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Review Article

A Review: Emerging Trends in Bionanocomposites

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ABSTRACT
In recent year's development of different type of bionanocomposites have increased their utilization in biomedical and pharmaceutical science. Bionanocomposites have huge potentional as future green materials comprised of biopolymer and their composites that prove to be a cost effective solution over petro based polymer. The present manuscript gives detail insight into components of biopolymers, preparation technique of bionanocomposites, characterization, properties and applications of bionanocomposites in pharmaceutical field.

Keywords: Bionanocomposites, Biopolymers, Drug delivery system.

INTRODUCTION
Nanotechnology is defined as the creation, processing, characterization and utilization of material devices and system with dimension in the range of 0.1- 100 nm. The word – composite means made up of two or more different parts. A composite material consists of a group of two materials of absolutely different natures and allowing us to obtain a material of which the set of performance characteristics is superior than that of the components taken separately.[1] The bionanocomposites can be defined as the materials that comprise of particles with at least one dimension in the range of 1–100 nm and a constituent of the biological origin or may be biopolymers. The word "bio" in bionanocomposites specifies the use of biodegradable material. They are different from nanocomposites in the sense of preparation method, properties, functionalities, biocompatibility, and biodegradability and applications.[2]The term bionanocomposites every so often called as nanocomposites, biocomposites, nanobiocomposites, green composites, as well asbiohybrids.[3]
Bio-nanocomposites are significant due to their nanoscale dispersion with size less than 100 nm. Nano drug delivery systems are submicron-sized particles with one or more therapeutic agents that are dispersed, adsorbed, or covalently bound in encapsulated vesicles, capsules, or polymer matrices. They are widely used in a variety of areas owing to multidimensional properties such as biocompatibility, antimicrobial activity, biodegradability and good mechanical, optical, barrier properties (etc.) as compared to micro- or macro composites.[4]
Bionanocomposite can be prepared by various methods. Common methods of preparation are solvent evaporation, emulsification solvent diffusion, solution intercalation, melt intercalation, double emulsion solvent evaporation, electro spinning, and ultrasonication.[5]
Generally synthetic and natural biopolymers are used in bionanocompositespreparation-

i. **Natural biopolymer**: cellulose, chitosan, starch, alginate, carrageen, xantum gum
ii. **Synthetic biopolymers**:Polyglycolic acid, poly-l-lactic acid, polylactic acid (PLA), and poly e-caprolactone, hydroxyl propyl metylcellululose (HPMC), Polyvinyl pylolidone(PVP)

Advantages of bioanocomposites
1. Bionanocomposites are much lighter in weight as compared to conventional composites due to the presence of nano-filler materials.
2. They are highly dispersible in aqueousmedium.
3. Bionanocomposites also offer extra benefits like low density, transparency, good flow, better surface properties and recyclability.[3,6]

Properties
Bio-nanocomposites have following improved properties such as biocompatibility, biodegradability, swellingindex, thermalstability,

packagingapplications, mechanical property (strength, elastic modules and dimensionalstability), permeability.[6,7] Bionanocomposites can be classified on the basis of type of matrix used, origin shape and size of reinforcements. Bionanocomposites can be classified into particulate, elongated particle and layered structures.[8]

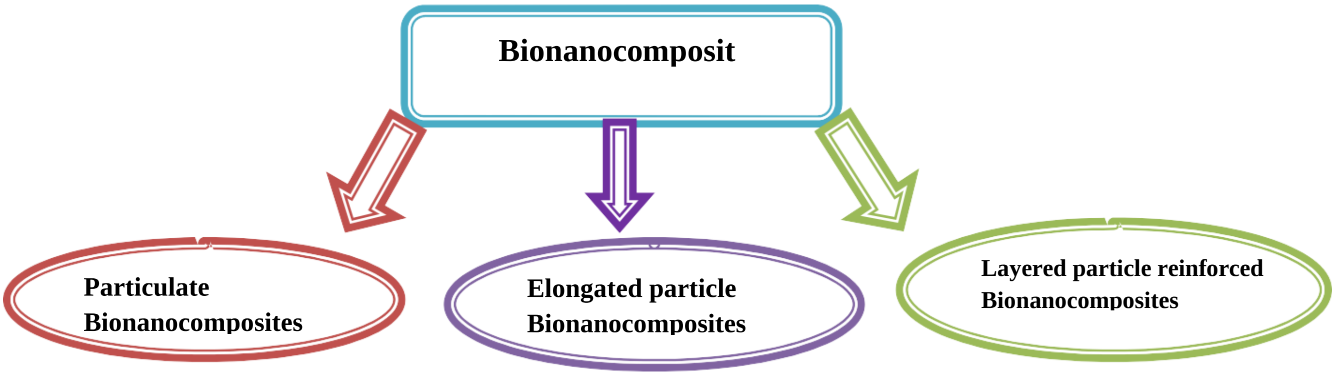


Fig:1

Particulate bio-nanocomposites

In particulate bio-nanocomposites, Is dimensional particles are widely use Darien for cements. There in forcing effect is moderate due to the low as pectratio and the main reason of utilizing such type of reinforcements is to enhance resistance to flammability, reduce permeability and cost of composites.

Elongated particle bio-nanocomposites

Elongated particles (carbon nanotubes and cellulose nanofib-rils) are employed as reinforcement in elongated particle bio nanocomposites. These bio- nanocomposites have higher mechanical behavior because of high aspect ratio of reinforcement.

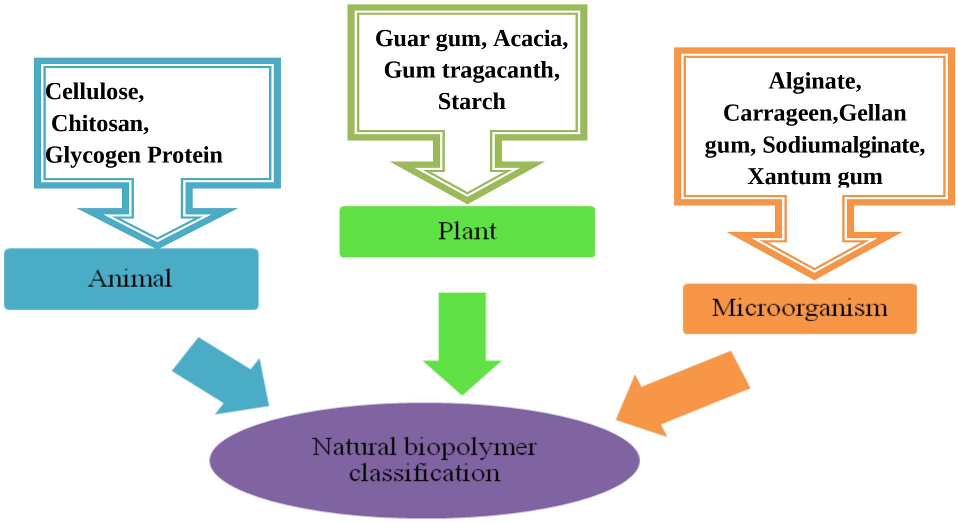
Layered particle-reinforced Bio nanocomposites

A layered particle-reinforced bio nanocomposite, also called layered polymer nanocomposite, is classified into three sub- classes on the basis of dispersion of particles in the matrix. Flocculated/phase-separated nanocomposites are formed when there is no partition between the layers because of particle– particle interactions. As the individual laminas are not separated, this class of composites is frequently named micro composites. Hence, acting as micro particles dispersed in the polymeric matrix. When polymer chains are intercalated between sheets of the layered nanoparticles intercalated nanocomposites are obtained. Whereas, exfoliated nanocomposites are produced when there are partition of individual layers.[9]

Components of Bio nanocomposites

Biomaterial

It is obtained naturally from plant, animal and microorganism. It contained mostly cellulose, lignin and hemicellulose.[10]



Cellulose

Cellulose is a building material of long fibrous cells and highly strong natural polymer. It is a polysaccharide. It is mostly found in plants and animals. Cellulose nanofibers are naturally a low cost and widely available material. Also, they are environment friendly and easy of recycling by incineration, and require low energy consumption in manufacturing. Basically two types of nanoreinforcements can be obtained from cellulose - microfibrils and whiskers[11,12]

Chitosan

structurally it is very similar to cellulose. It is a natural polysaccharide containing a large number of amino (-NH2) and hydroxyl (-OH) groups. Chitosan is a linear copolymer that can be synthesized from the deacetylation of chitin[13]. Chitin is used as a filler with gelatin (protein) in a protein matrix to form bionanocomposites These bionanocomposites are used in bone and tissue engineering. It has various medical applications such as wound dressings and absorbablesutures.[14,15]

Starch

Strach is produced by plants and it is the widely availalable biomass in nature. It is a polysaccharide. Starch is having the two component amylose and amylopectin. Mostly starch is helpful for storage of energy in plants and microorganisms. Potato, Maize, Topica, Wheat are the main source of starch[16].The nanocomposites display very distinctive characteristics even at low filler content when compared to conventional composites due to the nanosize effect.

Alginate

Alginate is a natural anionic polysaccharide whose natural source is brown algae Alginate-based hydrogels can were used for drug delivery, and scaffolds for tissue engineering in biomedical applications.[17,18]

Agar

is a water-soluble polysaccharide and forms a gel but is insoluble in cold water. It is obtained from agarophyte members of the Rhodophyta. Agar comprises repeatinganaerobioses units alternating between 3-linked β-D-galactopyranosyl (G) and 4-linked 3,6-anhydro-α-L- galactopyranosyl units. Agar films are clear, transparent, flexible, and strong at low moisture content ,buttheir utilization in food packaging has been limited due to their hydrophilicity and lowmechanical and barrier properties . The use of NPs as reinforcement is the best solutionto overcome these limitations. Atefetal.preparednanocrystalline cellulose frommicrocrystalline cellulose and incorporated them into agar film to form agar nanocompositefilms for food packaging.[19]

Gellangum

It is Natural polysaccharide. It has the composition of 20% glucuronic acid, 20% rhamnose, and 60% glucose that contribute as the repeating units with 60% glucose with acetate, glycerate, and two acyl groups attached to the glucose residue adjacent to glucuronic. The presence of metallic ions gives excellent stability, high gel strength, and a thermally reversible structure. It is easily available in its deacetylated form, which can be obtained by removing acetyl groups, thus affecting its mechanical properties, that is, making it more brittle and harder with higher thermalstability[20]

Poly lactic acid (PLA)

Poly Lactic Acid (PLA) is one of the most widely produced bioplastics. It is also known as Poly lactide. It is a linear thermoplastic polymer mainly derived from renewable resources such as corns or sugar beets. It has various applications such as medical devices, foilabod, packaging and textiles [21].

Polyhydroxyalkanoates

(PHA): Polyhydroxyalkanoates (PHA) belongs to a family of naturally occurring hydrophobic, biocompatible, and biodegradable polyesters. It is available in a wide variety of forms and used for carbon or energy storage in microorganism in the form of light refracting granules inside the cell [22]

Techniques used in preparation of bionanocomposites Solution interaction

In solution interaction, swellable nanofillers (e.g., inorganic silicate platelets) are used with biopolymers or bioprepolymers (e.g., starch and proteins). Silicate platelets in layer formation are swollen in a solvent such as chloroform. Then, soluble biopolymers are mixed with already swollen nanoparticles in a prepared solvent system. Due to the interaction of biopolymer with solvent, the biopolymer gets attached with the layered Nano particle when the solvent is removed and the conjugated structure remained intact. [23]

In situ intercalative polymerization

In this method, the nanoparticle is dispersed in a liquid monomer or a monomer solution, so the polymer formation can occur between the intercalated sheets. Polymerization can be done either by heat or radiation, by the diffusion of a suitable initiator, or by an organic initiator or catalyst.[24,25]

Melt intercalation

Melt intercalation is a relatively new technique that is used for the formation ofpolymer-layered silicate bionanocomposites. In this technique, the mixture of biopolymer and layered silicate are annealed at a specific temperature[26]. During annealing, biopolymer chains are dispersed in layered silicates leading to two types of structures, that is, intercalations or exfoliations. The formation of either structure depends upon the extent of the biopolymer penetrated inside the layered silicate Thistechnique is advantageous for producing the lower sized nanoparticle with improved impact strength, thermal stability, and tensile strength.[27]

Characterization of Bionanocomposites Particle size

Particle size can be measure using the XRD The particles are in nanosize. It can be find out by Motic images of particle with the help of Motic Microscope or Malvern Zetasizer. FTIR is used for investigating properties of nanosized material.[28]

Surface morphology

The surface morphology of particle can be studied by Scanning electron microscope (SEM), transmission electron microscope (TEM).

Thermal study

Thermal study of bionanocomposite can be studied by thermo gravimetric analysis (TGA), differential scanning calorimetric (DSC), Dynamical mechanical thermal analysis (DMTA) this technique commonly used to analyzed thermal stability, phase stability, and mechanical properties of bionanocomposites. It can prove that whether the nanoparticles are homogenously entrapped within polymer or not.[29]

Application of bionanocomposites

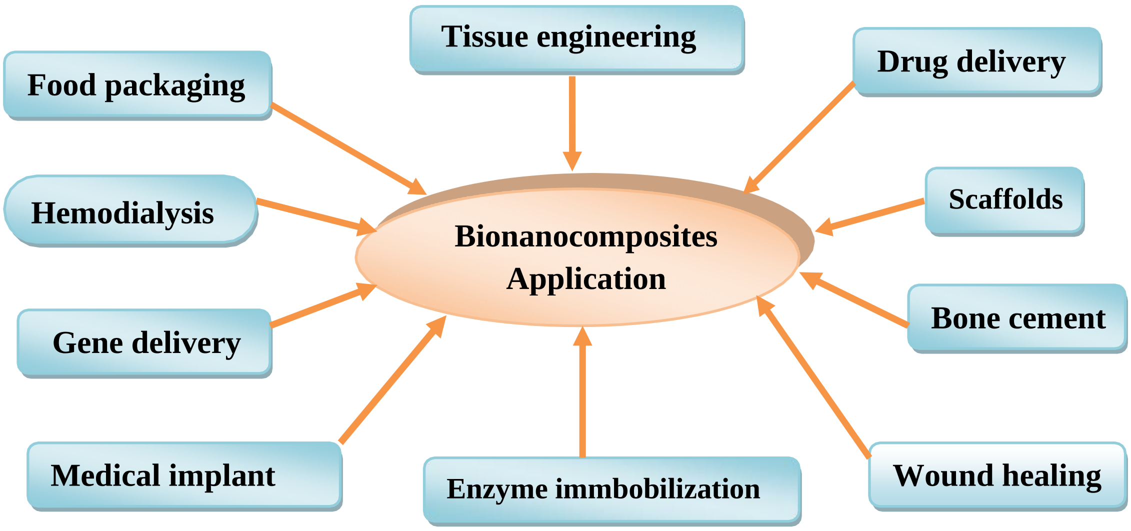


Fig:3

Bionanocomposites are used in and drug-delivery systems, implants, diagnostics,fabrication of scaffolds and biomedical devices. It also used in the cosmetics industries.[30]

Bionanocomposites have various applications in biomedical sciences. Magnetic resonance imaging (MRI) is a diagnostic technique used for the identification of specific cells, tissues, or organs and has some other applications in pharmaceuticalresearch[31]

Drug delivery

They have excellent potential in effective drug delivery system (i.e., loading, releasing, and targeting) [32]. In this regard chitosan is widely used in pharmaceutical industry as a drug carrier, in wound healing, and in biomedical fields because it has a cationic character, biocompatibility, the ability to bind some organic compounds, and a primary amino group which has the ability of controlled drug release and mucoadhesion etc. Akbar et al. developed novel mixed polymeric micelles as a drug carrier forhydrophobic drugs.[33] Wang et al. prepared a bionanocomposite based on chitosan and montmorillonite (clay) as a drug delivery system. In this way, they combined the characteristics of biopolymer and nanoclay. For characterization, TEM, XRD, and FTIR techniques were used. Their study showed the controlled drug released behavior and showed a nontoxic and high drug encapsulation capacity[34.] Gold-based chitosan-containing bionanocomposites were synthesized by using the solution evaporation method. TEM, SEM, Zeta potential, and UV-Visible spectroscopy were used for characterization. The research work improved the mechanical properties with excellent biocompatibility which suggested its use in biomedical applications.[35]

Bionanocomposites as antimicrobial agents

Modification of natural, seminatural, and artificial (synthetic) polymeric material with antimicrobial agents is one of the most quickly advancing areas in pharmaceutical research.

Human beings are still victim of many kinds of infections. To solve this issue, many polymeric biomaterials with antimicrobial activities are being used in many biomedical fields (drug delivery, medical devices, hygienic applications, etc.).[36] Researchers have found that chitosan has therapeutic properties, such as inhibition of growth of microorganisms, antitumor, promotion of hemostasis and epidermal cell growth, and pain alleviation. Chitosan-based drug delivery systems fall in the range of micro- to nanoparticles. A major drawback associated with chitosan drug delivery systems is the low solubility at physiological pH; they are soluble in acidic solution of water but insoluble in both alkaline and neutral water.[37]

Keratin chitosan ZnObionanocomposite (KCBZNs) bandages have been recently prepared by conjugatingZnO with keratin chitosan hydro gels. These preparations are very helpful in wound healing, possess antimicrobial activity, and researchers are working on using them in artificial skin formation bionanocomposites are widely used in site-specific/targeted drug delivery with improved stability and efficacy. Bionanocomposites are also widely used in biosensors and biocatalysts and in the field of disease diagnostics, especially radiology.[38]

Table:1

Sr no	Bioanocomposites	Application	Reference
1	Ibuprofen, nimusulide and nifidipine3d matrix nanocomposites	Enhance solubility and dissoluation	39
2	Gipizide and gelatin bionanocomposites	Immediate relesedosageform	40
3	Celecoxibbionanocomposites	Immdiate release tablet	41
4	Itraconazole nitrate chitosan nanocomposites	Enhance solubility,dissoluation and bioavilability	42
5	Ketoprofenbionanocomposites	Enhance solubility,dissoluation and bioavilability	43
6	Fenofibrate PVP Polymer nanocomposite	Immediate relese tablet	44
7	Kaolinite/ cashew gumbionanocomposites	Controlled release dosageform	45

Table 2: List of patent inventions of nanocomposites and their application of drug delivery and targeting of nanocomposites

Content	Patent no	Application	Inventor	Ref.
Nanocomositions For Imaging and Drug Delivery	US 20200172908A1	Drug delivery system	Even c.unger	46
Nonocomposites and process for their production	US 20100196611A1	Targeted drug delivery	Nopphawanphontham machai,ChaobinHe	47
In-situ polymerized nanocomposites	US 2010O240804A1	Drug delivery system targeting	Patricia Chapman Irwin,	48
Bionanocomposites Materials and methods	US 20100221304A1	Drug delivery system targeting	Wei Tan	49

Processes of making polymer nanocomposites producing and using the same.	US 20100012890A21	Drug delivery system targeting	Dmitry P.Dinega.	50
Process for making nanocomposites	US 20090281226A1	Drug delivery system targeting	Surbhimahajan	51
Mucoadhesivenanocomposite delivery system	US 20090232899A1	Drug delivery system	Allan E. David, RulyuJeong Park, Arthur Jin-Ming, Victor C. Yang.	52
Nanocomposies Drug Delivery Composition	Wo2004/098574 A1	Drug delivery system	Craig Duncan Q M	53
Polyvinyl alchol bacterial cellulose nanocomposites	US2009/0028927A1	Tissue engineering contolrelese	W. Wanl	54

CONCLUSION AND FUTURE PROSPECTUS

Bionanocomposites are novel invention of current times. The major benefits of bionanocomposites are that they provide good biocompatibility and degradability. Natural polymer are proffered for synthesis of bionanocomposites over synthetic polymer since, synthetic polymer are toxic and hazardous for health. Three synthetic techniques are used to make bionanocomposites: solution interaction, in situ intercalative polymerization, and melt intercalation. These techniques make it possible to use biopolymers, such as nucleic acids, lipids, carbohydrates, enzymes, antibodies, antigens, and proteins, in the formation of bionanocomposites. This is new manufacturing technique the Purpose of this research, development and advancement is to producedbionanocomposites pilot scale to the industrial level.

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