned about their health and the health of the environment [68-71]. The ongoing COVID-19 pandemic accelerated the focus on sustainability and planetary environmental changes [72]. Therefore, they are in search of methods that can guarantee personal wellness and planet preservation. This is the reason why recently, consumers have been willing to pay a hefty premium for healthy products [5, 61-65, 73]. Consequently, there is an increasing demand for skin-and environmentally-friendly apparel and cosmetics made from polymers obtained from waste materials, such as chitin nanofibrils and nanolignin [21, 30, 37, 39, 61]. In conclusion, people have well understood that waste, pollution, and ultraviolet light decrease the level of physiological wellness. The use of protective antioxidants results in skin modifications, and fine and coarse wrinkles appear on skins. Dyspigmentation also occurs [48-50, 62-67]. This is the reason behind the increased demand for *green beauty*-based clothes and cosmetics made of polymers and tissues. Thus, there is increasing demand for natural-derived ingredients and carriers that exhibit dose effectiveness and are safe to use. Consequently, all the materials used to realize these products have to be natural-derived, innovative and well document [12 37, 48, 74-77].

For all these reasons, natural polymers, including chitin and lignin, play important roles in the cosmetic/personal care items, food, and biofunctional/textile industries. These materials can be safely used to prepare high-performing comfort products wrapped in biodegradable, plastic-free packages [20-22, 37-39, 48-47, 61-67]. Polysaccharides represent a class of biomaterials that mimic the ECM structure. Thus they can be potentially used as nanomicrocarriers for the fabrication of medical and cosmetic tissues. They can also be used to prepare sustainable packages [21-26]. Moreover, these innovative tissues find a further potential use as *active c*arriers to formulate skin- and environmentally-friendly cosmeceuticals and nutraceuticals that are free of preservatives, emulsifiers, fragrance-imparting compounds, and chemicals [21, 38, 52-58]. In conclusion, it is necessary to promote the recycling of materials and use of cosmeceutical-tissues that can be obtained from waste materials at a low cost. The focus should be on the development of biodegradable materials and packages. We aim to study this new category of smart products in the future.

Author Contributions

idea of manuscript PM, GM, HDC; writing original draft PM, GM; Preparation PM, GM, AG; writing-review and editing PM, MBC; supervision WEY, HDC. All the authors have read and agreed to the publishing version of manuscript.

Conflict of interest

The authors declare no conflict of interest.

References

1. Berg A, Haug L, Hedrich S, Magnus KH. Time for change: How to use the crisis to make fashion sourcing more agile and sustainable. Mckinsey & Company; 2020. Available from: https://www.mckinsey.com/industries/retail/our-insights/time-for-change-how-to-use-the-crisis-to-make-fashion-sourcing-more-agile-and-sustainable.
2. EC. The impact of textile production and waste on the environment (infographics). Brussels: European Parliament; 2020 [cited date 2021 October 9]. Available from: https://www.europarl.europa.eu/news/en/headlines/society/20201208STO93327/the-impact-of-textile-production-and-waste-on-the-environment-infographic.
3. EC. Circular economy action plan. Final report. Brussels: European Commission; 2020. Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN.

4. Berg A, Granskog A, Lee L, Magnus KH. Fashion on climate. Mckinsey & Company; 2020. Available from: https://www.mckinsey.com/industries/retail/our-insights/fashion-on-climate.
5. EMAF. A new textile economy: Redesigning fashion's future. Ellen Mc Arthur Foundation; 2021 [cited date 2021 October 12]. Available from: https://ellenmacarthurfoundation.org/a-new-textiles-economy.
6. Jambeck JR, Geyer R, Wilcox C, Siegel TR, Perryman M, Andrady R, et al. Plastic waste inputs from land into ocean. Science. 2015; 347: 768-771.
7. Sanding G, Peters G. Environmental impact of textile reuse and recycling-A review. J Cleaner Prod. 2018; 184: 353-365.
8. Wagner MM, Heinzel T. Human perceptions of recycled textiles and circular fashion: A systematic literature review. Sustainability. 2020; 12: 10599.
9. Levanen J, Uusitalo V, Harri A, Kareinen E, Linnanen L. Innovative recycling or extended use? Comparing the global warming potential of different ownership and end-of-life scenarios for textiles. Environ Res Lett. 2021; 16: 054069.
10. Quantis. Measuring Fashion report delivers results from the first study on the global environmental impacts of the apparel and footwear industries [Internet]. 2018. Available from: https://quantis-intl.com/measuring-fashion-report-press-release/.
11. Shabandeh M. Global apparel market-statistics & facts. Statista; 2021. Available from: https://www.statista.com/.
12. Jindal S, Kwek S, McDouglas A. Global beauty and personal care trends 2030. Mintel; 2020. Available from: https://www.mintel.com/.
13. Roberts R. Beauty 2021 industry trends & cosmetics marketing: Statistics and strategies for yours ecommerce growth. Common Thread Collective; 2021. Available from: https://commonthreadco.com/.
14. Technavio. Health and wellness market by product and geography-forecast and analysis 2021-2025. Technavio; 2021 [cited date 2021 October 20]. Available from: https://www.technavio.com/report/health-and-wellness-market-industry-analysis.
15. GWI. Wellness economy: Working beyond covid. Global Wellness Institute; 2021. Available from: http://www.globalwellnessinstitute.org.
16. Morganti P, Yudin VE, Morganti G, Coltelli MB. Trends in surgical and beauty masks for a cleaner environment. Cosmetics. 2020; 7: 68.
17. Morganti P, Morganti G. Surgical & beauty facial masks: The new waste problem of post COVID-19. Biomed Sci Tech Res. 2020. DOI: 10. 26717/BJSTR. 2020. 29. 004878.
18. Westbrook G, Angus A. Top 10 global consumer trends 2021. Euromonitor International; 2021. Available from: https://www.euromonitor.com/.
19. Leone G, Tost I, Borras JM, De Villamore ME. The new plastics economy: Rethinking the future of plastics & catalysing action. Ellen McArthur Foundation; 2017. Available from: https://ellenmacarthurfoundation.org/the-new-plastics-economy-rethinking-the-future-of-plastics-and-catalysing.
20. Morganti P, Morganti G, Colao C. Biofunctional textiles for aging skin. Biomedicines. 2019; 7: 51.
21. Morganti P, Coltelli MB. A new carrier for advanced cosmeceuticals. Cosmetics. 2019; 6: 10.

22. Cinelli P, Coltelli MB, Latteri A. Naturally-made hard containers for food packaging: Actual and future perspectives. In: Bionanotechnology to save the environment: Plant and fishery's biomass as alternative to petrol. Basel: MDPI; 2019. pp.297-318.
23. Zheng Y, Monty J, Linhardt RJ. Polysaccharides-based nanocomposites and their applications. Carbohydrates. 2015; 405: 23-32.
24. Liu J, Willför S, Xu C. A review of bioactive plant polysaccharides: Biological activities, functionalization, and biomedical applications. Bioact Carbohydr Diet Fibre. 2015; 5: 31-61.
25. Xu J, Tam M, Samaet S, Lerouge S, Barralet J, Stevenson M, et al. Mucoadhesive chitosan hydrogels as rectal drug delivery vessels to treat ulcerative colitis. Acta Biomater. 2017; 48: 247-257.
26. Bhatia S. Nanoparticles types, classification, characterization, fabrication methods and drug delivery Applications. In: Natural polymer drug delivery systems. Berlin: Springer, Cham; 2016. pp.33-93.
27. Gotovtsev VM, Ignat'yev AA. The effect of structuring composite building materials. Mater Sci Eng. 2019; 666: 012079.
28. Yudin VE, Dobrovolskaya IP, Neelov LM, Dresvyanina EN, Popryadukhin PV, Ivan'kova EM, et al. Wet spinning of fibers made of chitosan and chitin nanofibrils. Carbohydr Polym. 2014; 108: 176-182.
29. Coltelli MB, Aliotta L, Vannozzi A, Morganti P, Panariello L, Danti S, et al. Properties and skin compatibility of films based on poly (lactic acid)(PLA) bionanocomposites incorporating chitin nanofibrils (CN). J Funct Biomater. 2020; 11: 21.
30. Morganti P, Morganti G, Nunziata ML. Chitin nanofibrils, a natural polymer from fishery waste: Nanoparticle and nanocomposite characteristics. In: Bionanotechnology to save the environment: Plant and fishery's biomass as alternative to petrol. Basel: MDPI; 2019. pp.60-81.
31. Chen HD, Hong LY, Morganti P. Chitin-hyaluronan block copolymeric nanoparticles for innovative cosmeceuticals. In: Bionanotechnology to save the environment: Plant and fishery's biomass as alternative to petrol. Basel: MDPI; 2019. pp.251-259.
32. Xu XG, Gao X, Chen HD, Morganti P. Chitin nanocomposite scaffolds for advanced medications. In: Bionanotechnology to save the environment: Plant and fishery's biomass as alternative to petrol. Basel: MDPI; 2019. pp.260-271.
33. Panariello L, Vannozzi A, Morganti P, Coltelli MB, Lazzeri A. Biobased and eco-compatible beauty films coated with chitin nanofibrils, nanolignin and vitamin E. Cosmetics. 2021; 8: 27.
34. Miletić A, Ristić I, Coltelli MB, Pilic B. Modification of PLA-based films by grafting or coating. J Funct Biomater. 2020; 11: 30. DOI: 10. 3390/ jfb11020030.
35. Obisesan KA, Neri S, Bugnicourt E, Campos I, Rodriguez-Turienzo L. Determination and quantification of the distribution of CN-NL nanoparticles encapsulating glycyrrhetic acid on novel textile surfaces with hyperspectral imaging. J Funct Biomater. 2020; 11: 32.
36. Coltelli MB, Danti S, Trombi L, Morganti P, Donnarumma G, Baroni A, et al. Preparation of innovative skin compatible films to release polysaccharides for biobased beauty masks. Cosmetics. 2018; 5: 70.
37. Morganti P, Morganti G, Memic A, Coltelli MB, Chen HD. The new renaissance of beauty and wellness through the green economy. 2021. DOI: 10. 32474/LTTFD. 2021. 04000185.
38. Morganti P, Carezzi F, Del Ciotto P, Morganti G. Chitin nanoparticles as innovative delivery system. Personal Care. 2012; 5: 95-98.

39. Morganti P, Morganti G, Gagliardini A, Lohani A. From cosmetics to innovative cosmeceuticals: Non-woven tissues as new biodegradable carriers. Cosmetics. 2021; 8: 65.
40. Tischenko G, Morganti P, Stoller M, Kelnar I, Mikesova J, Kovarova J. Chitin nanofibrils-chitisan composite films: Characterization and properties. In: Bionanotechnology to save the environment: Plant and fishery's biomass as alternative to petrol. Basel: MDPI; 2019. pp.191-226.
41. Cinelli P, Coltelli MB, Mallegni L, Morganti P, Lazzeri A. Degradability and sustainability of nanocomposites based on polylactic acid and chitin nano fibrils. Chem Eng. 2017; 60: 115-120.
42. Cinelli P, Coltelli MB, Lazzeri A. Naturally-madehard containers for food packaging: Actual and future perspectives. In: Bionanotechnology to save the environment: Plant and fishery's biomass as alternative to petrol. Basel: MDPI; 2019. pp.297-318.
43. Patti A, Cicala G, Acierno D. Eco-sustainability of the textile production: Waste recovery and current recycling in the composites world. Polymers. 2020; 13: 134.
44. Patti A, Acierno D. Toward the sustainability of the plastic industry through biopolymers: Propoerties and potential applications to the textiles world. Polymers. 2022; 14: 692.
45. Morganti P, Gao X, Vukovic N, Gagliardini A, Morganti G. Food loss and food waste for green cosmetics and medical devices for a cleaner planet. Cosmetics. 2022; 9: 19.
46. Watt FM, Fujiama H. Cell-extracellular matrix interactions in normal and diseased skin. Cold Spring Harb Perspect Biol. 2011; 3: 3a005124.
47. Joergensen P, Rattan SI. Extracellular matrix modulates morphology, growth, oxidative stress response and functionality of human skin fibroblasts during aging in vitro. J Aging Sci. 2014; 2: 2. Doi:10.4172/2329-8847.1000122.
48. Quan T, Fisher GJ. Role of age-associated alterations of the dermal extracellular matrix microenvironment in human skin aging: A mini-review. Gerontology. 2015; 61: 427-434.
49. Morganti P, Morganti G, Coltelli MB. Chitin nanomaterials and nanocomposites for tissue repair. In: Marine-derived biomaterials for tissue engineering applications. Singapore: Springer; 2019. pp.523-544.
50. Danti S, Trombi L, Fusco A, Azimi B, Lazzeri A, Morganti P, et al. Chitin nanofibrils and nanolignin as functional agents in skin regeneration. Int J Mol Sci. 2019; 20: 2669.
51. Morganti P, Morganti G, Coltelli MB. Skin and pollution: The smart nano-based cosmeceutical-tissues to save the planet' ecosystem. In: Nanocosmetics. Elsevier; 2020. pp.287-303.
52. Feber D, Nordigarden D, Gransko A, Gronewald F, Lingquist O. Sustainability in packaging: Investable themes. MacKinsey & Company; 2021. Available from: https://www.mckinsey.com/industries/paper-forest-products-and-packaging/our-insights/sustainability-in-packaging-investable-themes.
53. Morganti P, Tischenko G, Palombo M, Kelnar I, Brizova L, Spirkova M. Chitin nanofibrils for biomimetic products: Nanoparticles and nanocomposites chitosan films in health care. In: Marine biomaterials: Isolation, characterization and application. CRC Press; 2013. pp.681-715.
54. Desai KG. Chitosan nanoparticles prepared by ionotropic gelation: An overview of recent advances. Crit Rev Ther Drug Carrier Syst. 2016; 33: 107-158.
55. Cinelli P, Coltelli MB, Signori F, Morganti P, Lazzeri A. Cosmetic packaging to save the environment: Future perspective. Cosmetics. 2019; 6: 26.
56. Morganti P. Use of chitin nanofibrils from biomass for an innovative bioeconomy. In: Nanofabrication using nanomaterials. Manchester: One Central Press; 2016. pp.1-22.

57. Morganti P, Del Ciotto P, Gao X. Skin delivery and controlled release of active ingredients nanoencapsulated by chitin nanofibrils: A new approach. Cosmet Sci Technol. 2012; 20: 135-142.
58. Morganti P, Del Ciotto P, Morganti G, Fabien-Soule' V. Application of chitin nanofibrils and collagen of marine origin as bioactive ingredients. In: Marine cosmeceuticals: Latest trends and prospects. New York: CRC Press; 2011. pp.267-289.
59. Bourguignon LYW. Matrix hyaluronan-activated CD44 signaling promotes keratinocyte activities and improves abnormal epidermal functions. Am J Pathol. 2014; 184: 1912-1919.
60. Khang G. Biomaterials and manufacturing methods for scaffolds in regenerative medicine: Update 2015. In: Handbook of Intelligent Scaffolds for Tissue Engineering and Regenerative Medicine. Singapore: Jenny Stanford Publishing; 2017. pp.3-35.
61. Anniboletti T, Palombo M, Moroni S, Bruno A, Palombo P, Morganti P. Clinical activity of innovative non-woven tissues. In: Bionanotechnology to Save the Environmen. Basel: MDPI; 2019. pp.340-360.
62. Morganti P, Palombo P, Palombo M, Fabrjzi G, Slovacchia F, Guevara L, et al. A phosphatidylcholine hyaluronic acid chitin–nanofibrils complex for a fast skin remodeling and a rejuvenating look. Clin Cosmet Investig Dermatol. 2012; 5: 213-220.
63. Morganti P, Palombo M, Cardillo A, Del Ciotto P, Morganti G, Gazzaniga G. Anti-dandruff and anti-oily efficacy of hair formulations with a repairing and restructuring activity. The positive influence of the Zn-chitin nanofibrils complexes. J Appl Codmetol. 2012; 30:149-159.
64. Morganti P, Morganti G. Natural polymers for natural hair: The smart use of an innovative carrier. In: Nanocosmetics: Fundamentals, applications and toxicity. Amsterdam: Elsevier; 2020. pp.267-285.
65. Morganti P, Chen HD, Morganti G. Nanocosmetics: Future perspective. In: Nanocosmetics: Fundamentals, applications and toxicity. Amsterdam: Elsevier; 2020. pp.455-481.
66. Yudin VE, Dobrovolskaya IP, Ivan'Kova EM, Dresvyanina EN, Malevkaia EN. Natural fibers for natural tissues. In: Biofunctional textiles for an aging skin. Chisinau, Moldova: Lambert Academic Publishing; 2021. pp.333-370.
67. Morganti P, Morganti G, Yudin VE, Chen HD. Chitin and lignin: Old polymers and new bio-tissue-carriers. J Dermatol Dermatitis. 2021; 6. DOI: 10. 31579/2578-8949/083.
68. Bullock CH, Thorball N, Somlai, Gallanger J. Packaging waste statistics, producer motivations and consumer behaviour. Environmental Protection Agency; 2021. Available from: https://www.epa.ie/.
69. Henisz W, Koller T, Nuttal R. Five ways that ESG creates value. Mckinsey & Company; 2019. Available from: https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/five-ways-that-esg-creates-value.
70. Kim KE, Cho D, Park HJ. Air pollution and skin diseases: Adverse effects of airborne particulate matter on various skin diseases. Life Sci. 2016; 152: 126-134.
71. Yeung O, Johnston H. Resetting the world with wellness: A new vision for a post-covid-19 future. Global Wellness Institute; 2020 [cited date 2022 April 10]. Available from: https://globalwellnessinstitute.org/.
72. Creams M, Lieberman G, Mariarty S. Consumer trends 2030. London: Mintel Group Ltd; 2021 [cited date 2022 April 8]. Available from: https://www.mintel.com/.

73. Morganti P, Palombo M, Fabrizi G, Guarneri F, Slovacchia F, Cardillo A, et al. New insight on anti-aging activity of chitin nanofibril-hyaluronan block copolymers entrapping active ingredients: In vitro and in vivo study. J Appl Cosmetol. 2013; 41: 1-29.
74. Morganti P, Fusco A, Paoletti I, Perfetto B, Del Ciotto P, Palombo P, et al. Anti-inflammatory, immunomodulatory, and tissue repair activity on human keratinocytees by green innovative nanocomposites. Materials. 2017; 10: 843.
75. Amed I, Berg A Balchandani A, Hedrich S, Rölkens EC, Young R, Poojara S. The state of fashion 2020: Navigating uncertainty. Mckinsey & Company; 2021. Available from: https://www. mckinsey. com/industries/retail/our-insights/state-of-fashion.
76. Morlet A, Opsomer R, Hermann S, Balmond L, Gillet G, Fochs L. A new textile economy: redesigning fashion future. The Ellen MacArthur Foundation; 2017. Available from: https://ellenmacarthurfoundation.org/a-new-textiles-economy.
77. Amed I, Berg A, Balchandani A, Hedrich S, Rölkens EC, Young R et al The state of fashion 2021: In search of promise in perilous times. Mckinsey & Company; 2021. Available from: https://www.mckinsey.com/industries/retail/our-insights/state-of-fashion.