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Nanotechnology, Nanobiotechnology, and the Environment

Pierfrancesco Morganti

Abstract: The lack of industrial planning and management of the purchase, storage, preparation, and reuse of food and food packaging, as well as consumers' food wastage habits, are at the heart of the environmental waste problem. Thus, there is a need to increase public and private investments in R&D for the bionanotechnological valorization of marketable ingredients that are available in food waste, in addition to a need for the introduction of better environmental regulations, scholarly teaching, and mass media communications. In conclusion, an innovative policy to reduce, reuse, and recycle waste will ameliorate the environment and better our quality of life.

1. Introduction: The Environment and the Waste Problem

According to the United Nations Environment Programme (UNEP) [1], human health as well as economic and social progress are closely linked to the quality of the environment. Thus, "investing in improved natural resources", such as plant biomass and fishery waste, in addition to reducing carbon emissions and better planning of urban areas, could "generate high social rates of return" [2].

In fact, better environmental regulations and innovative policies can generate new forms of capital, pushing industry to make green technological progress. This is why UNEP research suggests that "an investment scenario of allocating 2% of global GDP to greening economic sectors will produce a higher global Gross Domestic Product (GDP), compared to the business-as-usual scenario, within 10 years." Moreover, reduced production with organized waste recycling, as well as the production and use of goods made of local, renewable materials, will have increased strategic importance to assure the availability of raw materials and drastically reduce the environmental impact of production.

Thus, it is necessary to reduce the production of waste by the imporoved design of goods and packaging, which also favours global recyclability. In so doing, it will be possible to increase products' shelf-life and gear people's mentality towards reuse, through the mass media and R&D involvement.

During the period 1964–2014, global plastic production increased from 15 to 311 million tons, the major portion of which was used for disposable packaging, with a lost material value of US$80–120 billion per year [3]. Thus, it has been estimated that only 5% of plastic packaging is retained for subsequent use, being used one time only [3,4]. For these reasons, plastics and their by-products are littering cities, oceans, and waterways, also contributing to health problems because of the durability of the involved polymers that accumulate as debris (Figure 1). Additionally, it is important to underline that only 14% of plastics are actually recycled by melting and the adopted methodologies are not only harmful to the environment, but also present health threats to people who come in contact with this material [3–5].

Figure 1. Plastic debris accumulated on land and in the ocean.

Plastic melting, in fact, generates volatile organic compounds (VOC) and fumes which are harmful to plant and animal life, near industrial sites. Moreover, the relative carbon emissions contribute to global warming. Finally, since plastic is not classified as a hazardous material, its recycling does not come under any international regulations, further complicating the efforts to solve the waste problem [3–5]. Thus, there is a necessity to produce and use more bioplastics (Figure 2), which unfortunately represent only 1% of the global plastic production (Figure 3) [6].

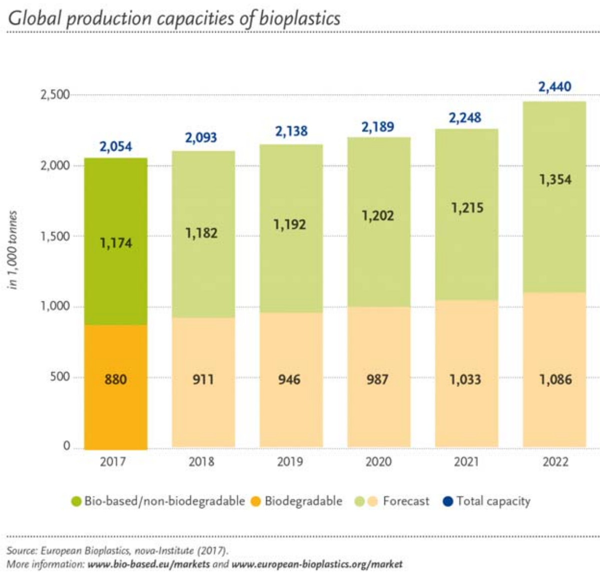

Figure 2. Bioplastics production.

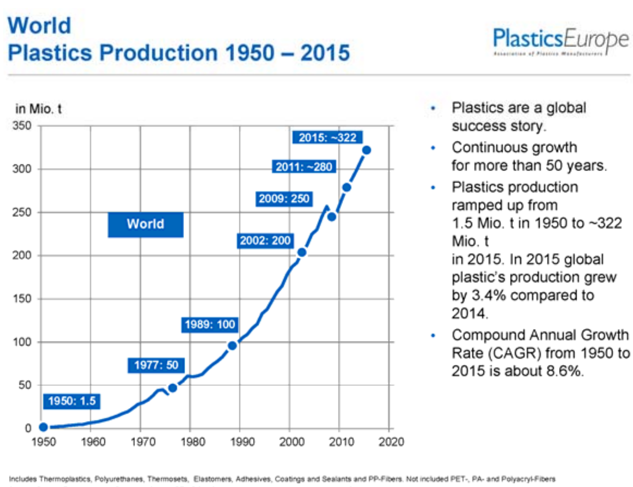

Figure 3. The global production of plastics.

R&D is therefore a fundamental pillar for the creation of novel products that, based on the use of new bionanotechnological science, are capable of profoundly changing today's economy and improving our standards of living. This is why the development of a bionanotechnological product normally starts with an innovative way of thinking that can offer better goods for human welfare.

On the one hand, it will be necessary to avoid food waste by improving consumers' household food management behavior, handling its know-how together with the knowledge of all the stakeholders and the supply chains involved [7]. On the other hand, the industry has to optimize the distribution chains and extraction conditions of food waste through environmentally-friendly biochemical and physical technologies, in order to utilize all of the potentially marketable components present in these discarded goods, as well as their packaging.

Continuous support for public funding and private investments are needed to further develop and increase the R&D means necessary to ameliorate the production, consumption, processing, storage, recycling, and disposal of food and food waste [8]. Towards this purpose, we must remember that 20–25% of food wasted is due to packaging matters. As an example, waste material from coffee-pods is considered to be represented by more than 20 billion pieces/year worldwide, with an annual growth of more than 18% per year over 2011–2016 [9]. Moreover, it must be underlined that in order to produce 1 kg of these capsules, 4 kg of water and 2 kg of petrol must be used together with 22 kW of energy!

In conclusion, along with North America, Western Europe is the chief region for where coffee drinking is a main driver. Thus, to address the problem of sustainability, it is necessary to produce innovative biodegradable pods by increasing the R&D studies on this topic [9].

2. Culture of Knowledge, R&D and Nanobiotechnology

It is fundamental to diffuse the culture and knowledge of these innovative, environmentally friendly nanomaterials and nanotechnologies by scholarly education, and by the use of newspapers, television and any other means of mass media communication.

It is necessary to remember that nanotechnology and bionanotechnology, based upon molecular self-assembly with nanoscale dimensions (a nanometer is a billionth of a meter), deal with the study and application of biological and biochemical activities from the elements of nature to make new and advanced products.

Nature, which self-assembles molecules by biological processes to create complex structures with nanoscale precision, is in fact the best nanotechnology platform, having developed a large array of different materials [10]. They range from feathers to shells, wood, bone and many other macro-, micro- and nanostructures that confer specific properties to materials, such as colour, permeability, elasticity, strength, etc. Inside the cell, for example, there are numerous self-assembled structures that encapsulate specific biomolecules to be released as a consequence of molecular signaling. The human body is composed of soft and hard structures such as skin or bone, made of different kinds of polymers and block copolymers, hydrophilic or hydrophobic, assembled into ordered architectures in the nanoscale regime. Thus, depending on the concentration and the volume ratio between insoluble and soluble blocks, they can form nanoparticles and thin films, used as signalling molecules or cell membranes. Other natural structures, made of chitin crystals, are capable of mimicking different colours found in bird plumage, butterfly wings, or rose flowers (Figure 4) [10,11].

Figure 4. Chitin crystals in birds, butterflies and flowers are capable of mimicking different kinds of colours.

The chitin polymers, organized in a nanostructure, give rise to photonic crystals that reflect sunlight in the presence of water so that the colours that appear depend on the angle from which we observe the animal. This phenomenon inspired the production of biomimetic nanoparticles in cosmetics and drug delivery, as well as the use of crystal chitin to produce innovative smart textiles [10,11].

3. Nanotechnology and Nanoscale

Chitin and chitosan have recently [12–14] found applications in cellular technology for one-, two- and three-dimensional matrices, which have shown good adhesion to stem cells, favouring cell proliferation and differentiation. Additionally, chitosan is a very promising material for the production of absorbable surgical sutures or threads because of its strength and flexibility. However, these properties have to be well preserved upon contact with aqueous media. Thus, a better kinetic investigation of the chitosan fibre resorption in vivo is required to best predict the properties of this type of product.

For all of these reasons, nanomaterials, as cornerstones of nanoscience and nanotechnology, have the potential to revolutionize the ways in which goods and products are created [14,15]. Today they can be found in cosmetics, food, sporting goods, stain-resistant clothing, tires and electronics, and they are also used in medicine for the purposes of diagnosis, imaging, and drug delivery.

Industrially, nanomaterial synthesis and processing may be by two different approaches: a bottom-up method based on the assembling of atoms or a top-down one that breaks or dissociates bulk solids into finer pieces, constituted of a few atoms [15,16]. Milling is a typical top-down method of making nanoparticles, whereas colloidal dispersion is a good example of the bottom-up approach in the synthesis of nanoparticles. These innovative materials, with structural features between those of atoms and bulk materials, possess special characteristics due to their nanosize, higher surface area to volume ratio, high surface energy, spatial confinement and reduced imperfections.

Other fascinating and useful aspects of nanomaterials are their optical and electrical properties, which depend on parameters such as feature size, shape, surface characteristics and other variables necessary to interact with the surrounding environment or other nanostructures.

In conclusion, nanobiotechnology is to be considered a marriage between biological science and engineering methodologies. It seeks to study and apply the biological and biochemical activities of elements in nature to fabricate new goods. The use of waste materials is an important way to protect the environment [17]. Environmental biotechnology, a system based on developing our scientific and engineering knowledge, is related to the use of microorganisms in the prevention of environmental pollution [18].

However, the fabrication and assembly of nanoscale materials, goods and devices capable of conferring health and safety benefits while maintaining the global ecosystem and biodiversity, still represent a major challenge [19]. With this book we have tried to propose some solutions to this challenge.

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Conflicts of Interest: I work as Head of the R&D Centre of Nanoscience, Mavi Sud, s. r. l, Italy.

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