STUDIES ON PREPARATION OF BIOPOLYMERS AND ITS INVITRO PHARAMACOLOGICAL ACTIVITY

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Abstract:

Imaginative arrangements utilizing biopolymer-based materials made of a few constituents appears to be especially appealing for bundling in biomedical and drug applications. In this course, some advancement has been utilized the electrospinning cycle towards fiber development dependent on biopolymers and natural mixes for the arrangement of novel bundling materials. Electrospinning can be utilized to make nanofiber mats portrayed by high immaculateness of the material, which can be utilized to make dynamic and current biomedical and drug bundling. Wise clinical and biomedical bundling with the utilization of polymers is a comprehensively and quickly developing field of interest for ventures and the scholarly world. Among different polymers, alginate has found numerous applications in the food area, biomedicine, and bundling. For instance, in medication conveyance frameworks, a cross section made of nanofibres created by the electrospinning strategy is profoundly wanted.Electrospinning for biomedicine depends on the utilization of biopolymers and regular substances, alongside the mix of medications, (for example, naproxen, sulfikoxazol) and fundamental oils with antibacterial properties, (for example, tocopherol, eugenol). This is a striking technique because of the capacity of creating nanoscale materials and designs of uncommon quality, permitting the substances to be embodiedwhat's more, the medications/organically dynamic substances put on polymer nanofibers. Along these lines, in this article we momentarily sum up the new advances on electrospinning of biopolymers with specific accentuation on use of Alginate for biomedical and drug applications.

Catchphrases: biopolymers; bundling; drug; biomedical; electrospinning; alginate

Introduction

Present day bundling ought to shield items from outer variables, broaden the time of keeping up

the nature of the item or more all, limit sway on the climate [1–6]. Figure 1 sums up a portion of the properties wanted in like manner bundling materials. Nitty gritty properties have been talked about in some fantastic survey articles, so we won't be broadly expounding [1,2,7–9].

Toward this path, public mindfulness is quickly developing and drawing in more noteworthy consideration regarding environment, too as the utilization of characteristic substances for a scope of uses from auto to biomedical [10–16]. An inclination in the bundling business to plan creative materials and present new arrangements is acquiring more prominent consideration [17,18]. Dynamic and current bundling often depends on regular substances Nanomaterials 2019, 9, 404;

doi:10.3390/nano9030404 www.mdpi.com/diary/nanomaterials Nanomaterials 2019, 9, 404 2 of 23 for example, normal polysaccharides [9]. It is basic to safeguard all parts of ecological wellbeing during creation, just as the adequacy and security of utilization for patients [19–23]. Strangely, the cyclic olefin copolymer (COC) is most generally utilized for alter safe bundling and is a amazing option in contrast to a damped polyvinyl chloride (PVC).

Bundling in clinical and biomedical designing is characterized as a strategy that empowers the conclusion of a drug item from its creation to its end use [24]. The part of drug bundling is to give life-saving medications, careful gadgets, nutraceuticals, pills, powders and fluids, to give some examples [7,25]. Drug bundling impacts the disconnection and guarantees the security, personality and accommodation of utilizing the medication. The bundling should discuss well with the patient so that there are no unfriendly consequences for the wellbeing of the patient. The central point of contention in bundling is likewise the issue of natural security [26,27]. Medication organizations that pack drugs are among the business chiefs because of their innovative advances. Latest things in mechanical exploration on such new materials are the consequence of a consistent arrangement of difficulties being looked by the business. The bundling business is continually advancing and is a significant factor in the advancement of the drug business and biomedical sciences. Electrospinning of polymers/nanomaterials [28,29] is one of the likely strategies in the bundling cycle that considers the utilization of biopolymers [30]/normal substances for the creation of clinical bundling, dressings, biosensors, clinical embeds, and is a developing pattern in biomedical sciences [10,31–39]. Figure 2 represents the schematic of a coaxial electrospinning arrangement. The inset shows a representation of a coaxial stream under applied voltage [39]. Mercante et al in their great survey articles have additionally indicated the quantity of distributions that is included the utilization of electrospinning in sensor applications and the quantity of these distributions is expanding step by step [10].

Various kinds of electrospun filaments are being delivered for biomedical applications [32]. In any case, the electrospinning of biopolymers is a difficult cycle. For instance, on account of chitosan, its balance lead to the deficiency of chitosan qualities by utilizing inadmissible substances. In the creation of nonstop fibers, reasonable solvents ought to be utilized so that there is no interference. What's more, during chitosan nanofiber blend, the estimation of the electric field created is additionally vital. Excessively high of an electric field causes aversion between ionic gatherings of the polymer spine, which upsets the development of constant fibers. The utilization of chitin and chitosan nanofibers in biomedical and different applications has been as of late explored [32–34]. Jayakumar et al, in their article, had principally centered around the properties, arrangement and biomedical applications [32]. Electrospinning of silk has likewise been accounted for [35]. It is utilized due to valuable properties, for example, non-harmfulness and biocompatibility.

Because of its positive mechanical properties, it tends to be utilized in different temperature and dampness ranges. Be that as it may, on account of silk, one of the protein parts, sericin, ought to be taken out before natural application since it can cause unfavorably susceptible responses, for instance, on account of clinical dressings [36–38].

One of the creatures that is delivered as a primary segment of silk protein is Bombyx mori [40]. The protein it produces, silk fibroin, is an enormous translucent macromolecule comprising of rehashing units of amino acids, for the most part alanine (A), glycine (G) and serine (S). The strands that are shaped with its cooperation show great mechanical properties [41]. Scientists have likewise shown that electrospinning of biopolymer mixes of chitin and silk fibroin is conceivable [42]. In this cycle, nanofibrous films of mixed chitosan and silk fibroin were effectively arranged utilizing electrospinning in a HFIP/TFA turning dissolvable. With the addition in the substance of silk fibroin, the common breadth of the as-arranged nanofibers was found to increment. The consolidation of silk fibroin was additionally found to add to the upgrade in the mechanical properties of nanofibrous layers. Moreover, with the addition in the chitosan content, the antibacterial movement turned out to be essentially appropriate for wound dressings [42]. Electrospun collagen–chitosan nanofiber having a commonplace fiber breadth of 434–691 nm was additionally set up as a biomimetic extracellular grid (ECM) for endothelial cells and smooth muscle cells [43]. Diverse portrayal procedures, for example, FTIR spectra investigation, XRD examination, DSC and ductile testing were completed to break down the created materials [43]. Twofold organization (DN) agarose/polyacrylamide nanofibers were set up by electrospinning [44]. The DN of agarose/polyacrylamide (PAAm) nano filaments created utilizing concurrent photograph polymerization and electrospinning. Diverse portrayal methods were utilized to affirm the acknowledgment of a crosslinked twofold organization. In contrast with the flawless agarose, the electrospun sinewy agarose/PAAm showed 66.66% upgrade in the strength [44]. Essentially, electrospinning of alginate is being done for various applications [45]. Alginate is a significant biopolymer with immense potential [46].

Synthetic Polymers

Various sorts of polymers going from normal to manufactured are quickly turning into the most intriguing subject of examination with regards to the area of the biomedical business [47]. They are frequently utilized in the bundling of prescriptions [48,49], just as in the improvement of adaptable ampoule/needles that are all the more simple to utilize. Nonetheless, adsorption and movement of the bioactive substance to the polymer changes in pH, porousness of oxygen, optical properties and the arrival of drained segments influence their utilization and ought to be considered [50,51]. Association of the distinctive external parts influences the medication as well as the capacity of the polymeric compartment. Polyolefins, high-thickness polyethylene (HDPE) or polypropylene (PP) are probably the most well-known polymers utilized for the creation of vials. Frequently, multilayer holders are created to accomplish such necessities as latency, oxygen or UV security. Polycyclic and olefinic polymers and

copolymers (Daikyo Crystal Zeniths) have been utilized for filling polymer needles [51,52]. Gadgets, for example, PVC tubes containing di-2-ethylhexylphthalate (DEHP) plasticizer are utilized in dialysis for blood supply or extracorporeal oxygenation. The sacks containing the polymer are utilized to give blood and store blood items. Because of lipophilicity, the plasticizer is moved from the polymer surface to lipids and red platelet films [53]. It has been discovered that the plasticizer in blood packs lessens haemolysis of red platelets by about half contrasted with blood put away in non-plastic compartments, which improves the nature of the blood item [50]. Cylinders for extracorporeal course are regularly heparinized to diminish the coagulation, which causes serious contact with PVC and expands thrombogenicity [54].

For the capacity of red platelets, an elective plasticizer, for example, butyryl-trihexyl-citrate (BTHC)

or then again di-iso-nonyl-1, 2-cyclohexanedicarboxylate (DINCH) is utilized. Polyolefins as elective polymers are utilized to store platelets [55,56]. Polyethylene and polyurethanes are utilized to make tubes. Containers of positronic siphons are typically made of silicone [51]. Hemodialysis layers are created as groups of empty strands with a surface in contact with blood. The specialized necessities concern for the most part the porousness for substances less than egg whites, keeping the section of pollutions from the dialysate to the blood, and the similarity of the film with blood. Already, dialysis layers were made of cellulose [51,57]. The hydroxyl bunches were supplanted with acetylene subordinates or other altered added substances, forestalling the initiation of the supplement framework and the related leukocyte enactment and leukocyte sequestration in the lungs [51,57]. Manufactured layers comprise of a hydrophobic base material and hydrophilic parts. The polyaryl sulfone co-precipitation layers, polysulfone (PSf) and polyvinylprolidone (PVP) films are the most well known for various applications [58]. Likewise, other layer materials, for example, polyamide (PA), polycarbonate (PC) and polyacrylonitrile (PAN), PMMA, polyester polymer combination (PEPA), ethylene vinyl liquor copolymer (EVAL), and sub-atomic meager nanoporous silicon stomachs are additionally utilized. Poly (ethylene glycol) (PEG) is utilized in layers to improve similarity with blood [59]. Polymer stents utilized in the upper segments of the ureter are intended to defeat the issues of sperm disease. Silicone is the best biocompatible material with the least incrustation inclination. Its utilization is restricted by low mechanical firmness and high obstruction. In this manner, polyurethane items with preferred mechanical properties over silicone were streamlined [51,60]. The stents were

covered with glycosaminoglycans (GAGs, heparin or pentosan polysulfone), phosphorylcholine, which builds the solace of patients, decreases bacterial colonization and encrustation [51,60].

Biopolymers: Structure of Alginate

As of late, there has been an extraordinary pushed on the utilization of biopolymers for various applications, particularly in the biomedical and drug [61–65]. The useful productivity of the biopolymer particles relies upon the sythesis, physicochemical properties and underlying highlights [66–68]. It is conceivable to sanely plan the piece and construction of the biopolymer to get the suitable practical ascribes [23]. The inner design of the polymer particle decides numerous useful attributes, for example, porousness, chargeability and trustworthiness [69]. The security of the biopolymer particles and their capacity to total is impacted by the electrical qualities. Biopolymer

particles with a high electric charge will repulse and forestall accumulation. Particles of biopolymers and their electrical properties impact the association with different atoms present in the general climate [69]. Among common biopolymers, alginate is quite possibly the most famous and strongly contemplated [70,71]. It is an anionic biopolymer comprising of units of mannuronic corrosive and guluronic corrosive in unpredictable squares [72]. Mannuronic corrosive and guluronic corrosive are connected by glycosidic linkages [73–75]. Mannuronic corrosive structures β (1 → 4) bonds and α bonds (1 → 4) with guluronic corrosive [76]. The solidness of atomic chains is guaranteed by the unbending and bowed conformities of guluronic corrosive [77,78]. Hadas and Simcha have as of late revealed their fascinating work on the portrayal of sodium alginate and calcium alginate with specific accentuation on their design [79]. Various properties and utilizations of alginate have additionally been surveyed [80]. The properties of alginates utilized in biomedicine can be molded by adjusting the accessibility of their hydroxyl and carboxyl gatherings [81]. It influences the properties of alginates, for example, solvency, hydrophobicity and their organic movement. Alginate hydrogels were made by crosslinking polymer chains [82]. The substance properties of alginate hydrogels were found to rely upon the cross-connecting thickness of the chain [83]. One of the techniques utilized in the plan of alginate hydrogels is intermolecular cross-connecting, in which just the alginate guluron bunches respond with the divalent cation regularly the calcium used to gel the alginate [84]. Marguerite has summed up the utilizations of alginate particularly for bundling in a brilliant survey article, so we won't broadly expound [85].

1. Biopolymers for Biomedical and Pharmaceutical Packaging

Dynamic and current bundling biomaterials contain characteristic substances that are richly found in nature [1,11,128]. Biomaterials are frequently founded on normal polysaccharides [129–133]. Among polysaccharides, Alginates have discovered applications in the food area, water decontamination, biomedicine and bundling [73,134–139]. Green growth contain supplements, for example, nutrients, salts, iodine and sterols. Life forms containing a lot of alginate in the cell dividers are the earthy colored green growth Phaeophyceae, for example, Fucus, Laminaria, and Aseophyllum. The measure of alginates acquired for the most part relies upon the types of green growth and the extraction strategies utilized [140]. They are direct polymers made out of (1→4)- α-L-guluronic corrosive squares (GG) β-D-mannuronic corrosive squares (MM) furthermore, of heteropolymeric arrangements of M and G (MG blocks) [74,80]. In biomedicine, alginates are utilized for controlled medication discharge, embodiment, platforms in tendons, tissue designing and in dentistry for the planning of structures within the sight of moderate delivery calcium salt [141]. The drug business utilizes purged alginates for scattering or adjustment of substances. In biomedicine, alginates are utilized for controlled medication discharge, exemplification, frameworks in tendons, tissue designing and in dentistry for the readiness of structures within the sight of moderate delivery calcium salt. Figure 7 shows the application regions of alginate hydrogels. The alginate produces palatable coatings with great boundary and mechanical properties permitting the insurance of dynamic fixings by embodiment [3]. Garlic oil is frequently added as a characteristic antibacterial specialist in such coatings. Alginate is incompletely cleaned with calcium and blended in with starch to get high water maintenance in the paper covering. This is significant to acquire a uniform mass and covering by squeezing to improve its rheology [85]. Alginates have discovered various applications in biomedical sciences as wound dressing materials [142]. Particularly sodium alginate utilized as a hydrogel has animated increasingly more logical interest because of its physicochemical properties. Materials made of alginate are viewed as agreeable to people because of tissue biocompatibility, which takes into consideration their utilization in biomedical designing [135,140]. Exceptionally spongy dressing materials are shaped by the creation of wet turning strands. With the expansion of calcium and sodium, high-retentiveness sodium and calcium filaments were created. Antimicrobial strands were additionally shaped by adding alginic corrosive or silver. By adding zinc, the strands that produce the invulnerable framework were made. Filaments for immobilizing or supporting bioactive particles were promptly arranged [143]. Antimicrobial properties were granted to cotton textures utilizing alginate–quaternary ammonium complex nanoparticles [144]. Utilizing the ionic gelation strategy, another sort of nanoparticle (normal size of 99 nm) that was made out of sodium alginate (SA) and 3-(trimethoxysilyl) propyl-octadecyldimethylammonium chloride (TSA) was combined. Strands showed an effective antimicrobial movement that was even kept up after 30 clothing cycles (non-draining antimicrobial specialist) [144]. Ionic gelation was utilized to build up another class of nanoparticles that comprises of sodium alginate (SA) and 3-(trimethoxysilyl) propyl-octadecyldimethylammonium chloride (TSA). The proportion of SA/TSA was found to show a huge impact on the normal size of the SA–TSA nanoparticles. Nanoparticles having a normal size of 99 nm were chosen for the examination and, subsequent to utilizing a cushion dry-fix strategy, were stacked onto cotton textures. Distinctive portrayal methods were utilized to examine the treated textures. It was finished up from the investigation that the SA–TSA nanoparticles display high potential to be utilized as a non-filtering specialist conferring strong antimicrobial qualities to the examined cotton textures [144].

The new age of clinical materials denotes the field of development for researchers and scientists [145]. The current dressings are non-harmful, bacteriostatic, antiviral, non-hypersensitive, hemostatic, profoundly spongy

and, most importantly, biocompatible. It is conceivable to adjust them so they contain drugs for certain mechanical properties. Current material materials in present day bundling are likewise profoundly assorted. These incorporate tapes, textures, non-woven textures, weaved textures, composite materials [16,146]. Lignin and cellulose [147,148] are the most bountiful regular polymers accessible as side-effects of different enterprises. Ongoing logical reports show that lignin is progressively utilized as a fundamental part of hydrogels [149]. This takes into account the making of different sorts of materials, particularly in the clinical or drug area [150]. It is likewise conceivable to add added substances to dressings, for example, smell engrossing, alleviating agony and bothering.

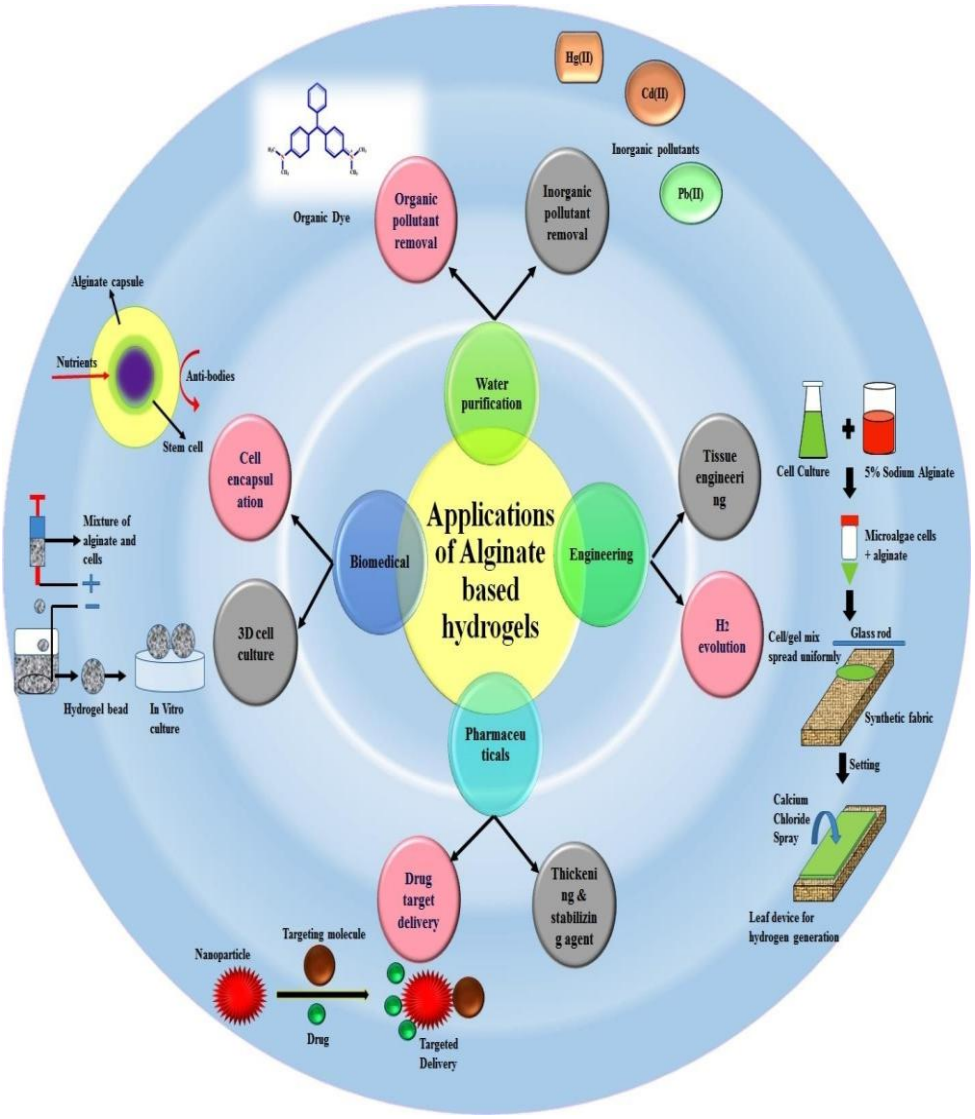

Figure 7. Various applied applications of alginate based hydrogels [135]. Reprinted with permission from Ref. [135]. Copyright Elsevier, 2018.

Smart Biopolymers

Astute biopolymers are getting increasingly more alluring in biotechnology and medication, just as in bundling [160,161]. They are utilized in biomedicine and tissue designing. Clever biopolymers have been accounted for to assume a significant part in medication conveyance [22,162,163]. They are not difficult to deliver, are a decent transporter of supplements and keep up the dependability of the medication [150,164]. It is conceivable to infuse them in vitro as a fluid and they can shape a gel at internal heat level. Thermosensitive polymers are utilized to solubilize hydrophobic medications and are utilized in the creation of arrangements with low solvency drugs as a medication transporter. The utilization of canny polymers for drug conveyance is promising considering the instrument of medication discharge noticed [165]. Outer and inward boosts that influence the system incorporate temperature, light illumination, electric flow and smart hydrogels that can immobilize catalysts can gel by stage progress [165]. The synthetic sign converts into a mechanical sign causing contracting or growing of the gel. This wonder is utilized for the controlled arrival of the medication. The dispersion of the medication from the dots

relies upon the state of the gel [166]. The canny polymer is for the most part incorporated with a divider microcapsule or a liposome lipid bilayer. The conformational progress of the polymer influences the trustworthiness of the microcapsule or liposome and permits controlled arrival of the medication consolidated into the microcapsule or liposome [167].

On account of the utilization of medications delivered in hydrogels, drug viewpoints can build efficiency, benefit and wide scope of uses [70]. One illustration of an insulin conveyance framework is a hydrogel including an insulin-containing store inside a poly (methacrylic corrosive g-ethylene glycol) copolymer in which glucose oxidase was immobilized [168,169]. At present, there is a restricted examination on fluorinated polymers as a medication transporter in medication conveyance applications. Polymer films have been utilized as aloof materials for drug discharge because of their capacity to be hydrophilic to hydrophobic in surface wettability. The attributes of the cycle are reversible and can go to the underlying state [170,171]. The utilization of lipid based biopolymers for disease treatment has been as of late looked into [172]. In this article, writers have zeroed in on the worthwhile biologic and physicochemical attributes including controlled medication discharge, long circulatory half-lives and effortless focused on treatment of the normal and manufactured lipid.

1. Summary and Future Prospective

Bundling assumes a basic part in inventory network and has gotten incredible consideration in number of enterprises. Nonetheless, the current bundling frameworks are basically founded on engineered polymers/plastics from fossil assets. Seeing the issues related with the manufactured polymers/plastics, biomedical and drug businesses specifically all around the planet are searching for new bio-based economical bundling materials that can expand the time span of usability of these materials because of the natural and medical problems related with conventional bundling waste. Expanding the utilization of practical polymeric materials in bundling could address such concerns. The fundamental objectives of polymer scientists in the improvement of new clinical and drug materials are related with a decrease in the danger of sickness transmission and the spread of diseases. The quest for new viable antimicrobial dressing materials is continually developing. Electrospinning is being utilized in medication for the creation of non-woven constructions at the nanoscale. In the electrospinning cycle, the synthetic and actual boundaries of the got nanofibre mats can be changed by dressing the suitable materials and boundaries of the cycle. The electrospinning cycle is additionally impacted by nanoparticles of different common materials and biopolymers. The expansion of common nanomaterials influences the morphology and size of the electrospun fiber. Alongside alginate, the other biopolymers being utilized in the electrospinning strategy incorporate hyaluronic corrosive, cellulose, silk, gelatin and collagen, to give some examples. The combination of biopolymers and engineered polymers is additionally used to make the novel biomaterials with explicit properties, for example, mechanical obstruction, warm strength and hindrance opposition. Blends with normal polymers may likewise influence the primary, morphological and ensuing debasement properties of the electrospun filaments

The treatment of illness states with the assistance of naturally dynamic materials made with the help of electrospun nanofibers is essential for present day regenerative medication. The utilization of normal materials, for example, plant oils and concentrates implies that the nonwovens made in the electrospinning cycle find numerous applications with security of utilization. It is critical that it is conceivable to upgrade measure conditions and make nanofibers that meet explicit necessities. Among the different materials examined, alginate has high potential for bundling applications and is being viewed as the eventual fate of bundling materials. Nonetheless, an exceptionally restricted investigation has been completed on the utilization of Alginate based

electrospun mats for pressing application, and to understand its genuine expected a broad examination toward this path is required.

References

1. Cazón, P.; Velazquez, G.; Ramírez, J.A.; Vázquez, M. Polysaccharide-based films and coatings for food packaging: A review. *Food Hydrocoll.* **2017**, *68*, 136–148. [CrossRef]
2. Gomez-Estaca, J.; Gavara, R.; Catala, R.; Hernandez-Munoz, P. The Potential of Proteins for Producing Food Packaging Materials: A Review. *Packag. Technol. Sci.* **2016**, *29*, 203–224. [CrossRef]
3. Hambleton, A.; Debeaufort, F.; Bonnotte, A.; Voilley, A. Influence of alginate emulsion-based films structure on its barrier properties and on the protection of microencapsulated aroma compound. *Food Hydrocoll.* **2009**, *23*, 2116–2124. [CrossRef]
4. Khalil, H.P.S.A.; Davoudpour, Y.; Saurabh, C.K.; Hossain, M.S.; Adnan, A.S.; Dungani, R.; Paridah, M.T.; Sarker, M.Z.I.; Fazita, M.R.N.; Syakir, M.I.; et al. A review on nanocellulosic fibres as new material for sustainable packaging: Process and applications. *Renew. Sustain. Energy Rev.* **2016**, *64*, 823–836. [CrossRef]
5. da Silva, F.T.; da Cunha, K.F.; Fonseca, L.M.; Antunes, M.D.; Mello El Halal, S.L.; Fiorentini, A.M.; da Rosa Zavareze, E.; Guerra Dias, A.R. Action of ginger essential oil (*Zingiber officinale*) encapsulated in proteins ultrafine fibers on the antimicrobial control in situ. *Int. J. Biol. Macromol.* **2018**, *118*, 107–115. [CrossRef] [PubMed]
6. Kuntzler, S.G.; Vieira Costa, J.A.; de Morais, M.G. Development of electrospun nanofibers containing chitosan/PEO blend and phenolic compounds with antibacterial activity. *Int. J. Biol. Macromol.* **2018**, *117*, 800–806. [CrossRef] [PubMed]
7. Kwon, H.; Kim, D.; Lee, K.; Seo, J.; Lee, H.-J. The Effect of Coating Process and Additives on EVA Coated Tyvek (R) for Gas Sterilizable Medical Packaging Applications. *Packag. Technol. Sci.* **2017**, *30*, 195–208. [CrossRef]
8. Lauriano Souza, V.G.; Fernando, A.L. Nanoparticles in food packaging: Biodegradability and potential migration to food—A review. *Food Packag. Shelf Life* **2016**, *8*, 63–70. [CrossRef]
9. Wróblewska-Krepsztul, J.; Rydzkowski, T.; Borowski, G.; Szczypiński, M.; Klepka, T.; Thakur, V.K. Recent progress in biodegradable polymers and nanocomposite-based packaging materials for sustainable environment. *Int. J. Polym. Anal. Charact.* **2018**, *23*, 383–395. [CrossRef]
10. Mercante, L.A.; Scagion, V.P.; Migliorini, F.L.; Mattoso, L.H.C.; Correa, D.S. Electrospinning-based (bio)sensors for food and agricultural applications: A review. *TrAC Trends Anal. Chem.* **2017**, *91*, 91–103. [CrossRef]
11. Thakur, S.; Chaudhary, J.; Sharma, B.; Verma, A.; Tamulevicius, S.; Thakur, V.K. Sustainability of bioplastics: Opportunities and challenges. *Curr. Opin. Green Sustain. Chem.* **2018**, *13*, 68–75. [CrossRef]
12. Shao, P.; Niu, B.; Chen, H.; Sun, P. Fabrication and characterization of tea polyphenols loaded pullulan-CMC electrospun nanofiber for fruit preservation. *Int. J. Biol. Macromol.* **2018**, *107*, 1908–1914. [CrossRef] [PubMed]
13. Ochoa, M.; Collazos, N.; Le, T.; Subramaniam, R.; Sanders, M.; Singh, R.P.; Depan, D. Nanocellulose-PE- b-PEG copolymer nanohybrid shish-kebab structure via interfacial crystallization. *Carbohydr. Polym.* **2017**, *159*, 116–124. [CrossRef] [PubMed]
14. Depan, D.; Misra, R.D.K. Hybrid Nanoscale Architecture of Wound Dressing with Super Hydrophilic, Antimicrobial, and Ultralow Fouling Attributes. *J. Biomed. Nanotechnol.* **2015**, *11*, 306–318. [CrossRef] [PubMed]
15. Singha, A.S.; Thakur, V.K. Synthesis and Characterization of Pine Needles Reinforced RF Matrix Based Biocomposites. *J. Chem.* **2008**, *5*, 1055–1062. [CrossRef]
16. Thakur, V.K.; Singha, A.S. Mechanical and Water Absorption Properties of Natural Fibers/Polymer Biocomposites. *Polym.-Plast. Technol. Eng.* **2010**, *49*, 694–700. [CrossRef]
17. Antunes, M.D.; da Silva Dannenberg, G.; Fiorentini, A.M.; Pinto, V.Z.; Lim, L.-T.; da Rosa Zavareze, E.; Guerra Dias, A.R. Antimicrobial electrospun ultrafine fibers from zein containing eucalyptus essential oil/cyclodextrin inclusion complex. *Int. J. Biol. Macromol.* **2017**, *104*, 874–882. [CrossRef] [PubMed]
18. Kurd, F.; Fathi, M.; Shekarchizadeh, H. Basil seed mucilage as a new source for electrospinning: Production and physicochemical characterization. *Int. J. Biol. Macromol.* **2017**, *95*, 689–695. [CrossRef] [PubMed]

19. Kohsari, I.; Shariatinia, Z.; Pourmortazavi, S.M. Antibacterial electrospun chitosan-polyethylene oxide nanocomposite mats containing ZIF-8 nanoparticles. *Int. J. Biol. Macromol.* **2016**, *91*, 778–788. [CrossRef] [PubMed]
20. Miculescu, F.; Maidaniuc, A.; Voicu, S.I.; Thakur, V.K.; Stan, G.E.; Ciocan, L.T. Progress in Hydroxyapatite– Starch Based Sustainable Biomaterials for Biomedical Bone Substitution Applications. *ACS Sustain. Chem. Eng.* **2017**, *5*, 8491–8512. [CrossRef]
21. Pandele, A.M.; Comanici, F.E.; Carp, C.A.; Miculescu, F.; Voicu, S.I.; Thakur, V.K.; Serban, B.C. Synthesis and characterization of cellulose acetate-hydroxyapatite micro and nano composites membranes for water purification and biomedical applications. *Vacuum* **2017**, *144*, 599–605. [CrossRef]
22. Corobea, M.C.; Muhulet, O.; Miculescu, F.; Antoniac, I.V.; Vuluga, Z.; Florea, D.; Vuluga, D.M.; Butnaru, M.; Ivanov, D.; Voicu, S.I.; et al. Novel nanocomposite membranes from cellulose acetate and clay-silica nanowires. *Polym. Adv. Technol.* **2016**, *27*, 1586–1595. [CrossRef]
23. Pandele, A.M.; Neacsu, P.; Cimpean, A.; Staras, A.I.; Miculescu, F.; Iordache, A.; Voicu, S.I.; Thakur, V.K.; Toader, O.D. Cellulose acetate membranes functionalized with resveratrol by covalent immobilization for improved osseointegration. *Appl. Surf. Sci.* **2018**, *438*, 2–13. [CrossRef]
24. Van de Walle, E.; Van Nieuwenhove, I.; Vanderleyden, E.; Declercq, H.; Gellynck, K.; Schaubroeck, D.; Ottevaere, H.; Thienpont, H.; De Vos, W.H.; Cornelissen, M.; et al. Polydopamine-Gelatin as Universal Cell-Interactive Coating for Methacrylate-Based Medical Device Packaging Materials: When Surface Chemistry Overrules Substrate Bulk Properties. *Biomacromolecules* **2016**, *17*, 56–68. [CrossRef] [PubMed]
25. Rogina-Car, B.; Grgac, S.F.; Katovic, D. Physicochemical Characterization of the Multiuse Medical Textiles in Surgery and as Packaging Material in Medical Sterilization. *Autex Res. J.* **2017**, *17*, 206–212. [CrossRef]
26. Rowson, J.; Sangrar, A.; Rodriguez-Falcon, E.; Bell, A.F.; Walton, K.A.; Yoxall, A.; Kamat, S.R. Rating Accessibility of Packaging: A Medical Packaging Example. *Packag. Technol. Sci.* **2016**, *29*, 607. [CrossRef]
27. Kale, R.D.; Gorade, V.G.; Madye, N.; Chaudhary, B.; Bangde, P.S.; Dandekar, P.P. Preparation and characterization of biocomposite packaging film from poly(lactic acid) and acylated microcrystalline cellulose using rice bran oil. *Int. J. Biol. Macromol.* **2018**, *118*, 1090–1102. [CrossRef] [PubMed]
28. Nasajpour, A.; Mandla, S.; Shree, S.; Mostafavi, E.; Sharifi, R.; Khalilpour, A.; Saghazadeh, S.; Hassan, S.; Mitchell, M.J.; Leijten, J.; et al. Nanostructured Fibrous Membranes with Rose Spike-Like Architecture. *Nano Lett.* **2017**, *17*, 6235–6240. [CrossRef] [PubMed]
29. Muhulet, A.; Miculescu, F.; Voicu, S.I.; Schütt, F.; Thakur, V.K.; Mishra, Y.K. Fundamentals and scopes of doped carbon nanotubes towards energy and biosensing applications. *Mater. Today Energy* **2018**, *9*, 154–186. [CrossRef]
30. Thakur, S.; Sharma, B.; Verma, A.; Chaudhary, J.; Tamulevicius, S.; Thakur, V.K. Recent approaches in guar gum hydrogel synthesis for water purification. *Int. J. Polym. Anal. Charact.* **2018**, *23*, 621–632. [CrossRef]
31. Nasajpour, A.; Ansari, S.; Rinoldi, C.; Rad, A.S.; Aghaloo, T.; Shin, S.R.; Mishra, Y.K.; Adelung, R.; Swieszkowski, W.; Annabi, N.; et al. Tissue Regeneration: A Multifunctional Polymeric Periodontal Membrane with Osteogenic and Antibacterial Characteristics (Adv. Funct. Mater. 3/2018). *Adv. Funct. Mater.* **2018**, *28*, 1870021. [CrossRef]
32. Jayakumar, R.; Prabaharan, M.; Nair, S.V.; Tamura, H. Novel chitin and chitosan nanofibers in biomedical applications. *Biotechnol. Adv.* **2010**, *28*, 142–150. [CrossRef] [PubMed]
33. Thakur, V.K.; Thakur, M.K. Recent Advances in Graft Copolymerization and Applications of Chitosan: A Review. *ACS Sustain. Chem. Eng.* **2014**, *2*, 2637–2652. [CrossRef]
34. Thakur, V.K.; Voicu, S.I. Recent advances in cellulose and chitosan based membranes for water purification: A concise review. *Carbohydr. Polym.* **2016**, *146*, 148–165. [CrossRef] [PubMed]
35. Xi, H.; Zhao, H. Silk fibroin coaxial bead-on-string fiber materials and their drug release behaviors in different pH. *J. Mater. Sci.* **2019**, *54*, 4246–4258. [CrossRef]
36. Voicu, S.I.; Condruz, R.M.; Mitran, V.; Cimpean, A.; Miculescu, F.; Andronescu, C.; Miculescu, M.; Thakur, V.K. Sericin Covalent Immobilization onto Cellulose Acetate Membrane for Biomedical Applications. *ACS Sustain. Chem. Eng.* **2016**, *4*, 1765–1774. [CrossRef]
37. Wenk, E.; Wandrey, A.J.; Merkle, H.P.; Meinel, L. Silk fibroin spheres as a platform for controlled drug delivery. *J. Control. Release* **2008**, *132*, 26–34. [CrossRef] [PubMed]

38. Valentini, L.; Bon, S.B.; Pugno, N.M. Combining Living Microorganisms with Regenerated Silk Provides Nanofibril-Based Thin Films with Heat-Responsive Wrinkled States for Smart Food Packaging. *Nanomaterials* **2018**, *8*, 518. [CrossRef] [PubMed]
39. Bedford, N.M.; Steckl, A.J. Photocatalytic Self Cleaning Textile Fibers by Coaxial Electrospinning. *ACS Appl. Mater. Interfaces* **2010**, *2*, 2448–2455. [CrossRef]

40. Montalban, M.G.; Coburn, J.M.; Abel Lozano-Perez, A.; Cenis, J.L.; Villora, G.; Kaplan, D.L. Production of Curcumin-Loaded Silk Fibroin Nanoparticles for Cancer Therapy. *Nanomaterials* **2018**, *8*, 126. [CrossRef] [PubMed]
41. Zhou, C.-Z.; Confalonieri, F.; Jacquet, M.; Perasso, R.; Li, Z.-G.; Janin, J. Silk fibroin: Structural implications of a remarkable amino acid sequence. *Proteins Struct. Funct. Bioinform.* **2001**, *44*, 119–122. [CrossRef] [PubMed]
42. Cai, Z.; Mo, X.; Zhang, K.; Fan, L.; Yin, A.; He, C.; Wang, H. Fabrication of Chitosan/Silk Fibroin Composite Nanofibers for Wound-dressing Applications. *Int. J. Mol. Sci.* **2010**, *11*, 3529–3539. [CrossRef] [PubMed]
43. Chen, Z.G.; Wang, P.W.; Wei, B.; Mo, X.M.; Cui, F.Z. Electrospun collagen–chitosan nanofiber: A biomimetic extracellular matrix for endothelial cell and smooth muscle cell. *Acta Biomater.* **2010**, *6*, 372–382. [CrossRef] [PubMed]
44. Cho, M.K.; Singu, B.S.; Na, Y.H.; Yoon, K.R. Fabrication and characterization of double-network agarose/polyacrylamide nanofibers by electrospinning. *J. Appl. Polym. Sci.* **2016**, *133*. [CrossRef]
45. Hu, W.-W.; Lin, C.-H.; Hong, Z.-J. The enrichment of cancer stem cells using composite alginate/polycaprolactone nanofibers. *Carbohydr. Polym.* **2019**, *206*, 70–79. [CrossRef] [PubMed]
46. Wang, J.; Salem, D.R.; Sani, R.K. Extremophilic exopolysaccharides: A review and new perspectives on engineering strategies and applications. *Carbohydr. Polym.* **2019**, *205*, 8–26. [CrossRef] [PubMed]
47. Iqbal, N.; Khan, A.S.; Asif, A.; Yar, M.; Haycock, J.W.; Rehman, I.U. Recent concepts in biodegradable polymers for tissue engineering paradigms: A critical review. *Int. Mater. Rev.* **2019**, *64*, 91–126. [CrossRef]
48. Clark, C.M.; Bottomley, L.; Jackson, P. The development of a training package for community pharmacists focused on medicines use review in common skin diseases. *Pharm. World Sci.* **2008**, *30*, 377–378.
49. Lorenzini, G.C.; Hellstrom, D. Medication Packaging and Older Patients: A Systematic Review. *Packag. Technol. Sci.* **2017**, *30*, 525–558. [CrossRef]
50. Jenke, D. Evaluation of the chemical compatibility of plastic contact materials and pharmaceutical products; safety considerations related to extractables and leachables. *J. Pharm. Sci.* **2007**, *96*, 2566–2581. [CrossRef] [PubMed]