Circular Economy: A New Horizon for Bio-Nanocomposites from Waste Materials

Pierfrancesco Morganti[1,2,*]

[1]Skin Pharmacology, 2nd University of Naples, Italy

[2]China Medical University, Shenyang, China

Circular Economy [1] will offer a major opportunity to increase resource productivity, decrease consume and waste dependence, offering the opportunity to create new employment and growth. At this purpose, today, science provides evidence that this new economical vision, enabled by the bio-nanotechnology revolution, could generate by 2030 to Europe's economy, a primary resource benefits of as much as € 0.6 trillion per year [1,2]. In addition and under the anchor points of the EU normative (Figure **1**) [3], it could generate €1.2 trillion in non-resource and externality benefits, bringing the annual total benefits to around €1.8 trillion versus to day [1,2]. Thus, the necessity to increase the resource efficiency, use agricultural and industrial by-products as raw materials, and minimize both greenhouse gas emissions (GHGs) and waste, for reducing the fossil-based products and maintaining the human wellbeing and the environment biodiversity.

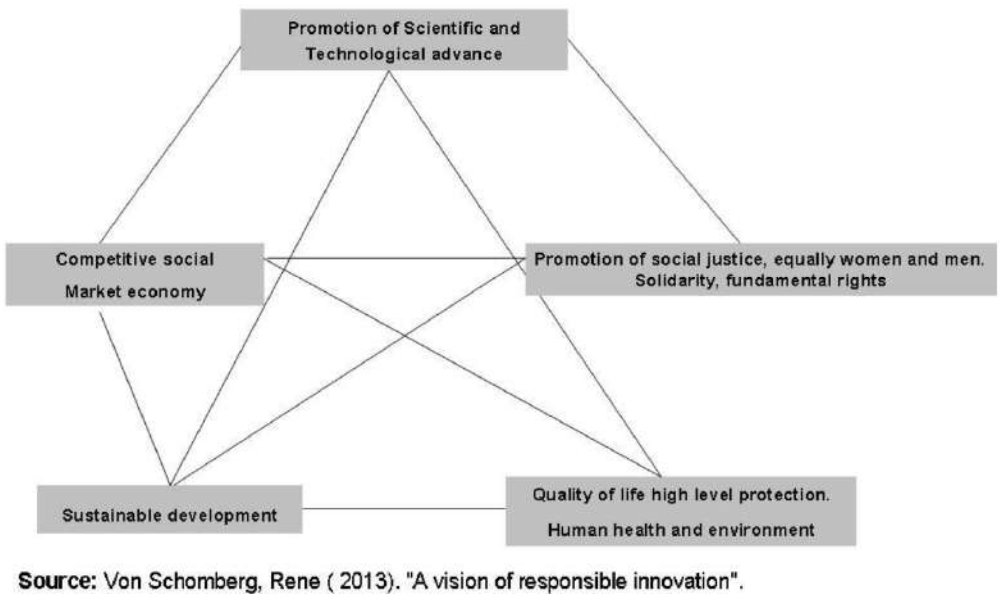

Figure 1: Normative anchor points derived from the Treaty on the European Union [3].

To achieve this result, it will be necessary a better management of water, energy, natural raw materials, and land biodiversity, integrating environment, sociality and politics into the main economic sectors for a sustainable development (Figure **2**).

At this purpose, the FAO and EU recommendation is to reduce waste, food loss, support cleaner investments, and transfer to consumers and businesses the knowledge about the needs to maintain the precious resources of our Planet for the incoming generations, due to the correlation existing between food loss and GDP pro capita (Figure **3**) [4-6].

Thus the growing interest in the area of degradable and compostable biopolymers, derived from renewable resources, such as, carbohydrates and lignocellulosic compounds.

*Address correspondence to this author at the Secretary General, International Society of Cosmetic Dermatology, Roma, Italy; R&D Director, Nanoscience Center MAVI, Viale dell'industria 1, 04011 Aprilia (Lt) Italy;
Tel: +39 069286261; Fax: +39 069281523;
E-mail: pierfrancesco.morganti@mavicosmetics.it, info@iscd.it

ISSN: 1927-3037/16

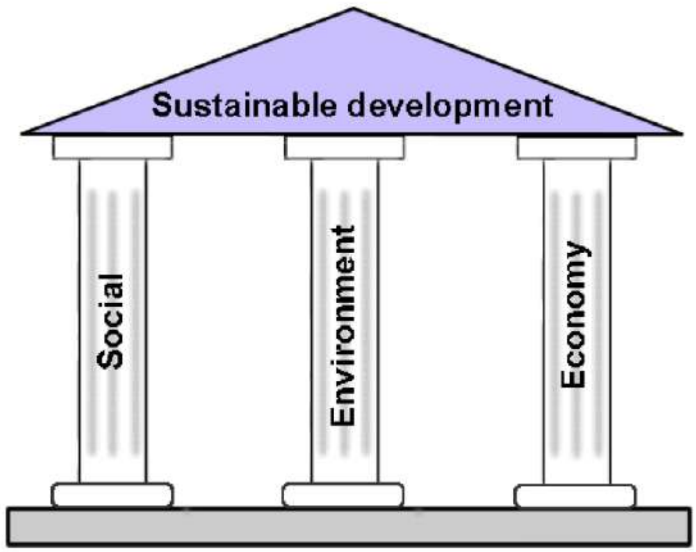

Figure 2: The pillars for a sustainable Development.

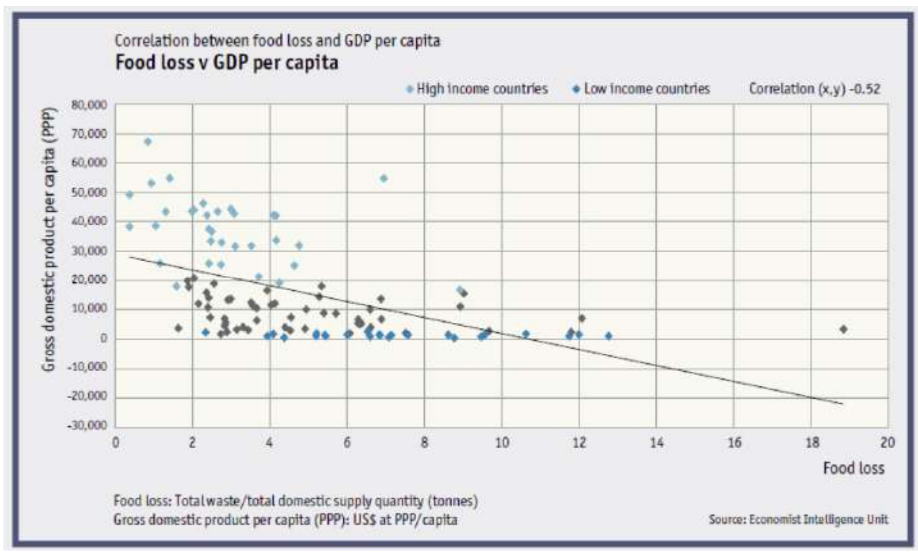

Figure 3: Food loss and GDP per capita.

Among waste materials, polysaccharides such as Chitin Nanofibrils (CNs), are to be taken into account for their capacity to develop greener nanocomposites and skin-friendly and environmentally-friendly goods. In the last years, the particular interest in this crystal-like nano-chitin has notably increased [7-9]. Because of its natural origin, CN has shown, in fact, many interesting properties (Figure **4**) which allowed its use in different fields of great biological interest (Figure **5**). For its highly crystalline structure and mean dimension of 240x7x5 nm with a molecular weight of 2x106 Dalton, this polymer develops a surface area up to 400m2/g compared to 2 m2 of the amorphous chitin (Table **1**).

Due to its mechanical, chemical, electrical, and optical, properties, CN is useful also as filler for nanocomposite reinforcement, is suitable for technological and biomedical, applications in tissue engineering, drug delivery, and wound dressing. It is, in fact, non toxic, odorless, biocompatible with living tissues, biodegradable and compostable in the environment, presenting also a moisturizing retention activity, due to the same molecular backbone of hyaluronic acid (Figure **6**) [10]. Moreover, CN is very interesting not only as reinforcing filler for nanocomposite applications, but also for biomedical food, and textile industries, because to the many advantages compared to native chitin, including antibacterial and anti fungal activity [10-12]. Finally, CN shows Interesting healing characteristics, because of its probable capacity to form microfibrillar arrangements in living tissues (Figure **7**).

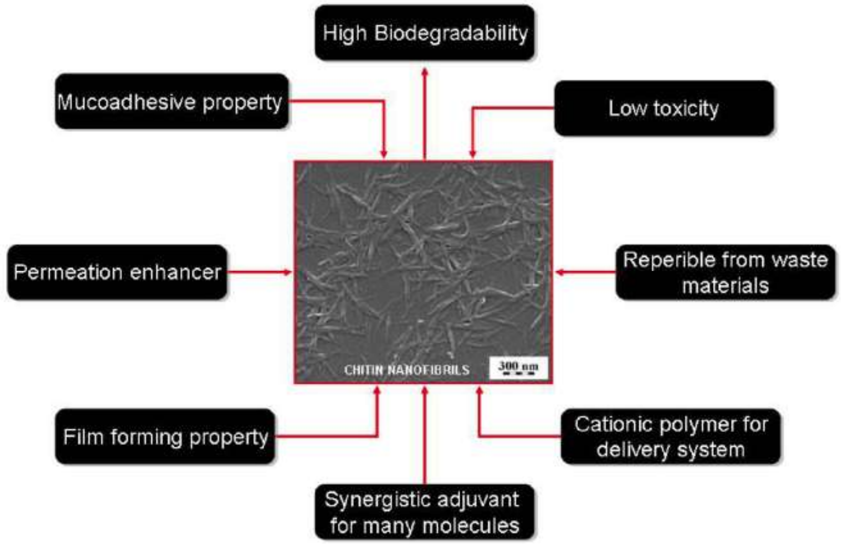

Figure 4: Different properties of chitin nanofibrils.

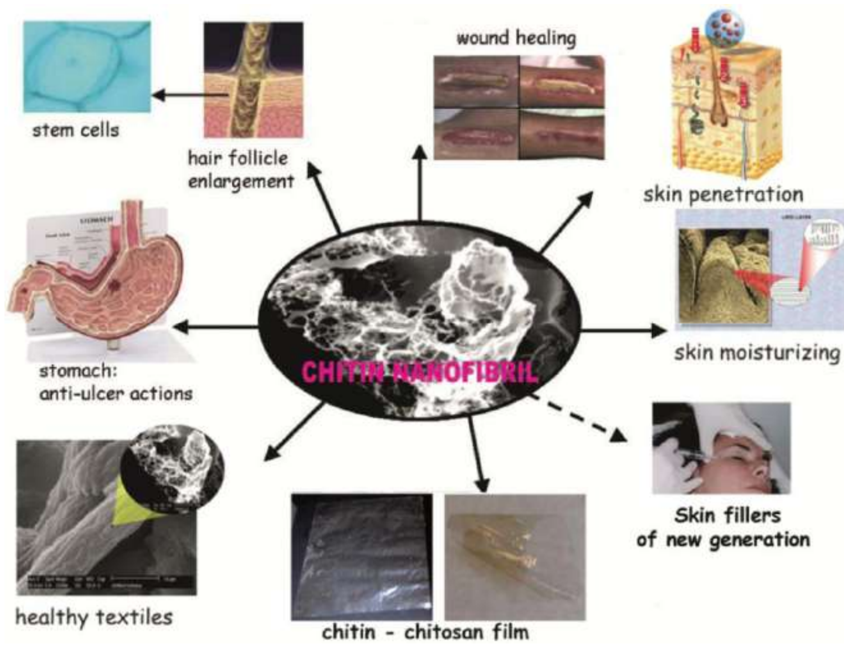

Figure 5: Different uses of chitin nanofibrils.

Table 1: Calculated Length and Surface Area for Chitin Fibers, One Gram

Production	Realistic size*	Lenght, meter	Surface area, square meter
Nanofibrils	10x10 nanom	1x1010 **	400
Electrospinning	300x300 nanom	1.107	12
Wet spinning	5x5 microm	4.104	0.8
Wet spinning	10x10 microm	1x104	0.4

*Square section adopted for uniformity with chitin nanofibrils.
**Nanofibrils are in general 200-300 nm long, the lenght reported here is for a series of nanofibrils. The number of nanofibrils in one gram, is in the order of 10^{18}.

It is also to underline that nanofibers have a close connection with our body where any type of tissue is made by fibers from micro-to nano-scale, generally in the form of bundle structure, which function to provide

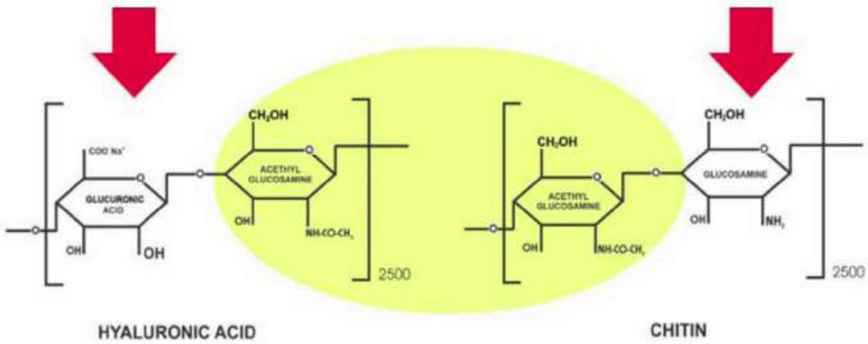

Figure 6: Hyaluronic acid and chitin have the same backbone structure.

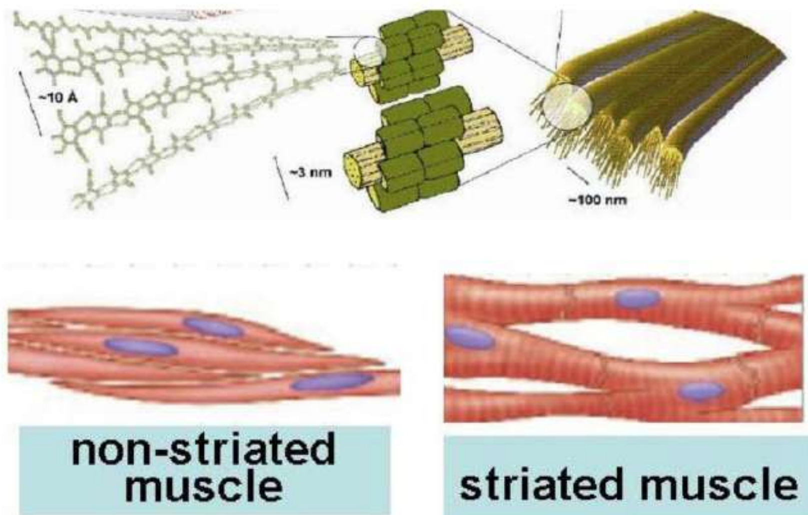

Figure 7: Chitin Nanofibrils have the same microfibrillar structure of the living tissues.

strength enforcement and elasticity, conduct nervous impulses and movements of the whole body or within organs.

At this purpose we have shown that non-woven tissues produced by the use of CN [13] or CN complexes with bio-Lignin [14] have shown to possess a repair and regenerative capacity on skin wounded tissue probably because of their large-surface-area-to-volume ratio, as large as ~1000 times that of a microfiber. This capacity is also reinforced from the capacity this fiber has to accelerate the granulation processes of the skin, because of its same hierarchical organization of Extra Cellular Matrix (ECM) (Figure **8**). Nanostructured biomaterials, mimicking as scaffolds the ECM structure, play important roles in regenerative medicine, actively regulating the cellular responses [15]. They, in fact, serve as temporary 3D substrates to guide neo tissue formation and organization.

This new economic horizon of keeping materials, products, and tools at their highest value could be part of a transition towards a restorative and regenerative economic cycle that will move professionals, marketers and industries from wasteful resource use to foster lower cost products and services, being also characterized by less carbon emissions, and more employment possibilities. It is time to rethink our technologies and economic future!

Thus, Circular economy goes beyond different mechanisms of production and consumption of drugs, cosmetics, medical devices and services to obtain an economy in which the today's goods are the tomorrow's resources. For example, one of the many challenges for marketers is to differentiate their sustainable brands from competing brands and to communicate this to consumers ;and for consumers to recognize the more sustainable brands [16].

This new way to produce, in fact, advocates the need for a functional service model in which manufactures or retailers increasingly retain the ownership of their products as services. Thus, the consumer is replaced from the user.

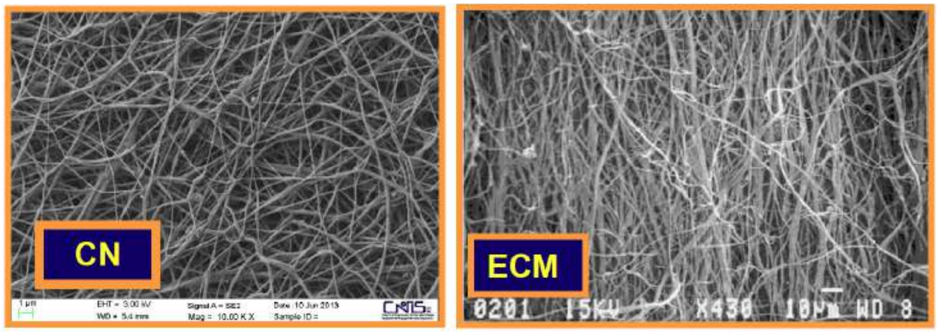

Figure 8: Hierarchical organization of the non-woven tissue of CN in comparison with human tissues.

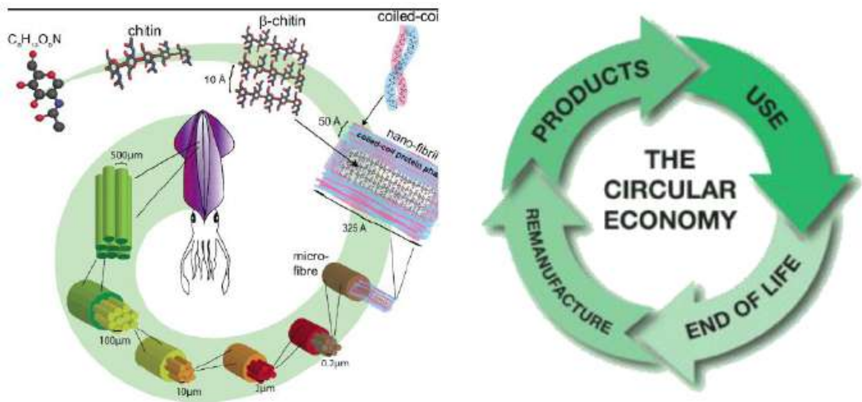

Figure 9: The meaning of the circular economy.

In order to materialize the savings associated with a circular system by reusing resources inputs to the maximum degree, Companies and users need to increase the rate at which the products are collected and subsequently reused and/or their components/ materials recovered (Figure **9**).

It should be necessary to modify the actual industrial and user chain by reusing materials to the maximum extent possible. So doing, this new economic vision of circular economy will be strategic not just for the industry but also for customers, to save planet's raw materials by efficiency and innovation. For example, it should be necessary to substitute petrol-derived polymers with natural polymers and other man-made materials, minimizing energy and water consume. This the reason to produce and use Chitin Nanofibrils (CN) and lignin (LG), obtained from crustaceans waste and plant biomass respectively.

Thus CN and LG, transformed in block co-polymeric nanoparticles and embedded into emulsions and non-woven tissues, have been used as basic natural raw materials to produce advanced medications (Figure **10**), innovative pharmaceutical and cosmetic delivery systems (Figure **11**), innovative beauty masks (Figure **12**), and new biodegradable food packaging (Figure **13**). At this purpose, following multiple extractions, purification, and other steps, these industrial by-products have been used to produce structural and

Figure 10: Wound healing activity of the in-study advanced medications.

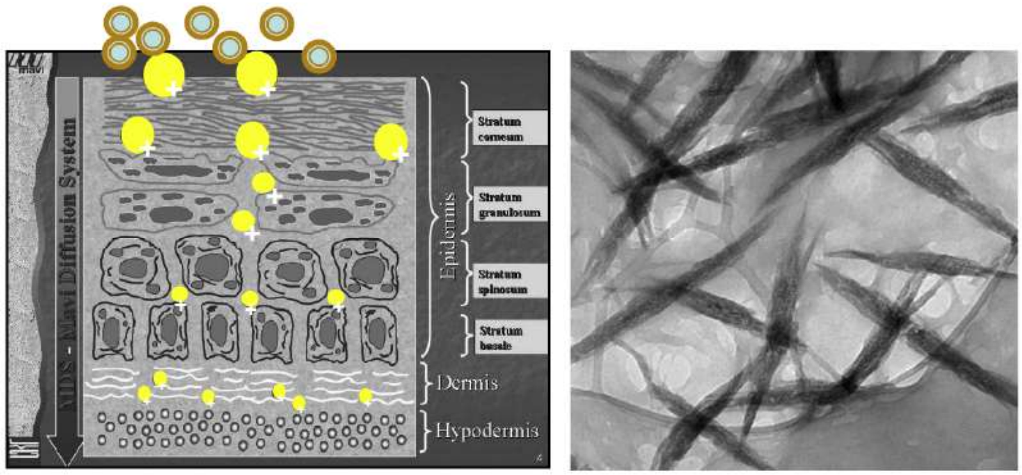

Figure 11: The delivery system carry out and depending from the nanoparticle size and the electrical charges covering is surface.

Figure 12: The innovative beauty mask.

functional bio-nano-composites useful to make innovative goods. Due to the matrix reinforcement of CN, used as nano-filler, the obtained biocomposites have shown improved and ameliorated mechanical, thermal and barrier properties at molecular level, without being affected the polymer processing.

These innovative products are a today reality to be remembered with the goal to generate a synergistic relationship between ecological and economical systems. In any way, it is to remember that on one hand Circular Economy has to involve large scale investments in new products, technologies, equipments, buildings, and infrastructures.

On the other hand, these investments will deliver social and economic benefits by improving resource efficiency and inducing Companies and Professional

Figure 13: The biodegradable and compostable food packaging.

Figure 14: A look to biodiversity.

organizations to innovate, for obtaining a competitive edge, capable also to eradicate poverty and improve social equity for maintaining the biodiversity of our Planet [14] (Figure **14**).

REFERENCES

[1] Ellen MacArthur Foundation. Towards the Circular Economy, 2013, available on www.thecirculareconomy.org

[2] MacArthur Ellen, Zumwinkel K, Stuchtey MR. Growth Within: A Circular Economy vision for a Competitive Europe. Ellen MacArthur Foundation, June 2015.

[3] Von Schomberg R. A vision of responsible Innovation. In: R. Owen R, Heinz M and Bessant J, editors. Responsible Innovation, John Wiley, UK, 2013; pp. 1-34.

[4] FAO. The State of Food Insecurity in the World, Meeting the 2015 international hunger targets in taking stock of uneven progress, FAO, Rome, 2015.

[5] EU. The European Environment State and outlook 2015, Copenaghen, Denmark, 2015.

[6] Hurst L, Stewart K, Vieiro M, Abruzzese L, *et al.* Food loss and its intersection with food security- Report of the Economist Intelligence Unit, Geneva, Switzerland, 2014.

[7] Morganti P, Li YH. Innovation in Cosmetic Dermatology and Medical Science. The role of Chitin Nanofibrils Composites. J Appl Cosmetol 2015; 33: 9-24.

[8] Morganti P. Bionanotechnology & Bioeconomy for a Greener Development, J Appl Cosmetol 2015; 33: 51-65.

[9] Morganti P. Green Economy and Bionanotechnology to transform waste materials in useful goods. Eurocosmetics 2015; 22(1/2): 12-16.

[10] Morganti P. Chitin-nanofibrils in skin treatment. J Appl Cosmetol 2013; 27: 251-270.

[11] Shang HY, Li RO, Liu WM. Effects of chitin and its derivative chitosan on postharvest decay of fruits: A review. J Molecular Sciences 2011; 12: 917-934. http://dx.doi.org/10.3390/ijms12020917

[12] Salaberria AM, Fernadez SCM, Diaz RH, Labidi J. Processing of alpha-chitin nanofibers by dynamic high pressure homogenization: characterization and anti fungal activity against A. niger. Carbohydrate Polymers 2015; 116: 286-291. http://dx.doi.org/10.1016/j.carbpol.2014.04.047

[13] Morganti P, Tischenko G, Palombo M, Kelnar I, *et al.* Chitin nanofibrils for biomimetic products: nanoparticles and nanocomposite chitosan films in health care In: Se-Kwon Kim, editor, Marine Biomaterials: Isolation, Characterization and Application, New York, CRC-Press, 2013; pp. 681-715. http://dx.doi.org/10.1201/b14723-39

[14] Morganti P, Del Ciotto P, Stoller M, Chianese A. Antibacterial and anti-inflammatory Green Nanocomposites. In: Sauro Pierucci e Joiri Klemes editors, chemical engineering transactions, Milano, Italy, HAIDIC 2016; 47: 61-66.

[15] Wei G. Nanostructured biomaterials for regeneration. Adv Function Mater 2008; 18(22): 3566-3582. http://dx.doi.org/10.1002/adfm.200800662

[16] Morganti P. New Horizon in Cosmetic Dermatology. J Appl Cosmetol 2016; 34: 15-24.

[17] Morganti P, Chen H-D. From the Circular Economy to a Green Economy. Note 1.Chitin Nanofibrils as natural by-product to manage the human and environment systems. J Appl Cosmetol 2015; 33: 101-113.

Received on 26-05-2016 Accepted on 13-06-2016 Published on 05-12-2016

DOI: http://dx.doi.org/10.6000/1927-3037.2016.05.04.1