Chapter

Introductory Chapter: Introduction to Biocomposites – New Insights

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1. Introduction to Biocomposites

Biocomposites are increasingly gaining approval on the industrial scale due to their high adaptability and superior performance. Some examples of these applications are tissue engineering, drug delivery systems, restorative applications, storage devices, photocatalysts, biosensors, the encapsulation of enzymes and cells, construction, energy, rail cars, automobiles, aerospace, military applications, and packaging systems. **Figure 1** is showing some of these applications.

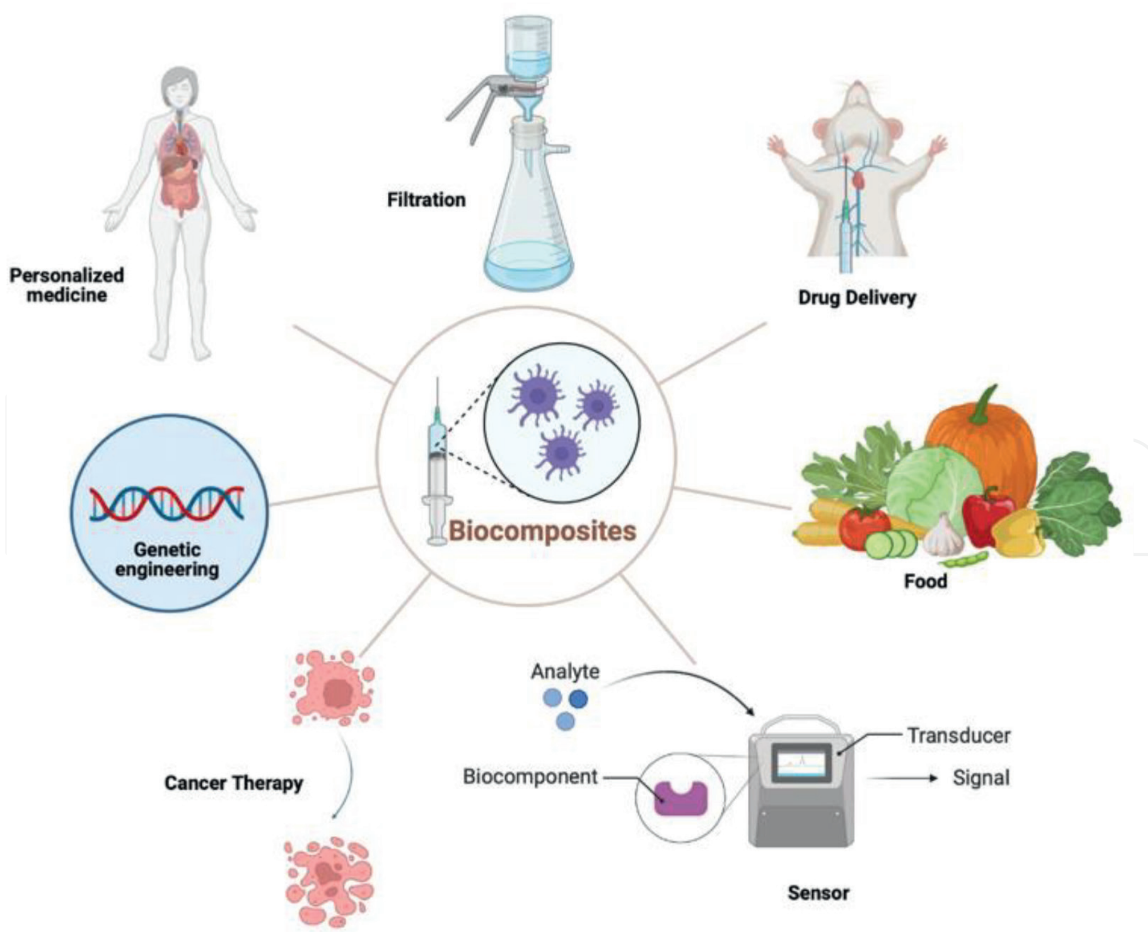

Figure 1.
Applications of biocomposites.

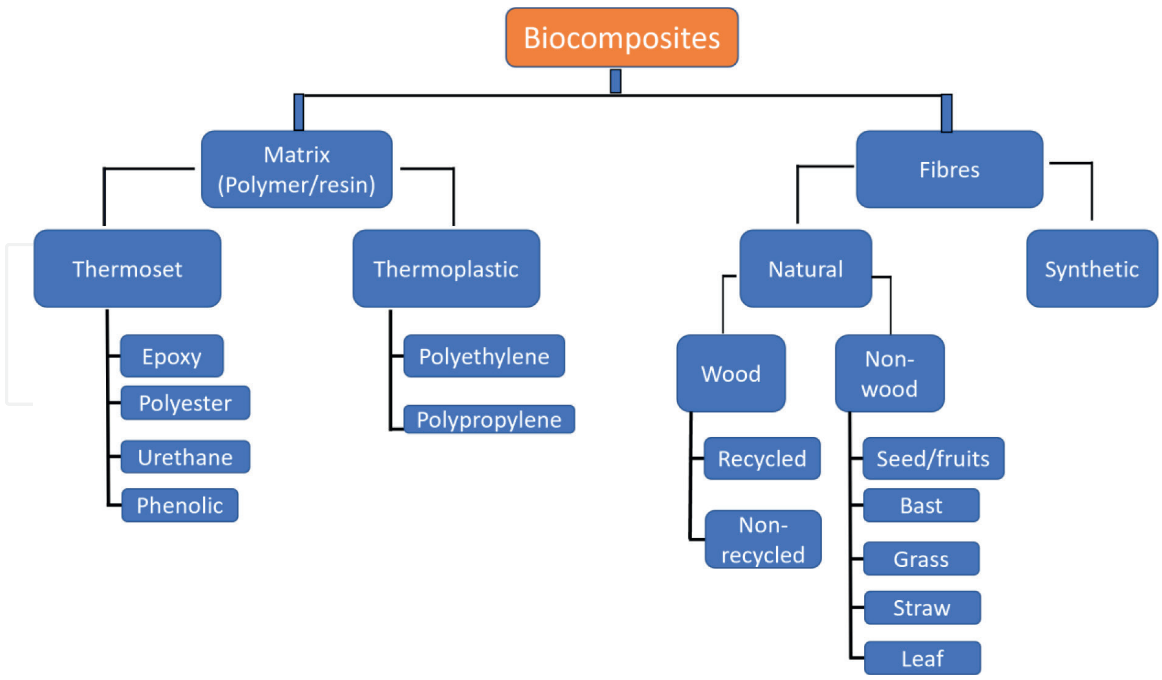

Figure 2.
Biocomposites structure.

Biocomposites are made of a matrix material (resins, biopolymers) and natural or synthetic fibers (reinforcing materials). In this context, the word "biocomposite" refers to fiber-reinforced polymer composite materials that contain bio-based fibers and/or bio-based matrix as shown in **Figure 2**. Depending on the type of polymer matrix employed, such as thermoplastics and thermosets, the characteristics of biocomposites change. The matrix plays a crucial role in holding the fibers together, transferring stresses onto them, and safeguarding them from mechanical harm and environmental deterioration.

2. Natural polymers (biopolymers)

Natural polymers (biopolymers) are more desirable than synthetic polymers due to their sustainable resources, low toxicity, biocompatibility, biodegradability, and ability to be modified, which enables tailoring of their properties to suit their application especially in the pharmaceutical industry [1]. Biopolymers are classified into three major categories as shown in **Figure 3** [2].

2.1 Applications of biopolymers

Biopolymers have a wide range of uses in the food, pharmaceutical, cosmetics, beauty, agricultural, biomedical, and many chemical industries [3–6]. The most common materials for such biopolymers are carboxymethyl cellulose (CMC), poly(amino acids), starch [7] poly(acrylamide) (PAAm), polydopamine, poly(lactide), poly(diethylaminoethyl methacrylate) (PDEAEMA), poly (acrylic acid) (PAA), poly(methacrylic acid) (PMAA), poly (ε-caprolactone) (PCL), gelatine, poly(dimethylaminoethyl methacrylate) (PDMAEMA), poly(2-methacryloyloxyethyl phosphorylcholine), albumin,

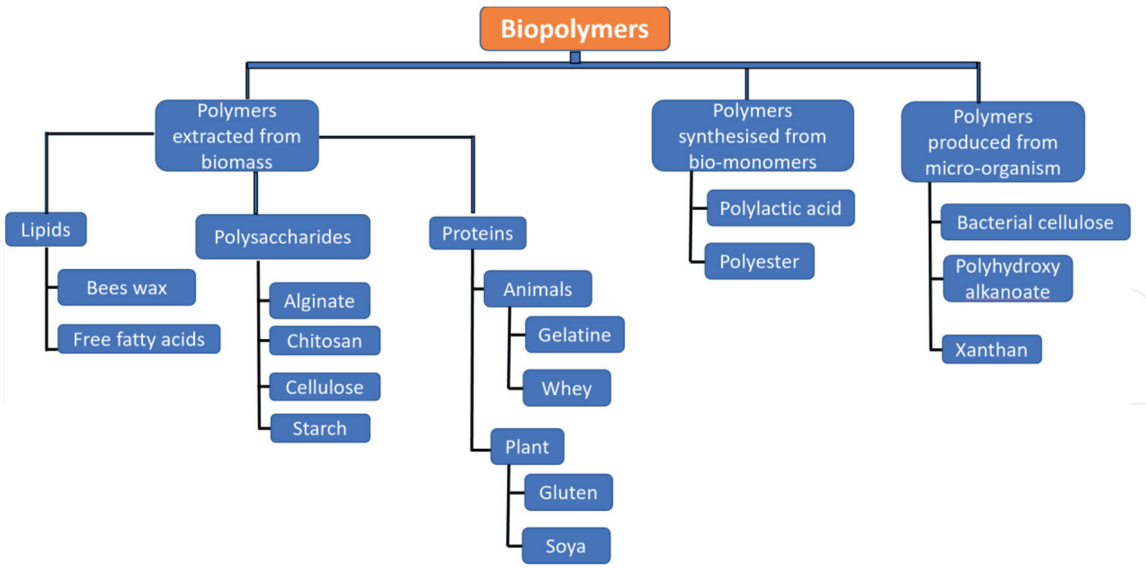

Figure 3.
Classification of biopolymers.

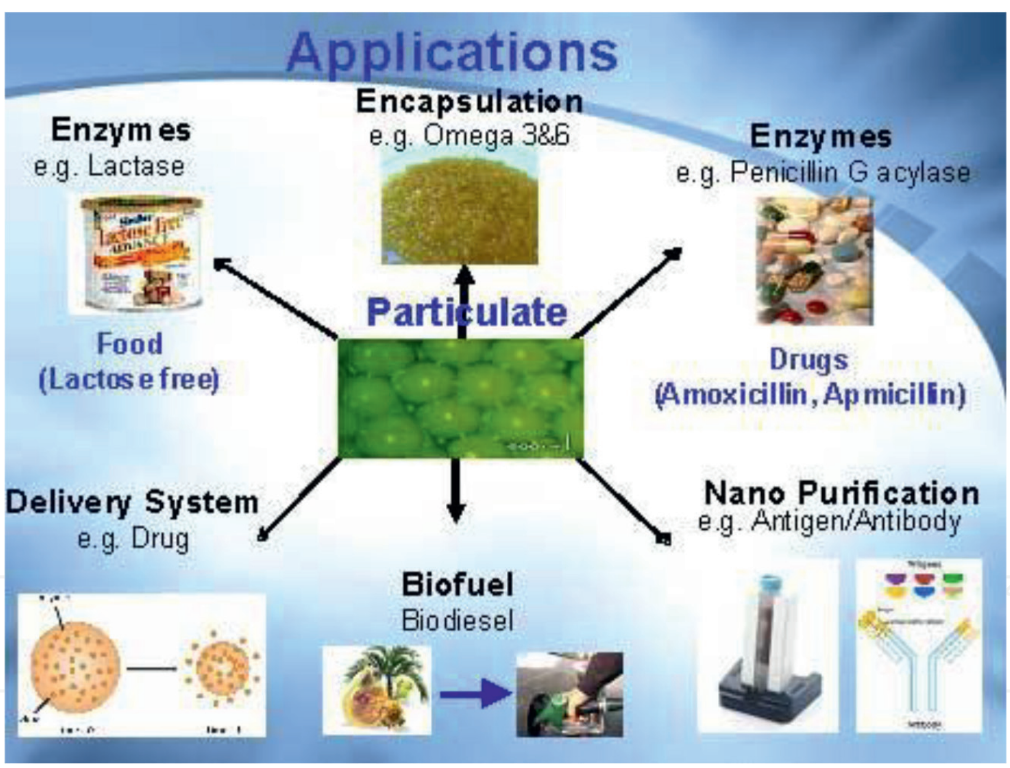

Figure 4.
Applications of grafted biopolymers.

polyvinyl alcohol (PVA), alginate, chitosan, carrageenan, and polyethylene glycol (PEG) [3, 4, 7–17]. As given in **Figure 4**, alginate [18, 19], chitosan [20–23], carrageenan [24–27] were studied, for instance, in the immobilization of enzymes (e.g. lactase), drug delivery systems, encapsulation of food (e.g. Omega 3&6), and biofuel [28, 29]. According to a forecast by European Bioplastics, the market of biopolymers will increase from 1.4 million tonnes in 2012 to roughly 6.2 million tonnes in 2027 [30].

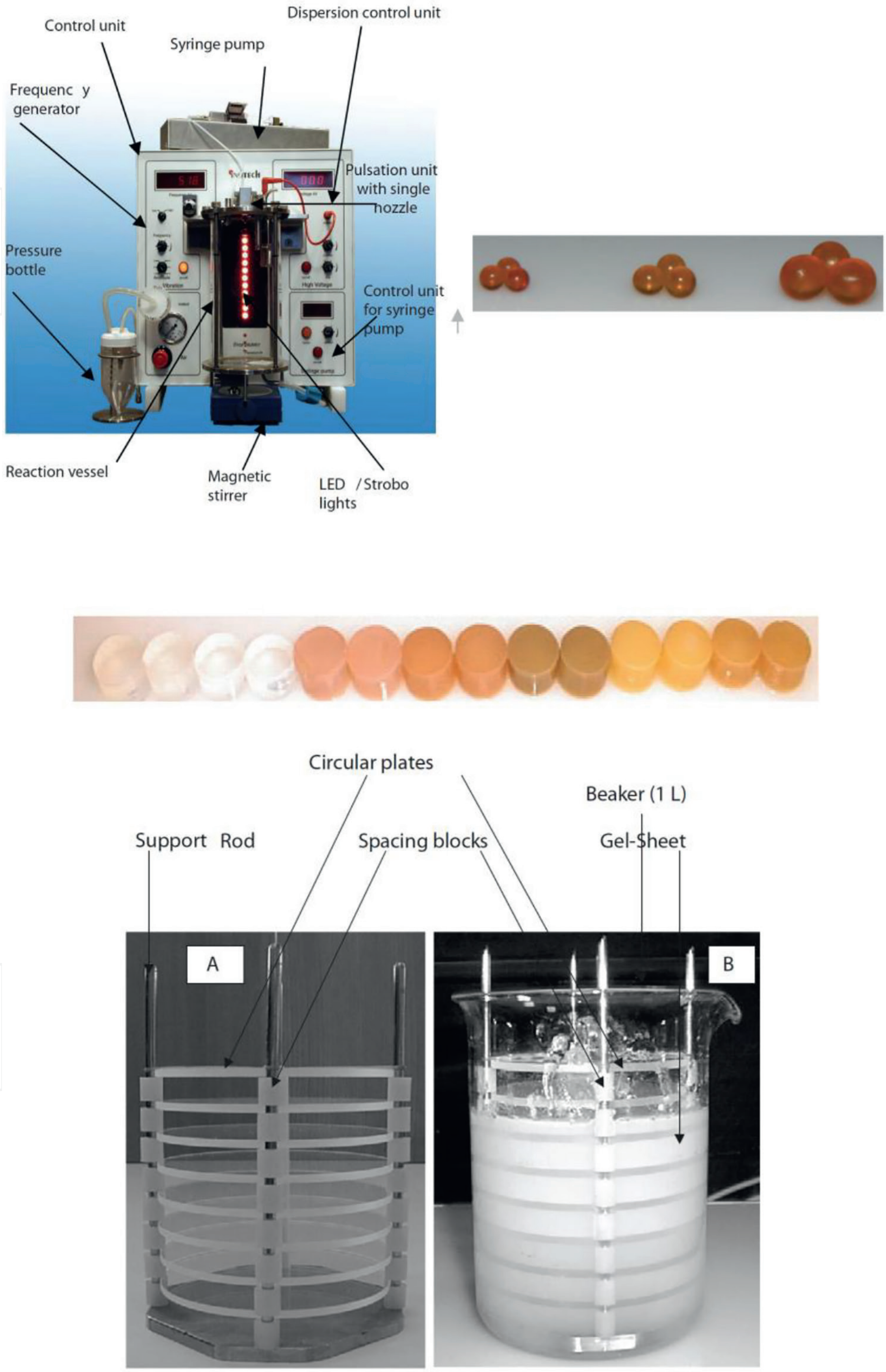

Figure 5.
Particulates prepared in the size of macro to nano including magnetized beads. Pictures reproduced from Elnashar (a) production of micro beads using the encapsulator [3], and (b) production of uniform gel sheets and disks using the parallel plate equipment [31, 32].

2.2 Shapes of biopolymers

The biopolymers can be treated and produced in different shapes using the Innotech Encapsulator, vibrational jet-flow technology, ionic-gelation methods, parallel plates, dripping and interphase techniques. Gel sheets, disks, and beads were produced using the Innotech Encapsulator and the parallel plates as shown in **Figure 5** [3, 31]. Nanoparticles can be synthesized using a variety of techniques that fall under the top-down or bottom-up method categories [33].

Nanotechnology has become an attractive research field with a high potential in field of development of advanced nano-products due to their superior surface, physical, chemical, biological, and mechanical properties. That was also due to their nano-size, morphology, shape, solubility, biodegradability, and biocompatibility. Particularly, bio/nanocomposites have high surface to volume ration (small particles ranging from 1 to 100 nm in size), thus the interaction between the matrix (shell/biopolymer) and reinforcement (core/fiber) is particularly strong [34].

3. Fibers

The fibers provide strength and stiffness to the structure. The classification of fibers is presented in **Table 1**. Fibers are obtained either naturally or man-made as shown in **Table 1**. Although synthetic and natural fibers can be used in biocomposites, the use of natural fiber as reinforcement in polymeric composites has been preferred due to environmental concerns and the high cost of synthetic fibers [35, 36]. Naturally occurring fibers can be classified into three main categories: mineral, animal, and plant fibers. The latter are the most abundant fibers among all the natural fibers. Silk fiber (animal fiber) has the highest tensile strength among all the natural fibers [37]. Whereas asbestos and ceramic (mineral fibers) can function in high temperatures [38]. More than 65% of natural fiber-based composites are used in the packaging sector, with the remaining 35% being used in the medical, textile, electrical, and agricultural sectors [39].

Biocomposites							
	Wood fibers		**Non-wood natural fibers**				
	Recycled	**Non-recycled**	**Seed/ fruits**	**Bast**	**Grass**	**Straw**	**Leaf**
Examples	Papers, magazines, newspapers fibers	Soft and hard wood	Cotton, coconut, coir	Help, flax, jute, kenaf	Switch grass, elephant grass, bamboo, bamboo fiber	Wheat, corn, rice, straw	Pineapple leaf, sisal, henequen

Table 1.
Classification of biocomposites' fibers.

4. Future overview

Recent developments in the study of bio-based nanostructures, with an emphasis on the environmentally sustainable production of biocomposites, have tremendously benefited biomedical applications. The low-cost, environmentally beneficial method of creating biocomposites with biodegradable and biocompatible polymers currently has a variety of advantages. The advantages of pH and temperature sensitive dual-stimuli responsive nano-systems should be investigated by next-generation drug delivery systems using in vitro or in vivo methods. These discoveries imply that additional research in this field is required given the lack of experimental knowledge and understanding of drug release systems, bio-sensing mechanism, and therapeutic effects of these biocomposites.

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