STM JOURNALS

International Journal of
Crystalline Materials

Volume 2, Issue 1, 2025
January–June
DOI (Journal): 10.37591/IJCM

https://journals.stmjournals.com/ijcm

Review IJCM

Magnetic Nano polymer: Applications and Challenges in Medical Imaging and Theragnostic

Gizachew Diga Milki[1,*]

Abstract

Biopolymers are valuable complex materials. They attract attentions of many scientists, engineers and medical professionals' for application research. In this research, an assessment of emerging Nanopolymers including magnetic nanopolymer is focused. Hence, sources, magnetic properties, and biomedical application of such polymers are given attention. As ordinary polymers, nano sized biopolymers are visualized as natural and synthetic polymers. However, more emphasis is given to green synthesized magnetic polymer, particularly magnetic Chitosan nanoparticles. Hence, systematic descriptions of nanosized biopolymers, it synthesis procedure, and characterization methods is presented. In this regard, the green synthesis of Chitosan nano particles is illustrated. Hence, the effect of magnetic field and light on the crystallographic bond formation and structure of Chitosan nanoparticles is overseen. Properties such biodegradations, biocompatibility, photo catalytic activity, sensitivity, and fluorescence of magnetic nanopolymer is also reviewed. The biomedical applications of such nanosized polymers are presented by enumerating its nanobiophysical properties. More importantly drug delivery, medical imaging, and theranostics are discussed as a core function of magnetic polymer nanoparticles. Due to its peculiar physio - chemical properties, Chitosan is preferred in biomedical applications as diagnosis, cell/tissue imaging, therapy, wound healing, and nano carrier of drug delivery. Moreover, challenges associated with drug delivery, imaging and theranostics procedures using nanopolymer is presented.

Keywords: Biopolymers, Nanopolymers, Magnetic nanopolymers, Magnetic chitosan, nanoparticles Green synthesis

INTRODUCTION

Polymers like Collagen are tough and strong substance. Collagens are stronger than steel. Biopolymers are naturally degradable or non-degradable nanomaterials. Biopolymers like Cellulose, chitin, starch, alginate, and carrageen can be utilized in energy storage technology.

Polymer nanoscience is the study and application of nanoscience to polymer-nanoparticles matrices. Nanopolymers are the most promising building blocks for mounting complex and simple hierarchical nanosystems. Nanopolymers may be classified by their self-assembly and non-self-assembly capabilities. It can further classified by the number of the dimensions in the nanometer range. Nanopolymers include silicon nanosphere, magnetic nanopolymer microsphere, and polymer nanocomposite.

Polymeric nanocomposite is a combination of a polymer matrix and inorganic NPs. Biopolymer nanocomposite: are bio-based multiphase materials composed of two or more constituents, in which the continuous phase (matrix) is a biopolymer, and the

***Author for Correspondence**
Gizachew Diga Milki
E-mail: phygidg@gmailc

[1]Assistant Professor, Department of Nanoscience and Technology, Jimma University, Ethiopia

Received Date: January 06, 2025
Accepted Date: January 14, 2025
Published Date: January 30, 2025

Citation: Gizachew Diga Milki. Magnetic Nanopolymer: Applications and Challenges in Medical Imaging and Theranostics. International Journal of Crystalline Materials. 2025; 2(1): 11–21p.

discontinuous phase (fillers) is composed of NPs. Biopolymer nanocomposite is bio-based multiphase materials composed of two or more constituents. They consists of continuous phase (matrix) called biopolymer, and the discontinuous phase (fillers) materials called nanoparticles. According to Dwivedi et al. 2013 [1], Polymer nanocomposite represent a new alternative to conventionally filled polymers.

Magnetic nanopolymers are class of polymers that can be controlled and monitored by magnetic fields. Magnetic nanopolymer includes magnetic polymer nanocomposite which consists of suspended magnetic nanoparticles such as Fe_3O_4. The physical properties of magnetic nanoparticles are greatly affected by the external magnetic fields. The size of magnetic nanopolymer is within the limit of 1-100nm. Magnetic nanopolymers have variety of applications. There are numerous sources of nanopolymer. As the research of A Yu Gervald, et al. 2010 [2] indicates magnetic polymeric microspheres were obtained in situ by the deposition of a polymer. Ramnandan, D 2020 [3] also state that Chitosan can be derived from chitin which is biocompatible and biodegradable linear polysaccharide with amine functional group.

SOURCE AND CLASSIFICATIONS OF NANO BIOPOLYMERS

Polymers can be natural or synthetic. A bacterium converts carbon and nitrogen into intercellular & extra cellular biopolymers. Bacterial polymers have important roles in pathogenicity and their varied chemical and material properties make them suitable for medical and industrial applications. In the following section natural polymers and synthetic polymers are presented separately.

Natural Nano biopolymers

Green polymers are constituents of natural fiber and animal resins. Green polymer nanocomposite is class of biopolymers that can be extracted from natural materials. Natural polymers for hydrogel preparation include hyaluronic acid, Chitosan, heparin, alginate, & fibrin. Natural polymers, such as DNA, RNA, and proteins are essential for carrying and translating genetic information. Other biopolymer like polysaccharides generates energy/fuels like ATP for cellular activity. As Mishra RK et al. 2018 [**4**] categorized, polymers including natural rubber latex, polyhydroxy alkanoates, Polylactic acid synthesized from bacteria are Green polymers.

Microbial derived biopolymers are another class of natural polymers. There are three major classes of microbial derived biopolymers. These are polyesters, proteins, and polysaccharides. The physical properties of these polymers are illustrated in the following cartoon.

Basavegowda N. Baek et al. 2021[**5**] natural biopolymers are subdivided into polysaccharides (starch, wheat, cellulose, pectin, and Chitosan), proteins, and lipids (gluten, soya, Zein, peanut, casein, whey, gelatin, and collagen. Carmen P. Jimenez Gomez and Juan Antonio Cecilia, 2020 [6], Gelatin is a natural polymer widely used in pharmaceutical, cosmetic, photographic films, and food industries. Chitin is de acetylated to form Chitosan, which is soluble in acidic medium. Chitosan is a cationic polysaccharide that forms polyelectrolyte complexes with other polysaccharides. As Sneha Mohan et al. 2016 [**7**] Chitosan forms $\beta - (1 \rightarrow 4)$ linked D-glucosamine and N-acetyl-D-glucosamine.

As Leonid Sukhodub et al. 2023 [8] Chitosan consists of repeating units of glucosamine and N-acetyl glucosamine which are linked together by glycoside bond. *X. Jia et al. 2009 [9] defined Chitosan is Primary component of exoskeletons of crustaceans and insects as well as cell walls* of some fungi. It is extracted from shellfish, crabs, lobster and shrimp. On the other hand, Villalba-Rodriguez, A. M et al. 2022 [10] noted the possibility of extracting Chitosan from chitin, which is abundant nitrogenous biopolymer, found in crustaceans or insects. Hence, it can act as a precursor for carbon dots and nitrogen.

Although Chitosan and cellulose resemble the same, Chitosan has amino group while cellulose has a hydroxyl group. As Dutta et al. 2004 [11] indicates the reaction of Chitosan is more versatile than cellulose due to the presence of NH_2. Catia Bastioli, 2005 [12] a hydrolytic enzyme of microorganisms fastens biodegradations of biopolymers such as proteins, Cellulose, and starch. Another class of natural bio Nano polymer is DNA. Nucleotides are the Monomeric unit of DNAs and contain genetic information. This concept is useful in digital and microelectronics. As discussed by Dan Huang et al. 2011 [13] it is possible to design a stimuli responsive DNA reaction network in order to integrate sensing, translation, and decision-making operations. As Zahed Nasab, S. et al. 2024 [14] investigated, scientists have continued to develop different Chitosan NPs (CSNPs) to deliver theranostics agents directly to cancer cells.

Synthetic Biopolymers

Synthetic nano biopolymers are usually made of amino acids, glucose, vegetable oils, resins, Proteins, chitin, Keratins etc. Synthetic Polymers includes polycaprolactone (PCL), polyvinyl alcohol, polyethylene, glycol, sodium polyacrylate, acrylate polymers, and copolymers.

A green nanofluid like Poly Lactic Acid (PLA) is used for preparing polymer films. Balaji Ayyanar Chinnappan et al. 2022 [15], realized that Poly vinyl alcohol/Chitosan (PVA/CS) electro spun nanofiber can be fabricated by the electro spinning method. Polyaniline (PANI) is highly conductive polymer with attractive qualities such as low density, mechanical flexibility, easy process ability, and synthesis, tunable shielding response and high environmental stability, Samiha Hossain, 2019 [16].

Polysaccharides are a polymer of monosaccharide, which are linked with glycosidic bonds. The monomers have cyclic structures, mostly containing pentose hexoses carbon atoms. An example of a pentose is ribose, which is one of the building blocks of nucleic acids. Many polysaccharides are made of hexoses, such as sucrose and galactose. Amylose and cellulose are linear chains of α -*D*–glucose and β - *D*–glucose, respectively.

As the Juan R.C Van Dar Marcel, 2007 [17] described Polymer nanocomposite (PNC) consist of a polymer, or copolymer having nanoparticles or Nano fillers dispersed in the polymer matrix. These may be of different shape (e.g., platelets, fibers, spheroids. Biopolymers are used for preservation of bone collagen, and in isotope fractionation. They serve as a passivation agent in the synthesis of nanoparticles like CdSe, ZnSe, GeSe, ZnS etc. the functional properties of smart magnetic nanopolymer can affected by external Rheology. Particular the sensitivity of magnetic nanopolymer can be influenced by temperatures, light, PH value, magnetic fields, and electric fields.

Nano sized biopolymers are highly degradable. Biodegradable polymers synthesized from renewable resources provide alternatives to fossil-fuel-based polymers. To achieve this goal, studying the biophysical properties of magnetic nanopolymer is of prime importance. Magnetic nanopolymer undergoes biodegradation which results in the production of CO_2 under aerobic environments or CH_4 under anaerobic environments. This property of magnetic nanopolymer makes them a good material in water treatment by fermentation process. In this process the fermentation process is accelerated by light which breaks the covalent bonding between each monomers of Chitosan and enhance crystal vibrations and interactions.

As James Njuguna, 2004 [18] reported, biopolymers are gas barriers, good thermal performance, oxygen resistant, and improved ablative performance than carbon filler polymers. Nanopolymers are multifunctional nanomaterials. Polymer based printing enables to fully print electronic products. Nanopolymers are used in organic light emitting diodes, solar power panels, and fluorescent materials. Due to their high modulus, stain and strength, nanopolymer can serves as a filler material in constructions. Biopolymers are being developed for use in textile industries, medical materials, water treatment chemicals, absorbents, and flexible biosensors. Magnetic nanopolymer are the demand of nanobiotechnolgy, nanomedicine, and tissue engineering. Collagens are used for replacement of skin cells due to their ability to strengthen skin. Hanna Valo, 2012 [19] verified that natural biodegradable polymers are stabilizing agents and platform form several nanoparticles based drug systems.

Polymer Conformation

Pankaj Mehta, 2021 [20] ideal polymers ignore all interactions between monomers, except between neighboring monomers. Thus, in ideal polymers, the interaction between neighboring monomers is elastic. Hence, the elastic crystal vibration of monomers will produce a frequency proportional to the square root of pressure and directly proportional to wave number at, >>> 1

CHARACTERISTICS OF NANO BIOPOLYMERS

Biopolymers have emergent properties associated with their hierarchical structures. Starting from the primary structure, the monomer units are organized in a certain local molecular conformation. This local conformation is commonly referred to as the secondary structure. Here, the meaning of emergence is that the biopolymers have properties that cannot be attributed to the individual building blocks. For instance, the nucleic acid bases are just molecular components made of carbon, nitrogen and oxygen. It is their specific sequence in a strand of the DNA or RNA molecule, which carries the genetic code. Alemu, D. 2023 [21], revealed, the properties of Chitosan emerge from their physicochemical features, including solubility, deacetylation degree, viscosity, and molecular weight.

Nanopolymers such as magnetic Chitosan nanoparticles are versatile nanomaterials which are easily adaptable with body cells, tissues, and skins. This properties make is suitable in cell and tissue imaging. Heat treatment of Chitosan nanoparticles can distort its molecular structures and break covalent bonds. Hence with heat treatment, it can be carry a cargo of drug and nanocarriers within the body fluids.

METHODS

Synthesis Methods

Magnetic nanopolymer can be fabricated from microorganism like Algae, bacteria, cellulose, and virus. Chitosan nanoparticles can exist in various forms. They can also be derived green plants, biomolecules, and organic matter. Masa Sprajcar et al. 2012 [22] Polymers can be synthesized by i) Gelation or polymerization of monomers ii) Emulsions i.e. micro emulsion, and Nano emulsion’s. Louis et al. 2015 [23] stated that Chitosan nanoparticles can be formed by a variety of methods including emulsion, ionic gelation, reverse micelle methods, or self-assembly. M. Fata Moradali1 and Bernd H. A. Rehm 2020 [24] investigate the possibility of synthesizing bacteria in various classes’ of biopolymers, such as polysaccharides, Polyamides, polyesters, and polyphosphates.

In this research, green synthesis method is given a greater degree. Green methods involve the use of enzyme hydrolysis to produce gelatin. The procedural steps of these biocatalysts are further modified and coming simple, and controllable. On the other hand, Green method involves the synthesis of biopolymers from microorganisms’ virus, bacteria, algae, fungi, and planktons, leaves, and stem by enzymatic action. Their synthesis includes enzyme catalyzed polymerization reactions of activated monomers, which occur within cells as products of complex metabolic processes while in the industrial scale this is a fermentation of sugar (glucose) under the influence of microorganisms and under the optimal conditions.

In order to accelerate the degradation rate, solid fungi should be exposed to a light (photon) of optimum energy, $\hbar\omega$. The photon-activated fungi are then feed with active enzymes like yeast cells which further increase the degradation rate. The effect of photon is to speed up the rate of chemical reaction during the synthesis process and breaks the covalent bond between edible solid fungi in addition to enzyme. It also fastens the biodegradation process.

It is then converted in to plant protein. The protein extracted from fungi by the action of enzyme is then allowed to react with potassium hydroxide, KOH and processed to form Ethylene Alcohol. It is then allowed to react with Hydro chloric acid (HCL). Then any chromatic pigments are removed by washing with KOH/water. In this process chitin is formed which undergoes deacetylation process to produce Chitosan. Such chronological sequence of Chitosan production is represented in Figure 1.

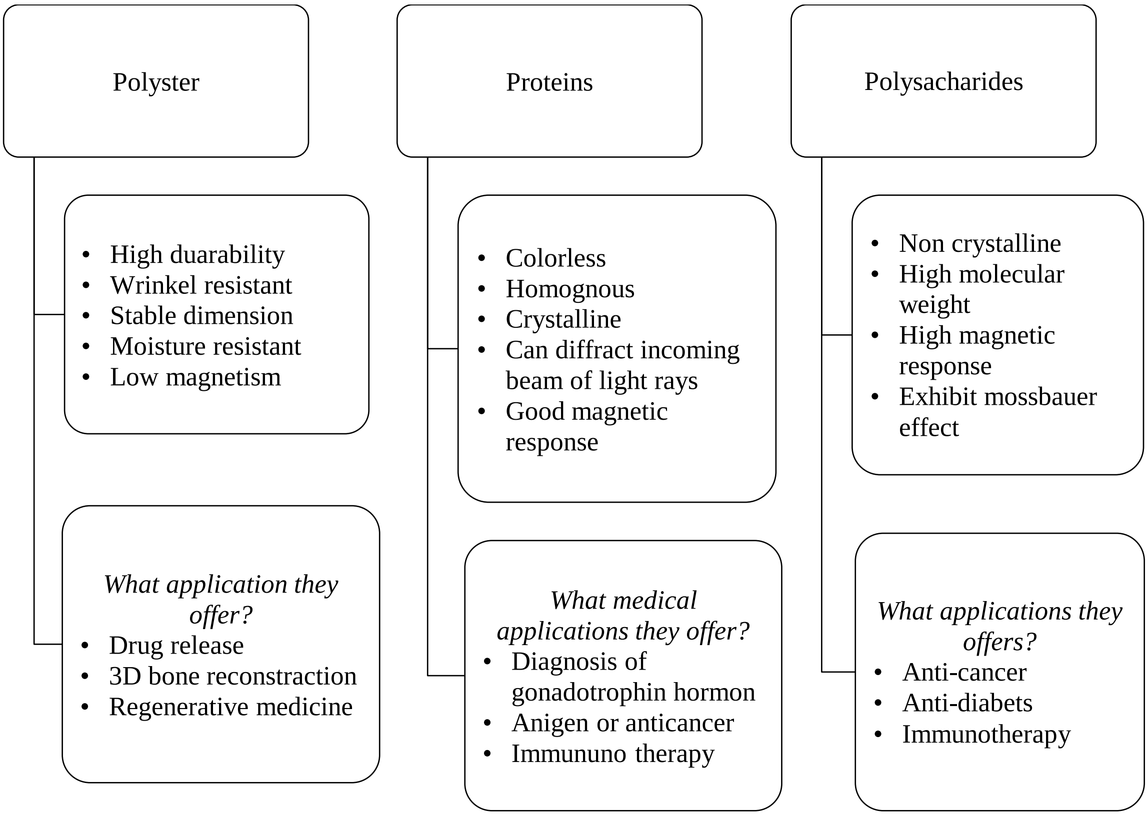

Figure 1. The biophysical properties and medical applications of biopolymers

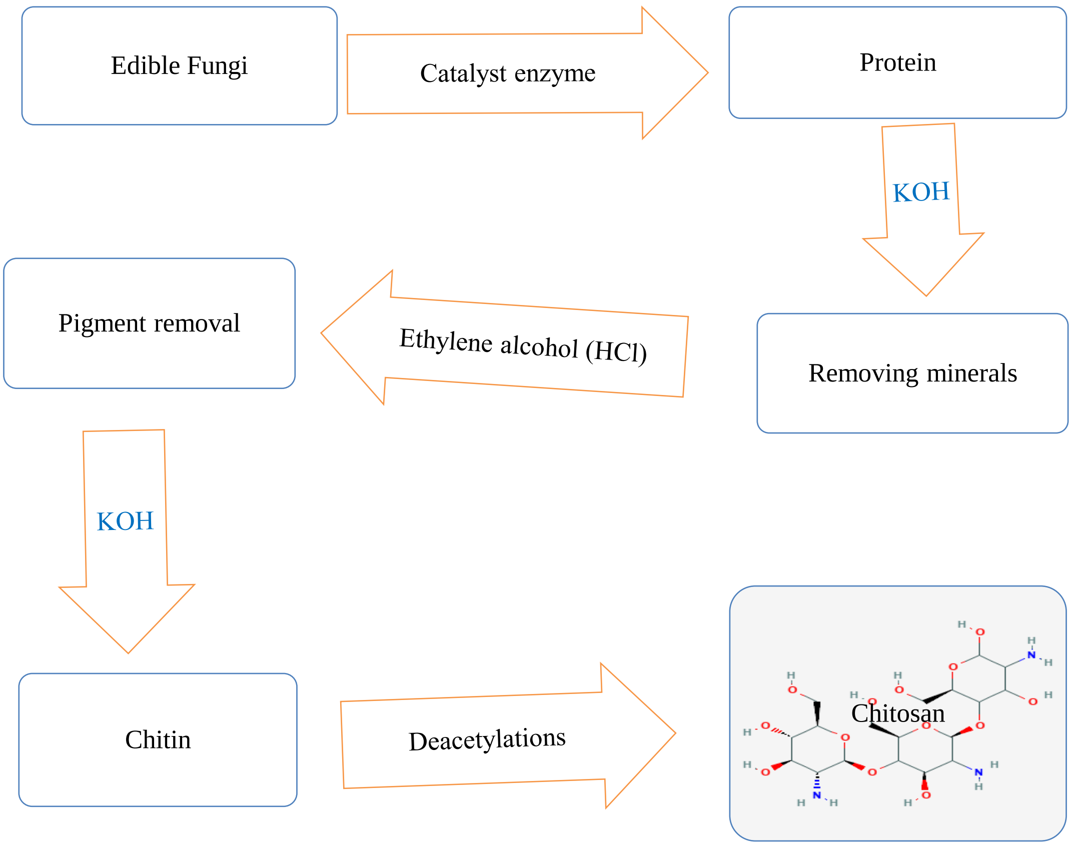

Figure 2. Green synthesis of Chitosan.

As researchs Doan Thi Kim Dung et al. 2009 [25] indicates, magnetic Chitosan nanoparticles can also be synthesized by suspension of cross-linking with 5% Chitosan solution, and 0.2g of Fe_3O_4 NPs and 2% aqueous solution of acetic acid.

The enzymes link the synthetic organic nanomaterials including sugars, amino acids or hydroxyl fatty acids yield polymer molecules with high molecular weight. In order to increase the mechanical strength, bio Nanopolymers are doped with green nanoparticles like graphene nanoparticles. In addition, to increase the molecular weight, bio Nanopolymers are treated with gold/silver nanoparticles to form polymer nanocomposite. Figure 2 ionic gelation must also be performed in the synthesis of Chitosan nanoparticles, in order to separate positive charge amino acid and negatively charged polyanion in the Chitosan molecule. Alcohol or water is used for purification process. In the final step, chitin is converted into Chitosan by enzymatic action or deacetylation process. Nathan R. Zaccai et al. 2017 [26], stated the modern techniques of studying biological macromolecules and includes mass spectrometry, hydrodynamics, microscopic, molecular dynamics simulations, and nuclear magnetic resonance.

In the theoretical basis, biopolymers like, Chitosan, DNA, and polyesters, numerical solutions can be carried out using the non-linear Poisson–Boltzmann equation in the unit cell model. As Gustavo Adolfo Munoz Ruiz et al. 2016 [27], the molecular weight of Chitosan is between $5x10^5$ Da and $5x10^5$ Da. The degree of Polymerization is given by

$$Q = \frac{W_p}{W_s} \times 100\%$$

Where Q is the degree of Polymerizations, W_P is the molecular weight of polymer and W_s is the molecular weight of single polymers.

Characterizations

Different techniques have been used to characterize magnetic nanopolymer. However, some of the most widely used techniques are spectroscopic, microscopic, and nuclear magnetic resonance (NMR). Biopolymers like Cellulose & chitin are characterized by FT-IR spectroscopy, Raman spectroscopy, and X-ray photoelectron spectroscopy and Nuclear magnetic resonance spectroscopy. As the research Kesharwani P. 2024[28] verified, dynamic light scattering and Laser diffractions can be used to measure the particle size and zeta potential for ease of stability.

Mirta i. Aranguren, 2013 [29] verified that physicochemical Characterization method is employed for the determination of size, charge distributions, polarity, and morphology of biopolymers. A common biopolymer like Chitosan can be converted to hydrogel by modifying the ionic character and PH value.

The magnetic properties of Chitosan nanocomposite can be characterized by Apreo-chemi SEM, XRD, and NMR. Other methods such as Electron spin resonance (ESR) can be used to characterize Chitosan nanoparticles and composites.

DISCUSSION ON NANO BIOPOLYMERS

Sensitivity of Nanopolymer

Magnetic nanopolymer exhibits different properties when exposed to light, magnetic field, and even heat. In this section, the response of magnetic nanopolymer to such stimuli is discussed. Nanosized biopolymers are greatly sensitive to PH and its activity can be expressed as function of time and its number density. A Chitosan nanoparticle is a good model of magnetic nanopolymer. It is highly sensitive to PH. The solubility of Chitosan depends on different factors such as molecular weight, degree of acetylation, pH, light, temperature, and crystalline structure. However, it can be improved by deacetylation, depolymerization, or quaternisation process, Aranaz, I et al. 2021 [30]. As Chen, Z, Wang et al. 2013 [31] demonstrated, Chitosan nanoparticles exhibits weak resonance, light scattering intensity. Heating Chitosan nanoparticles reduce its crystallite and crystal quality. However, controlled heat treatment will produce bubbles to take spherical shape.

Thermal Stability of Nanopolymer

Ulf W. Geddes, 1999 [32] thermo gravimetric analysis method (TGA) is an effective method determination of the content of volatile species, fillers, and polymer degradations. Meyer B. Jackson, 2006 [33] revealed that the enzyme lysozyme from T_4 bacteriophage can be used to screen its sensitivity to temperature-sensitive mutants. Lysozyme unfolds or denatures as the temperature is raised, and the unfolded state has no enzymatic activity. In temperature-sensitive mutants, denaturation occurs at lower temperatures than in the wild type enzyme. Biopolymers such as chitin and Chitosan can enhance the Functionalization and dispersibility of magnetic nanoparticles such as α-Fe_2O_3.

Hydrolysis of Biopolymers

Like any other polysaccharides, Chitosan is hydrolyzed by aqueous solution of acids in order to break the bond between functional groups and hydroxyl. It is also used to makes the bond instability. Siti Hajar Othman et al., 2014 [34] realized that biopolymers have the capability to be degraded or broken down natural organism and organic matter. In this process, CO_2 and H_2O are formed as a by-product.

Micro and Nano capsule biopolymers have good biocompatibility and biodegradability. These polymers can be made suitable for drug delivery by hydrolysis or enzymatic attack. Hanna Valo, 2012 [19] Nanofibrillar cellulose aero gels with versatile characteristics could be used to release the drug in a controlled manner. As Katarzyna Nawrotek et al. 2016 [35] Chitosan based hydrogel implants intended for peripheral nervous tissue regenerations by electro deposition methods.

MEDICAL APPLICATIONS

In this section, the medical application of Green synthesized Chitosan nanoparticles is presented. Green synthesized Chitosan nanoparticles can be applicable in chromatography, optical information technology, sensors, Photocatalysis, and immobilization of drug delivery. Magnetic Chitosan nanoparticles are used as biomedicine, drugs, and regenerative medicine. Moreover, magnetic Chitosan nanoparticles are used in tissue engineer as multilayer and multivariate cell structure. Gum Arabica, which is edible biopolymers, is used as an antimicrobial to inhibit the formation of plaque and improve dental re mineralization. Research of Noura El-Ahmady El - Naggar et al. 2022 [36] indicates that biologically synthesized Chitosan nanoparticles are used for medical treatments and food preservation.

Biopolymer composites can serves as nanocarriers of genes, drugs and implantable device. Chitosan nanoparticles synthesized from edible fungi has a potential application in medicine particularly antitumor, antimicrobial, nano carrier of drug delivery, diagnostic imaging agent, and skin and soft tissue imaging. In the subsection, the roles and challenges of magnetic Chitosan nanoparticles in drug kinesis, imaging and theranostics is presented.

Drug Delivery and Kinesis

The functional groups of polyelectrolyte's polymers forms electrostatic equilibrium since their charges are equal and opposite. These polymers form nanosystems through electrostatic interaction. They have potential application in drug delivery system. Gomes L. P. et al. 2017 [37] Chitosan has also been widely used in antimicrobial films to provide edible protective coating, and antifungal agent. Belen Begins et al. 2020 [38] natural polymers, such as dextran, gelatin, guar gum, collagen and CH are used in oncology and drug release. Korhegyi et al. 2019 [39] verified that self-assembling nanoparticles of Chitosan based polyelectrolyte complexes are used for drug delivery systems.

In addition, the cell walls of gram-positive bacteria are mainly composed of Teichoic acid, which is negatively charged, and can react with Chitosan. Teichoic acids (TAs) are the surface copolymers, which are phosphate rich molecules in gram-positive bacteria, and pathogens. They are suitable for performing electrostatic interaction. This makes optimum electrostatic potential interactions, which can be expressed in terms of electric charge, made lung constant, and separation distance, R. This interaction reinforces destructions of bacterial cell wall or cell death. The research by Kim et al. 2020 [40] indicates, Chitosan colloid is useful in developing food ingredients or drug carrier templates which is stable over a wide pH range. Due to its good antimicrobial and stiffness, hydrogel, sponges, nanoparticles, and thin films of Chitosan can serves as a better drug delivery carrier to treat disease as injures and lesions of the of skin, muscles, blood vessel, and nerves system.

Although Chitosan has a Varity of application, it is mostly insoluble. It is hydrophobic rather than hydrophilic. Hence, it can be not be directly used for drug delivery process. Due to this limitation, controlled heating or making composite with magnetic materials such as ZnO or Fe_2O_3 is advisable.

Medical Imaging

Chitosan is primary component of exoskeleton system and cell wall. This enables Chitosan nanoparticles as a functional nanopolymer in cell imaging therapeutic applications. Chitosan nanocarriers are preferred nanoparticles for diagnostic imaging agents. Ding J & Guo Y, 2022 [41] realized that Chitosan-based vehicle can be used for the encapsulation of chemotherapeutic drugs, therapeutic gene, targeted therapy for cancer.

Nano biopolymers synthesized by photon assisted green method are used for incubating viruses or bacteria from penetrating the cell wall and membrane. Current researches of Zahra Fakhroueianet al. 2018 [42] indicate, ZnO co-assisted nano polymers are used for cancer therapy and preventing the psychological patient's stress from the injection. In addition, Chitosan nano films and nanoparticles are also used in immune therapy and oncology therapy. Superparamagnetic iron oxide nanoparticles are used in magnetic fluid hyperthermia. The magnetic properties of Chitosan can be altered by forming the Fe_2O_3/Chitosan nanocomposite. Cell imaging and tissue imaging can be improved by incorporating magnetic Fe_2O_3/Chitosan nanocomposite in magnetic resonance imaging. These composites are also used for enhanced immune therapy and cancer therapy. Self-assembled Chitosan nanoparticles and poly- γ-glutamic acid (PGA) can form stable complexes which are anticipated for MRI.

The major challenge of using Chitosan nanoparticles in medical imaging relays on its light absorption capacity and intensity. Ordinary magnetic nanopolymers such as Chitosan nanoparticles possess low intensity. For this reason, it gives low image resolution, cell contrast and image quality. In order to over, come this limitations, an external Rheology such as light and magnetic fields are required to produce sufficient intensity and improve image quality. In the subsequent section the potential role of magnetic Chitosan nanoparticles seen in imaging and theranostics.

Theranostics Applications

Some natural polymers are essentially useful in biomedical applications. Chitosan is valuable natural as well as synthetic nanopolymer which is valuable in imaging of skin, bone, tissue engineering, artificial kidneys, nerves, and livers. It can be applicable for wound healing, regenerative medicine, and immunotherapy with heat treatment. Polymers are suitable for repairing damaged kidney or heart, S.L Kakani and Amit Kakani, 2004 [43]. The activity of Chitosan nanofiber and ether oil particles had been proven in action against P. Aeruginosa, E. coli. Green Chitosan nanoparticles are useful magnetic nanopolymer in reducing cholesterols, hypertension, combined diagnosis and therapeutic procedures. Dwivedi et al. 2013 [1] suggested that the diagnosis and surgery of infection using biomaterials has challenge. However, the pitfall can be resolved by doping bio Nanopolymers either by Meso gold nanoparticles or by silver nanoparticles. In addition, Gökçen Yaşayan, 2020 [44] indicates, silver sulfadiazine is loaded in the films are designed for wound healing due to its antimicrobial properties. On the other hand, biodegradations of bio Nanopolymers may result in the production of toxic gases like CO_2 and Ch_4, which are hazardous for breathing.

Zhang et al. 2015 [45] Chitosan is used within some wound dressings to decrease bleeding, treatment of chronic diabetic wounds and hydrofluoric acid burns. Chitosan can produce nano film on the cell surface, which blocks the path ways of oxygen and pathogens from entering the cell. Besides, Inorganic polymers like nanocomposite of Zirconium oxide, aluminum oxide and calcium phosphates are used as bone replacing materials. Magnetic nanopolymer has multifunctional including Blood-Brain Barrier Delivery, wound healing, and theranostics. Although magnetic Chitosan nanoparticles are undoubtly useful, its sensitivity, solubility, and stability are dependent on heat, magnetic field, or light. At least one of them is required for its proper function. For example its diagnostic procedures, therapeutic procedures, and even imaging are dependent on these factors. Moreover, the nanosensor one of the diagnostic tools based on natural Chitosan nanoparticles will present low quantum yield. These challenged must be resolved by coating the Chitosan with magnetic nanoparticles or carbon nanotube.

CONCLUSION

In this research, emerging materials notably magnetic nanopolymer is studied. As the study revealed, magnetic nanopolymer can exist naturally or made artificially. It is realized that naturally occurring magnetic nanopolymer exhibits distinguished biophysical properties which are tunable for medical application. Naturally occurring magnetic nanopolymer are stable, biodegradable, biocompatible, and have high mechanical strength. More importantly, Chitosan nanoparticles and films meet such criteria. It is shown that the stability of Chitosan is distorted by activating with light,, magnetic field, or hydrolysis with aqueous acid. Activating edible fungi by photon of optimum energy, ωo will enhance the biodegradation, process and produce vibration between neighboring ions. This vibration with a pronounced frequency makes Chitosan nanoparticles and nanocomposite suitable for cell imaging and drug delivery. Besides, due to charge difference between pathogens like gram-positive bacteria and negative ions of Chitosan surface charges produce attractive interaction, which makes suitable condition for immunotherapy. Due to its biodegradability, compatibility, and qualified physio-chemical properties like high stiffness, Chitosan is widely used in medical sectors for therapy, diagnosis, drug delivery and cell/tissue imaging and wound dressing. Likewise by careful guiding magnetic nanopolymer such as Chitosan nanoparticles with magnetic fields, it can be used for CT scans, cell imaging, and theranostics. The biophysical properties of Chitosan nanoparticles can be modified by forming hybrid with magnetic nanoparticles such as Fe_3O_4. This hybrid presents enhanced theranostics applications. Doping magnetic nanopolymer with metal nanoparticles such as Au NPs, Ag NPs increases its molecular weight as well as biological activity. Moreover, forming nanocomposite Chitosan/ZnO, Chitosan/Fe_2O_3, and Chitosan/Ag promising is promising for enhanced cell imaging, immunotherapy and theranostics applications.

REFERENCES

1. Dwivedi et al. Application of polymer nanocomposite in the nanomedicine landscape: envisaging strategies to combat implant-associated infections Appl. Biomater Funct. Mater 2013, 11 (3): 129-142.
2. A Yu Gervald, I A Gritskova, N I Prokopov. Synthesis of magnetic polymeric microspheres. Russian Chemical Reviews. 2010. 79 (3) 219 -229
3. Ramnandan, D., Mokhosi, S., Daniels, A., & Singh, M. (2020). Chitosan, Polyethylene Glycol and Polyvinyl Alcohol Modified $MgFe_2O_4$ Ferrite Magnetic Nanoparticles in Doxorubicin Delivery: A Comparative Study In Vitro. Molecules, 26(13), 3893. https://doi.org/10.3390/molecules26133893
4. Mishra RK (2018). Efficient insitu reinforced Micro/Nano fibrillar Polymer-polymer composites: A new class of materials for biomedical applications. J. Med Chem. Drug Design 1(1): dx: doi. org/10.16966/Jmcdd.106
5. Basavegowda N. Baek, K. H. Advances in Functional Biopolymer-Based Nanocomposite for Active Food Packaging Applications. Polymers 2021, 13, pp. 4198
6. Carmen P. Jimenez Gomez and Juan Antonio Cecilia. Chitosan: A Natural Biopolymer with a Wide and Varied Range of Applications Molecule. 2020, 25, 3981
7. Sneha Mohan et al. Biopolymers – Application in Nanoscience and Nanotechnology, 2016, V-106, 49882, Pp. 47 – 72.
8. Leonid Sukhodub et al. Electrical properties of biodegradable Chitosan calcium Phosphate nerve conduits doped with inorganic nanoparticles. Colloids and surface A: Physicochemical and engineering aspects. 2023. Vol. 678. 5. 132425.

9. X. Jia et al. Tracing transport of Chitosan nanoparticles and molecules in Caco-2 cells by fluorescent labeling Carbohydrate Polymers, 2009, V. 78, 323- 329
10. Villalba-Rodriguez, A. M et al. Chitosan-based carbon dots with applied aspects: New Frontiers of International Interest in a Material of Marine Origin Mar. Drugs. 2022, 20, 782
11. Dutta et al. chitin and Chitosan, Journal of scientific and industrial research. 2004, V. 63, Pp. 21-30
12. Catia Bastioli, Handbook of biodegradable polymers, 2005, ISBN: 1-85957-389-4, pp. 1- 353
13. Dan Huang, et al. Information processing using an integrated DNA reaction network, 2021, 13, and 5706 -5713
14. Zahed Nasab, S., Akbari, B., Mostafavi, E., & Zare, I. (2024). Chitosan nanoparticles in tumor imaging and therapy. Fundamentals and Biomedical Applications of Chitosan Nanoparticles, 405-445. https://doi.org/10.1016/B978-0-443-14088-4.00006-X
15. Chinnappan, B.A.; Krishnaswamy, M. Xu, H.; Hoque, M.E. Electro spinning of Biomedical Nanofibers/Nanomembrane; Effects of Process Parameters. Polymers 2022, 14, 3719
16. Samiha Hossain, optical properties of polymers and their applications, 2019, Theses. 1685.
17. Johan R.C Vander Marcel. Introduction to biopolymers, 2007, ISBN 13 978-981-277-603-7
18. Njuguna J. Polymer Nanocomposite for Aerospace Applications: Properties, 2004, V.24, 24-155.
19. Hanna Valo, Biopolymer-Based Nanoparticles for Drug Delivery, 2012 ISSN, 3. 1799-7372, pp. 1- 5
20. Pankaj Mehta. Introduction to polymer physics. 2021
21. Alemu, D., Getachew, E., & Mondal, A. K. (2022). Study on the Physicochemical Properties of Chitosan and their Applications in the Biomedical Sector. International Journal of Polymer Science, 2023(1), 5025341. https://doi.org/10.1155/2023/5025341
22. Masa Sprajcar, Petra Horvat, Andrej Krzan, biopolymers and bio plastics, European union, 2012
23. St. Louis et al. Polymeric drug delivery techniques. Material science. 2015, (314) 771-5765
24. M. Fata Moradali1 and Bernd H. A. Rehm, Bacterial Biopolymers, 2020, V. 18, 195Nathan R. Zaccai, Joseph Zaccai, and Igor N. Serdyuk, Methods in Molecular biophysics, 2017, 2, ISBN 978-1-107-05637-4
25. Doan Thi Kim Dung et al. preparation and characterization of magnetic nanoparticles with Chitosan coating. 2009. J. Phys.: Conf. ser. 187, 012038
26. Serdyuk IN, Zaccai NR, Zaccai J. Macromolecules as physical particles. In Methods in Molecular biophysics: Structures, dynamics function for biology and medicine, Cambridge University press; 2007: 2^{nd} edt, 38-64.
27. Kesharwani P. Halwai, K, Jha, S,K et al. Folate engineered Chitosan nanoparticles; next generation anticancer nanocarrier. Mol. Cancer 23, 244 (2024). https:doi. Org/10.1186/s12943-024-02163-z.
28. Gustavo Adolfo Munoz Ruiz et al. Chitosan, Chitosan Derivatives and their Biomedical Applications. 2016, 3. 249.
29. Mirta i. Aranguren, Mirna A. Mosiewicki, and Norma E. Marcovich, spectroscopic characterization, 2013
30. Aranaz, I, Alcantara, A.R., Civera, M.C., Arias, C., Elorza, B, Heras Caballero, A., Acosta, N. Chitosan: An Overview of Its Properties and Applications. Polymers 2021, 13, 3256
31. Chen, Z, Wang Z, Chen, X, et al. Chitosan caped gold nanoparticles for selective and colorimeteric sensing of heparin. J. Nanopart Res 15, 1930 (2013). https://doi.org/10.1007/s11051-013-1930-9.
32. Ulf W. Geddes, polymer physics, Springer, science and business media, 1999, ISBN 978-0-412-62640-1
33. Meyer B. Jackson, Molecular and cellular biophysics, 2006, ISBN-13 978-0-511-34472-5
34. Siti Hajar Othman et al., Bio-nanocomposite Materials for Food Packaging Applications: Types of Biopolymer and Nano-sized Filler, 2014 V. 2, Pp. 296-303
35. Katarzyna Nawrotek et al. Chitosan based hydrogel implants enriched with Calcium ions intended for peripheral nervous tissues regeneration. Carbohydrate Polymers. 2016. Vol.136.20. 764-771.
36. Noura El - Ahmady El - Naggar et al. Green synthesis of Chitosan nanoparticles, optimization, characterization and antibacterial efficacy against multi drug resistant biofilm-forming Acinetobacterbaumannii, Scientific Reports, 2022, 12:19869

37. Gomes L. P. et al. Chitosan Nanoparticles: production, physicochemical characteristics and Nutraceutical applications, Rev. Virtual Quim., 2017, 9 (1), 387-409
38. Belen Begines et al. Polymeric Nanoparticles for Drug Delivery, Nanomaterials 2020, 10, 1403
39. Korhegyi et al. Synthesis of 68ga-labeled biopolymer-based nanoparticles imaging agents for positron-emission tomography 2019, *39*: 2415-2427
40. Kim et al. Dispersion of Chitosan nanoparticles stable over a wide pH range by adsorption of polyglycerolmonostearate, Nanomaterials and Nanotechnology, 2020, V. 10: 1-9
41. Ding J & Guo Y, Recent Advances in Chitosan and its Derivatives in Cancer Treatment Front. Pharamacol.2022; 13: 888740
42. Zahra Fakhroueian et al. ZnO Q-dots as a potent therapeutic nanomedicine for in vitro cytotoxicity evaluation of mouth KB_{44}, breast MCF_7, colon HT_{29} and HeLa cancer cell lines, mouse ear swelling tests in vivo and its side effects using the animal model, Artificial cells, Nanomedicine, and Biotechnology, 2018, VOL. 46, NO. S2, S96–S111
43. S.L Kakani and Amit Kakani, Material science, 2004, ISBN (13) pp. 555- 592
44. Gökçen Yaşayan. Chitosan films and Chitosan/pectin polyelectrolyte complexes encapsulating silver sulfadiazine for wound healing, J Pharm. 2020, 50 (3): 238-244
45. Zhang, Yin-Juan Gao Bo, Liu, Xi-Wen. Topical and effective homeostatic medicine in the battlefield Int. J. Clin Exp Med. 2015, 8 (1): 1019

