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Nanostructured Biopolymers for Biomedical Applications: A Review

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ABSTRACT:

Bio-based materials are considering as efficient, low cost and environmental friendly material for the different purposes including biomedical applications. Last few decades Nanostructured biopolymers have been widely used for several medical applications including wound heling, drug delivery, tissue engineering etc. as because of low cost, efficient and abundant presence of raw materials in around. This review was aimed to evaluate the role of nanostructured biopolymers for medical applications by the published works. The review also explored the efficiency, stability and mechanistic insight of different biopolymers for diverse medical applications by reported research published in the past.

Keywords: Nanomaterial, Biopolymer, Biomedical, Wound Heling, Tissue Engineering.

Introduction

Nanostructured materials are considering the one of the best alternative materials due to their exciting surface properties including surface chemistry, surface area, and selectivity Nanoparticles are reported as the efficient and they are capable to making bridge between pristine and composite within the nanometre range [1-5]. Among other nanostructured materials, the polymeric materials are owing great interest to increase the capabilities of other bio-active molecules in a material [6]. The biopolymers are originating/fabricating by using living organisms including proteins, peptides, cellulose etc. these are abundant in the environment [7-10]. They can have synthesized by using living organisms or chemically synthesized applying hybridization with biological materials [11]. Last few decades, researchers are focusing for synthesis of more and more eco-friendly nanostructured materials as the green chemistry approaches for environmental sustainability [12]. Hence, biopolymer nanoparticles are using for fabrication of nanostructured materials for numerous uses including medical applications. In addition, the polymeric material including conducting polymers, biopolymers and polymeric hydrogel etc. have been widely applying in the field of biomedical sectors including pharmaceutical carriers, tissue engineering and development of devices as seen in the Fig-1[13]. Biopolymers including alginate, cellulose, heparin, chitosan, gelatin and polyvinyl alcohol (PVA) etc. can be utilized to coating of pharmaceutical products, tissue engineering and wound healing as the nanostructured materials [14,15]. Some of reported biopolymers and their inclusive applications are listed in the Table-1.

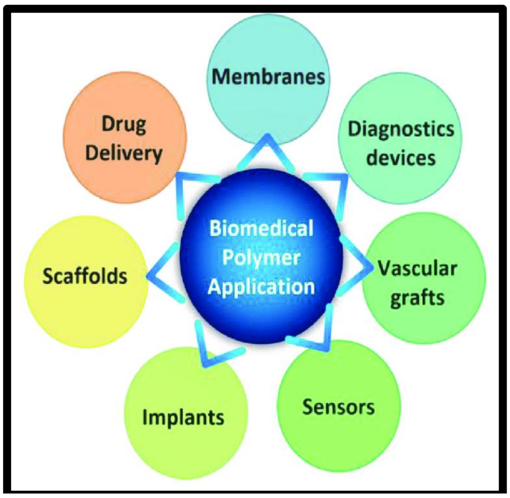

Fig.1: The applications of bio-based materials [13].

Table-1: Applications of biopolymers for biomedical applications

Name of biopolymer	**Applications**	**Refs.**
Cellulose	Drug delivery, tissue engineering and other biomedical applications.	[16]
Alginate	Alginate based biopolymers are widely applying for drug delivery, pharmaceutical and tissue engineering applications.	[17]
Hyaluronate	Biomedical and pharmaceutical field.	[18]
Carboxymethyl cellulose(CMC)	Biomedical applications including drug delivery, pharmaceutical and tissue engineering.	[19]
Polyamides (γ-PGA)	Hydrogels and blends for biomedical, bioremediation applications	[20]
Polyhydroxyalkanoates (PHAs)	Applied for vaccine development, regenerative medicine, implants and tissue engineering and biomaterials etc.	[21]

Currently, reviews are demanding for inventing the modification routes, chronological development and advancement of nanostructured biopolymers for exploring more and more environmental friendly materials for biomedical applications.This review was aimed to evaluate the role of nanostructured biopolymers for medical applications by the published works. The review also explored the efficiency, stability and mechanistic insight of different biopolymers for diverse medical applications by reported research published in the past.

Biopolymer

Generally, the polymeric materials can be classified into functionalized synthetic polymers and carbohydrate polymers [22]. The chitosan, starch, cellulose and other carbohydrate molecules those are composed of extended chains of monosaccharides and subsequently these are bound with glycosidic linkages [23]. On the other hand, the synthetic polymers having carboxyl and amino groups can be enhanced the surface properties due to their availability of functional groups and well as bound to the polymeric matrices. Among other polymeric materials, the biopolymers are developing by using biological living organisms and are synthesized over processes enzymes with combining blocks of hydroxy fatty acids, amino acids and sugar as the hyperlink and subsequent long chain of molecules [24]. The characteristics of polymeric substances were showed as storage molecules with coated with capsular layers surrounding cells. Currently, in the bioengineering and artificial biology is widely applying the biopolymers for coating and packaging of medicinal drugs [25]. The rational design of biopolymer-producing cellular factories has increasingly attracted research and commercial interest. Over the beyond few a long time, genome sequencing and superior molecular techniques have generated a huge set of statistics not handiest supplying perception into the position of bacterial polymers in pathogenesis however additionally for engineering bacteria as mobile factories that produce tailor-made bio-primarily based substances. Such renewable and biodegradable materials ought to replace oil-based commodity substances and could also develop improvement of novel excessive-price biomaterials to offer answers for unmet clinical wishes as they're regularly inherently biocompatible [26-28].

Types of biopolymer

Generally, biopolymers can be broadly divided into biodegradable and non- biodegradable, both of this categories of biopolymer are different types (Fig.2) [29]. Among numerous, starch, cellulose, chitosan, and agar that are derived from carbohydrate as well as gelatin, gluten, alginate, whey protein, and collagen which can be derived from protein [18-22]. Nowadays, the advent of technology has carried to formation of synthetic biopolymers which encompass polylactic acid (PLA), polycaprolactone (PCL), polyglycolic acid (PGA), polyvinyl alcohol (PVA), and polybutylene succinate PBS [30]. The importance of synthetic biopolymers consists of the potential to create a sustainable industry as well as enhancement of their characteristics that includes flexibility, excessive gloss, clarity, and tensile strength. Biopolymers can be classifying into four categories based on sources and origin of the biopolymers as seen in the flowing figure and flow chat [29].

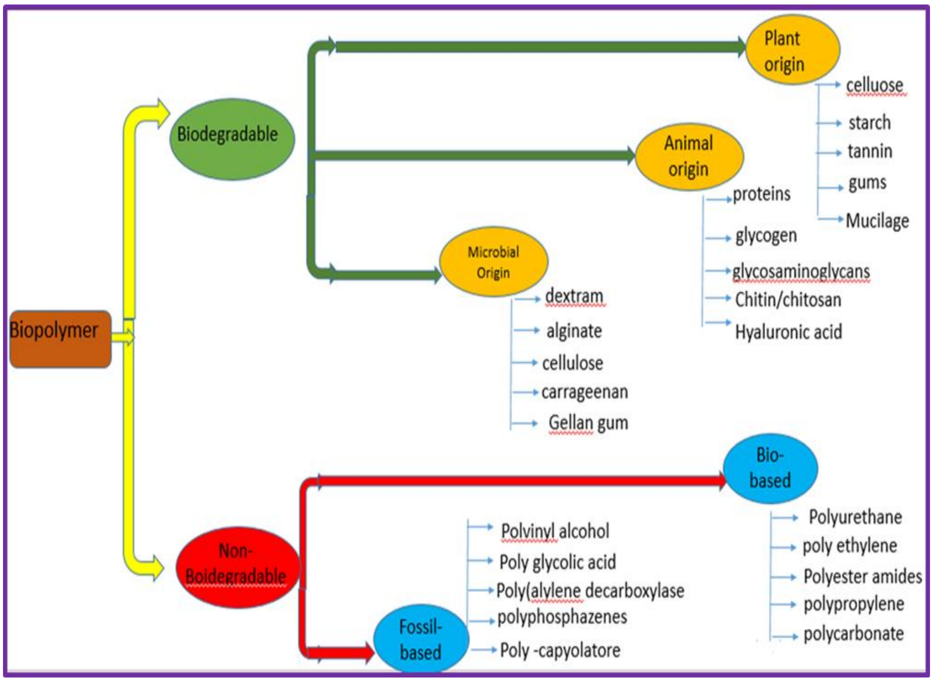

Fig.2: Different types of biopolymer [29].

Nanostructured materials

Nanostructured refers to the functional elements that are within 1-100 nm of size [31]. Nanostructured materials are considering as best alternative materials due to their exciting surface properties including surface chemistry, surface area, and selectivity. Nanostructured materials allowing and making building blocks with other pristine material in a nanometre range, so that, they are creating abundant new fabricated materials with improving the properties of materials [1,2]. Nanomaterials can be modified by different modification process including functionalization, surface modification, modification of shapes of materials, assembling, size control and composition of materials as seen following Fig.3[32].

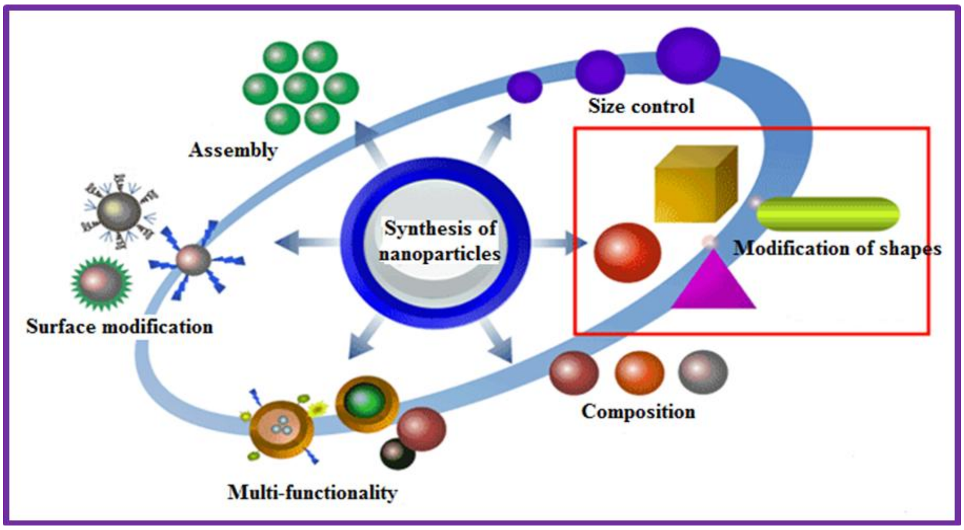

Fig.3: Different types of modification of nanoparticles [32].

Now a day's nanomaterials are of immense methodical and scientific interest for biomedical applications. Nanostructured material can be fabricated and modified with different functional groups including metal oxides, modification of polymers, modification with biological sources of pristine or polymerization with bio materials those are denoted as biopolymer.

Bio-based materials

The materials have synthesized with biological sources of pristine is called bio-based materials [1]. These are considering as environmental friendly, abundant in nature and cost-effective materials. The combination and polymerization with bio-based materials including cellulose, starch, chitosan, and alginate to hybridized of bio-polymer composites are essential for improvement of surface properties of materials and subsequently bio-polymer materials could be used afar of the customary applications of scientific fields including biomedical applications [3,18,22].

Nanostructured biopolymer for biomedical applications:

Biomedical applications including drug delivery, tissue engineering, medical devices, pharmaceutical carriers and wound healing are very prioritized field of research as one of the basic requirements of human society [33,34]. Last decades, researchers have been emphasized their great attention in the versatile subsectors of biomedical research by using biopolymer nanocomposites due to existing properties of bio-based materials. Among biopolymer, the gelatin was applied in pharma products for wound dressing as because of their properties like adhesion. Gelatin films and skeletons having porous morphology of biopolymer have been developed with solvents associated normal porogens owning the drug holding capacity on their scaffolds for dressing the wound [35]. Other studies reported that, the Electrospun PLGA-based scaffolds were widely used in the field of medical research including drug-delivery and tissue repairing as biomedical engineering application [36]. Numerous biopolymers applied in the biomedical research fields discussing are follows those are reported in past studies.

Biopolymer for tissue engineering

The synthetic or modified additives of materials has to capacity of repair and substitute of damaged tissues through tissues engineering. In this connection bio-based materials including biopolymer having biodegradability and biocompatibility has been explored good alternatives for the tissue engineering of biomedical application. Substantial number of previous studies have been found to construction of numerous biopolymer nanomaterials for tissue skeletons [38]. Having 3-D Scaffolds of artificial ECM was applied for proliferation, cellular seeding and new tissue construction as the application of tissue engineering. One of the sanctifications of biopolymers (nanocellulose, collagen, xylans, etc.) for scaffolds is the biological standing that may positively covenant cellular function and adhesion. For safely eliminate of damaged tissue, the used tissue scaffold should be biodegradable in the body spontaneously at the similar growing rate of replaced tissue, biopolymer can do that due to biodegradable nature [39].

In the case of nanocellulose based polymer have certainly maintained hydrogen bond network of chemical structure having excellent hydrophilic nature with very good mechanical strength as well as their biocompatibility properties create the opportunities as the very good alternative of candidates for application of biomedical field including tissue engineering. This types of cellulose skeletons have to capacity and owning all the properties for tissue engineering including high pollutants adsorption capability of wastewater, retention of water, good mechanical and chemical strength along with biocompatibility [40]. The CNC and CNF has been used for fabrication of different polymer nanocomposite to owing suitable chemical structure and requires properties same to native tissue by enhancing the swelling, thermal and mechanical strength as well as biocompatibility for skin tissue repairing technology. The polylactide-polyglycolide (PLGA) was modified by hybridizing with CNC to prepare PLGA/CNC membranes by applied electrospinning to enhancing spreading, adhesion, proliferation and cell compatibility over the pristine PLGA for tissue engineering technology [41]. On the other hand, chitosan, gelatin, PVA, collagen and GelMa, has been applied for modification by using nanocellulose to develop suitable structures for obtaining favorable properties of microenvironment for new skin cell adhesion as similar to native skin [42,43].

Biopolymer for drug delivery

The cellulose based biopolymers and their derivatives have been extensively applied for drug delivery as because of their mechanical strength and other properties as biomaterials [44,45]. The cellulose ether was applied in solid tablets and found that, the cellulose ether permits and released the physiological fluids in form of swelling-driven medicine during contact of tablets. The physical hydrogels were form as an entanglements chain when cellulose ether biopolymer come into contact on the surface of tablet by their swelling. The used polymer outer structure accelerates the diffusion of drug from water very quickly due to swelling from shiny surface of the tablet [46,47].

Other biomaterial, the chitosan's and their derivatives were used for drug delivery due to their promising absorption behavior and potentials for drug components stabilization those are led to increment of the targeting prospects of drugs. The chitosan has to capacity to prevent the DNA subsequently increment of genes expression period as well as their derivatives also capable for releasing the drug to cancer tissues by anticancer acts with the association of many agents of anticancer elements [48].

The collagens and derivatives have been used to repairing the damaged tissues including liver cancer and corneal tissue replacing. The tetracycline and gentamycin as high dose of antibiotics were used for repairing the damaged corneal tissue and subsequently enhancing the formation of bone using this collagen types of gene delivery [49].

Biopolymer for wound healing

Cellulose based biopolymers were applied for the dressing of wound due to their obtained necessary properties for wound healing. Among other essential acts, the cellulose and their derivatives can prevent the outside tissue of wound, killing the pain, release the damaged tissue, preserve appropriate wetness, inhibit as well as resistor biofilms from microbes and purify the wounded tissues [50]. Moreover, bacterial cellulose (BC) also reported as biopolymer for dressing the wounded tissue due to their cleanliness and excellent retention capability of water [18].

Recently, nanocellulose based biopolymers were evaluated as the prospective bio-materials for dressing of wounded cell as because of their improving proliferation due to high surface to volume ratio, as well as replace and repairing capacity of damaged tissues [1-5].

Future prospects of biopolymer

The substantial numbers of studies have been reported that the biopolymers are applying in different fields. Among other, one reported research has been found that biopolymers are owed cell explosion and anti-inflammatory as well as antimicrobial agent [30-35]. The biocompatibility nature of biopolymer like chitosan based biopolymers have opened their promising application in biomedical application including, drug delivery, tissue engineering and other surgical purposes etc. Moreover, chitosan based biopolymers also have found as revolutionize materials for biomedical applications. Hence, the biopolymers are promising and capable to overawed the environmental constraints as eco-friendly and low cost materials for developing the nanostructured materials and subsequent vibrant applications including biomedical applications.

Conclusion

This reviewed has concluded as that, the researchers are concerning the hybridization of natural substances together with biopolymers in place of synthetic materials for the packages of various fields of cutting-edge sciences and technology as extra focusing to sustainable used and development with thinking about the environment focus. Last few decades Nanostructured biopolymers have been widely used for several medical applications including wound heling, drug delivery, tissue engineering etc. as because of low cost, efficient and abundant presence of raw materials in around. Therefore, day by day the use of bio-based substances in the field of nanotechnology are also open their new horizon for applications of biopolymers as biodegradable and biocompatible materials in replaced of synthetics substances ensuring sustainable development and ultimate environmental sustainability due to the nature of eco-friendly characteristics of biopolymers. Moreover, researchers, scientists, and academicians are extra centered on environmental conservation by enhancing the sustainable biomaterials to reduce the worldwide warming and secure the earth. Bio-substances because the great resources of pristine materials obtained from several renewable assets and can be used as a capability reinforcement in composites for business, commercial and biomedical uses. Limitations which includes biocompatibility and hydrophilic nature can be resolved through acting diverse surface modifications and chemical treatment strategies. In this regard, the biomaterials can be tailored so that it will beautify its mechanical, thermal and physiological typical performance in flexible applications.

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