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Chitosan based Nanocomposites: Its Synthesis, Characterization and Applications in Various Fields: A Review

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Abstract:- Nanocomposites: modern material are multiphase martial composed of one or many phases of less than 100 nm dimensions. Polymer –matrix nanocomposites are composed of polymer matrix reinforced with nanoscale fillers. Chitosan is the most abundant biopolymer after cellulose, extracted from chitin present in insect exoskeleton fungal cell wall, and crustaceans. Chitosan gains the attention of many researcher because of its unique properties like biodegradable, plant growth regulator, biocompatible, antimicrobial agent and nontoxic. Chitosan nanocomposites combine the benefits of chitosan with enhanced properties provided by nanoparticles making them versatile and high performing material. Chitosan nanocomposites has numerous application in industries, biomedical, food packaging, and environmental remediation. This review focuses on the Chitosan nanocomposites synthesis, their characterization and applications in various fields.

Keywords:- *Nanocomposites, Chitosan, TGA, Antimicrobial Activity, Polymer.*

I. INTRODUCTION

Nanocomposites are multiphase solid material made up of two or more component like polymer and nanostructured materials with at least one dimension in nanoscale (less than 100 nm. Nanocomposites are the solid combination of matrix and nanostructed phase and markedly differ in their mechanical, thermal, electrical, optical and catalytic properties from that of component material due to dissimilarities in structure and chemistry. Nanocomposites are designed to improve the efficiency of matrix by refining its physicochemical and biological properties Different types of nanocomposites like a) ceramic –matrix nanocomposites which composed of ceramic fibers implanted in ceramic matrix possessing optical, magnetic, electrical, corrosion resistance and protective properties [1,2] b) Metal-matrix nanocomposites made up of carbon nanotube with high tensile strength and electrical conductivity.[3] c) Polymer-matrix nanocomposites prepared by embedding nanoadditives to polymer matrix to enhance its properties[4] d) Heat resistant nanocomposites designed to withstand high temperature by carbon dots addition in polymer matrix. Chitosan becomes centre of attraction of researchers as alternative to synthetic plastic due its biodegradability, antimicrobial and film making properties also its abundance in nature after cellulose [5]

Chitin present in crustaceans, fungal cell wall. By treating chitin with alkali (deacetylation) chitosan is obtained. It is polysaccharide made up of β-(1 → 4) D-Glucosamine and β-(1→4)-N-acetyl-D-glucosamine units,. Chitosan exhibit remarkable mechanical strength flexibility and thermal stability. It has chemical ability to form complexes with transition metals and ions [6] Charged nanostructure can bind electrostatically with chitosan [7] Addition of nanoparticle enhances its mechanical properties and thermal stability making them suitable for structural applications and thermal conductivity and resistivity. Also becomes excellent barrier against moisture, gases and radiation. Different types of chitosan nanocomposites are 1) Chitosan-metal nanocomposites composed of metal nanoparticles and chitosan possessing antimicrobial properties, catalysis and used as a sensors. 2) Chitosan-carbon nanotube 3) Chitosan polymer nanocompsites.

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II. SYNTHESIS OF NANOCOMPOSITES

Chitosan based nanocomposites are prepared using various methods like sol-gel method, solution casting, electro spinning, freeze-drying, in situ synthesis, layer-by-layer assembly, emulsion techniques. [6] By dissolving chitosan and nanoparticles in solvent which then casted into mold and dried to obtained nanocomposites used for fabrication of films, membranes and coatings. They are also prepared by in situ polymerisation which involves simultaneous formation of polymer matrix and nanoparticles dispersion within the solution. Chitosan and nanoparticles are electrostatically spun into nanofiber. Sol-gel method is apply for the formation of colloidal suspension containing chitosan and nanoparticles which undergoes gelation to form solid matrix. Chitosan, due to its biocompatibility, cost effectiveness, biodegradability and antimicrobial properties becomes polymer under high concern. Green approach for synthesis of silver nanoparticles with chitosan reported for its antibacterial activity [8].Silver-based chitosan bionanocomposites synthesized by green approach [9].

III. CHARACTERIZATION

Different characterization techniques used for nanocomposites as follows;

- *Transmission Electron Microscopy (TEM) :*

In this technique high magnification measurement of that images transmission of beam of electrons through a sample. It has higher resolution than light based imaging techniques.

- *Scanning Electron Microscopy(SEM) :*

It measures the electron scattered from the sample, used for determining the size, shape and morphology of nanoparticles in the form of images of surface of the sample.

- *Thermogravimetric analysis (TGA) :*

This techniques measures the weight change in sample when heated or kept constant, to distinguish materials by their composition.

- *UV Visible Spectroscopy:*

This is an optical analysis technique used to quantify li absorption of photon in sample in UV range.

- *X-ray Diffraction (XRD):*

Diffraction pattern obtained when directing X-ray beam onto the sample reveals information about the lattice spacing and crystal orientation. XRD can be employed to determine the composition, phase purity, and crystallinity of nanocomposites.

- *Fourier Transform Infrared Spectroscopy (FTIR):*

FTIR used infrared radiation for identification of functional groups and chemical bonds in nanocoposites.

IV. CHITOSAN BASED NANOCOMPOSITES APPLICATION

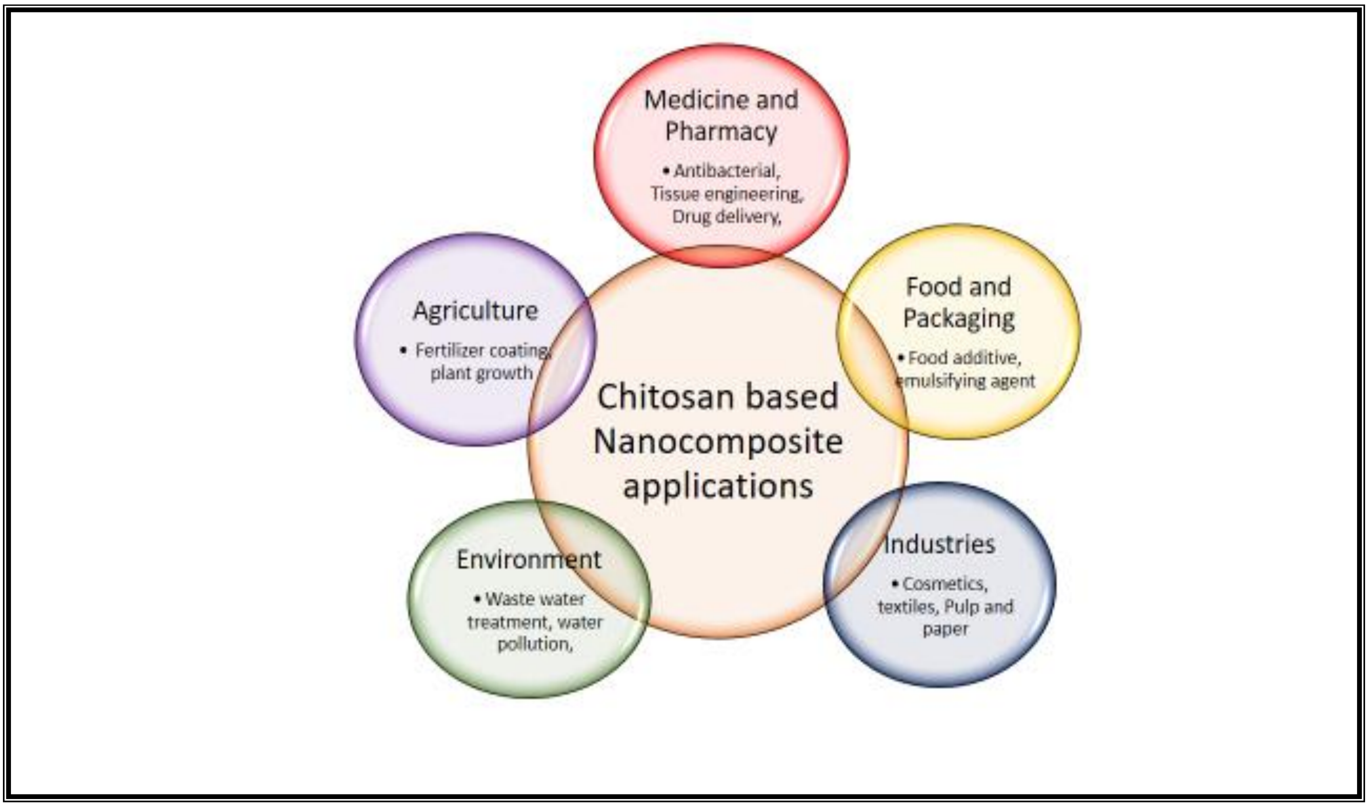

Fig. 1. Chitosan based Nanocomposites Applications in Various Fields

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Chitosan nanocomposites are the composites of chitosan with nanoparticles, nanofillers or nanofibres with improved properties such as mechanical strength, barrier properties, thermal stability making them appropriate for wide range of applications [10,11] Fig. 1. Shows the applications of chitosan based nanocomposites in various fields like medicine, food and packaging, waste water treatment and many more.

Many researchers [12, 13] reported food packaging application of chitosan-octadecylammonium and zinc oxide nanoparticles. Applications of these nanocomposites in wound and burn treatment, tissue engineering, and drug delivery systems. [13] Yu et al. [11] reported the plant growth stimulator and microbial activity of these nanocomposites in agricultural field. Multipurpose sunscreen for protecting skin surface from UV rays and inhibiting growth of bacteria was described using chitosan/TiO2 nanocomposite by Petrick et al. [14] also useful in lip care products for its long lasting effect of color adhesion. Chitosan has ability to inhibit activity of enzyme producing bacteria hence used as an active ingredient in deodorizers, antimicrobial agents. [15] Improve the inhibition of dental biofilm [16]. The application ZnO-chitosan nanocomposites as a powerful adsorbent for the removal of Congo red from aqueous solutions in wastewater treatment.[17] A drug delivery system aims to deliver the dose of drug to its right target within time, thus increasing therapeutic efficacy, bioavailability and decreasing adverse effects[18,19] Chitosan-based devices are used for the delivery of proteins and peptides, growth promoters, anti-inflammatory agents, antibiotics, and vaccines, also in gene therapy and bioimaging applications[15] Nanocomposites of Chitosan possesses chitosan with wide range of physical and chemical modification to enhance its function henceforth can used as an active and promising packaging for food preservation. [20] Also with improved physical properties of the biopolymer, used in the food packaging industry. The preparation of curcumin-loaded Chitosan-NPs has been described to increase the drug solubility and stability in the gastro intestinal tract. [21] Transmucosal delivery of two hydrophobic drugs, triclosan and furosemide, has been accomplished by emerging drug-loaded Ch-NPs [22].Enhanced oral absorption and comparative bioavailability, of heparin (LMWH) when loaded into Ch NPs [23]. Chitosan nanocomposites gained the attention in the field of oncology due its enhanced tumor targeting, ability to load different hydrophobic anticancer drugs, and the ability to control the release of anticancer drug [24, 25]. Chitosan-loaded paclitaxel NPs revealed excellent tumor-homing ability in tumor-bearing mice [26–30]. Authors reported genetic immunization using Ch NPs-loaded plasmid DNA. It shows quantifiable levels of gene expression and significant antigen titer [31]. Researchers reported the potential of Chitosan nanoparticles as carriers for antigens by using recombinant hepatitis B surface antigen [32]. A novel scaffold composed of chitosan (CS), poly (2-hydroxyetyl methacrylate) (PHEMA), and SiO2 nanoparticles (NPs) was fabricated for bone Tissue engineering application. [33] The fabricated scaffold showed proper physicochemical and biological properties. [34] Beenish Khanzada, et al reported the improved shelf life of packaged food due synergistic effect with enhanced thermo-mechanical and barrier properties of CNC, nano-keratin and extracts in chitosan films. Roy, S et al. described [35] strong antioxidant and antibacterial activity of pullulan/chitosan-based binary composite film used in meat packaging. Muhammad Tariq Saeed Chani [36] reported chitosan-cerium oxide-cadmium oxide nanocomposites used as humidity sensors. Alireza Foroughnia et al synthesized chitosan Schiff base and its Fe_2O_3 nanocomposites showing antibacterial activity and used as a catalyst for removal of methyl orange from aqueous solution. [37]. Organic dyes used in many industries are hazardous to environment due to toxicity and carcinogenic nature. Chitosan based nanocomposites develop as a potential material to endorse sustainable and efficient dye removal [38] chitosan binding semiconductor metals can be used as photo catalysts which can improve the quality degradation of organic pollutants or dye removal [39-41] Zhao et al reported AuNR-based NCs showing multiple smart responsivenesses at tumors due combined effect of chemoembolization and photothermal therapy for solid tumor treatment [42] Geeta et al. devised smart Chitosan – TiO_2 nanobiocomposite films for extending white bread shelf life to 10 days.[43]

V. CONCLUSION

Chitosan because of its unique properties like biodegradable, biocompatible, non-toxic possessing antimicrobial activity becomes an attractive, ecofriendly alternative to other polymers. Introduction of nanoadditives into chitosan enhances its mechanical strength, thermal stability and biological activity. Such chitosan based nanocomposites with enhanced physicochemical and biological properties possessing wide range of applications in food packaging, medicine, tissue engineering, textiles, pulp and paper industries, cosmetics, agriculture and waste water treatment.

The development of novel chitosan based nanocomposites will drive novelty in assorted applications.

REFERENCES

[1]. F. E. Kruis, H. Fissan and A. Peled "Synthesis of nanoparticles in the gas phase for electronic, optical and magnetic applications – a review". J. Aerosol Sci. 1998, 29 (5–6): 511–535.
[2]. S. Zhang; D. Sun; Y. Fu; H. Du "Recent advances of superhard nanocomposite coatings: a review". Surf. Coat. Technol. 2003, 167 (2–3): 113–119.
[3]. Janas, Dawid; Liszka, Barbara "Copper matrix nanocomposites based on carbon nanotubes or graphene". Mater. Chem. Front. 2017, 2: 22–35
[4]. Manias, Evangelos "Nanocomposites: Stiffer by design". Nature Materials., 2007, 6 (1): 9–11
[5]. Mincea, M.; Negrulescu, A.; Ostafe, V. Preparation, modification, and applications of chitin nanowhiskers: A review. Rev. Adv.Mater. Sci. 2012, 30, 225–242.
[6]. Priyadarshi, R., & Rhim, J. W. Chitosan-based biodegradable functional films for food packaging applications. Innovative Food Science and Emerging Technologies, 2020 , 62(102346), 1–20.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUL661

[7]. Zouaoui, F., Bourouina-Bacha, S., Bourouina, M., Jaffrezic-Renault, N., Zine, N., & Errachid, A , Electrochemical sensors based on molecularly imprinted chitosan: A review. TrAC, Trends in Analytical Chemistry, . 2020, 130, Article 115982

[8]. Santiago, T.R.; Bonatto, C.C.; Rossato, M.; Lopes, C.A.P.; Lopes, C.A.; Mizubuti, E.S.G.; Silva, L.P. Green synthesis of silvernanoparticles using tomato leaf extract and their entrapment in chitosan nanoparticles to control bacterial wilt. J. Sci. Food Agric. 2019, 99, 4248–4259.

[9]. Paulkumar, K.; Gnanajobitha, G.; Vanaja, M.; Pavunraj, M.; Annadurai, G. Green synthesis of silver nanoparticle and silver based chitosan bionanocomposite using stem extract of Saccharum officinarum and assessment of its antibacterial activity. Adv. Nat. Sci.Nanosci. Nanotechnol. 2017, 8, 035019.

[10]. Azmana M., Mahmood S., Hilles A. R., Rahman A., Arifin M. A. B., Ahmed S. A review on chitosan and chitosan-based bionanocomposites: promising material for combatting global issues and its applications. Int. J. Biol. Macromol. 2021, 185, 832–848.

[11]. Yu J., Wang D., Geetha N., Khawar K. M., Jogaiah S., Mujtaba M. x Current trends and challenges in the synthesis and applications of chitosan-based nanocomposites for plants: a review. Carbohydr. Polym. 2021, 261, 117904.I.S.

[12]. Rodrigues C., de Mello J. M. M., Dalcanton F., Macuvele D. L. P., Padoin N., Fiori M. A., et al. Mechanical, thermal and antimicrobial properties of chitosan-based-nanocomposite with potential applications for food packaging. J. Polym. Environ. 2020, 28 (4), 1216–1236..

[13]. Ahmad S., Abbasi A., Manzoor K., Mangla D., Aggarwal S., Ikram S. “9—chitosan-based bionanocomposites in drug delivery,” in Bionanocomposites in tissue engineering and regenerative medicine. Editors Ahmed, S., Annu A. (Sawston: Woodhead Publishing;), 187–203, 2021, M. Young, The Technical Writer’s Handbook. Mill Valley, CA: University Science, 1989.

[14]. Petrick J., Ibadurrohman M., Slamet C. (2020). Synthesis of chitosan/TiO2 nanocomposite for antibacterial sunscreen application. AIP Conf. Proc. 2255

[15]. Bakshi P. S., Selvakumar D., Kadirvelu K., Kumar N. S. (2020). Chitosan as an environment friendly biomaterial – a review on recent modifications and applications. Int. J. Biol. Macromol. 150, 1072–1083.

[16]. Resende A. H. M., Farias J. M., Silva D. D. B., Rufino R. D., Luna J. M., Stamford T. C. M., et al. (2019). Application of biosurfactants and chitosan in toothpaste formulation. Colloids Surfaces B Biointerfaces 181, 77–84.

[17]. Nguyen N. T., Nguyen N. T., Nguyen V. A. (2020). In situ synthesis and characterization of ZnO/chitosan nanocomposite as an adsorbent for removal of Congo red from aqueous solution. Adv. Polym. Technol. 2020, 1–8.

[18]. Wang W., Meng Q., Li Q., Liu J., Zhou M., Jin Z., et al. (2020a). Chitosan derivatives and their application in biomedicine. Int. J. Mol. Sci. 21 (2), 487

[19]. Ewart D., Peterson E. J., Steer C. J. (2019). A new era of genetic engineering for autoimmune and inflammatory diseases. Seminars Arthritis Rheumatism 49 (1),

[20]. Inanli A. G., Tümerkan E. T. A., Abed N. E., Regenstein J. M., Özogul F. (2020). The impact of chitosan on seafood quality and human health: a review. Trends Food Sci. Technol. 97, 404–416.

[21]. Guzman-Villanueva, D.; El-Sherbiny, I.M.; Herrera-Ruiz, D.; Smyth, H.D.C. Design and in vitro evaluation of a new nanomicroparticulate system for enhanced aqueous-phase solubility of curcumin. Biomed Res. Int. 2013, 2013.

[22]. Maestrelli, F.; Garcia-Fuentes, M.; Mura, P.; Alonso, M.J. A new drug nanocarrier consisting of chitosan and hydoxypropylcyclodextrin. Eur. J. Pharm. Biopharm. 2006, 63, 79–86. [CrossRef]

[23]. Wang, J.; Tan, H.N.; Yu, A.H.; Ling, P.X.; Lou, H.X.; Zhai, G.X.; Wu, J. Preparation of chitosan-based nanoparticles for delivery of low molecular weight heparin. J. Biomed. Nanotechnol. 2011, 7, 696–703.

[24]. Prabaharan, M. Chitosan-based nanoparticles for tumor-targeted drug delivery. Int. J. Biol. Macromol. 2015, 72, 1313–1322.

[25]. Lee, S.J.; Park, K.; Oh, Y.K.; Kwon, S.H.; Her, S.; Kim, I.S.; Choi, K.; Lee, S.J.; Kim, H.; Lee, S.G.; et al. Tumor specificity and therapeutic efficacy of photosensitizer-encapsulated glycol chitosan-based nanoparticles in tumor-bearing mice. Biomaterials 2009, 30, 2929–2939.

[26]. Kwon, I.C. Chitosan-based nanoparticles for cancer therapy; tumor specificity and enhanced therapeutic efficacy in tumor-bearing mice. J. Control. Release 2008, 132, E69–E70.

[27]. Pan, Y.; Li, Y.J.; Zhao, H.Y.; Zheng, J.M.; Xu, H.;Wei, G.; Hao, J.S.; Cui, F.D. Bioadhesive polysaccharide in protein delivery system: Chitosan nanoparticles improve the intestinal absorption of insulin in vivo. Int. J. Pharm. 2002, 249, 139–147.

[28]. Vila, A.; Sanchez, A.; Tobio, M.; Calvo, P.; Alonso, M.J. Design of biodegradable particles for protein delivery. J. Control. Release 2002, 78, 15–24.

[29]. Garcia-Fuentes, M.; Prego, C.; Torres, D.; Alonso, M.J. A comparative study of the potential of solid triglyceride nanostructures coated with chitosan or poly(ethylene glycol) as carriers for oral calcitonin delivery. Eur. J. Pharm. Sci. 2005, 25, 133–143.

[30]. Katas, H.; Raja, M.A.; Lam, K.L. Development of chitosan nanoparticles as a stable drug delivery system for protein/siRNA. Int.J. Biomater. 2013, 2013, 146320.

[31]. Cui, Z.R.; Mumper, R.J. Chitosan-based nanoparticles for topical genetic immunization. J. Control. Release 2001, 75, 409–419.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUL661

[32]. Prego, C.; Paolicelli, P.; Diaz, B.; Vicente, S.; Sanchez, A.; Gonzalez-Fernandez, A.; Alonso, M.J. Chitosan-based nanoparticles for improving immunization against hepatitis B infection. Vaccine 2010, 28, 2607–2614.
[33]. Soheila Zare, Morteza Eskandani, Somayeh Vandghanooni, Hadi Hossainpour, Mehdi Jaymand, Ciprofloxacin-loaded chitosan-based nanocomposite hydrogel containing silica nanoparticles as a scaffold for bone tissue engineering application,Carbohydrate Polymer Technologies and Applications,Volume 7,2024,100493
[34]. Beenish Khanzada, Bushra Mirza, Aman Ullah,Chitosan based bio-nanocomposites packaging films with unique mechanical and barrier properties,Food Packaging and Shelf Life,Volume 35,2023,101016,
[35]. Roy, S.; Priyadarshi, R.; Rhim, J.-W. Development of Multifunctional Pullulan/Chitosan-Based Composite Films Reinforced with ZnO Nanoparticles and Propolis for Meat Packaging Applications. Foods 2021, 10, 2789.
[36]. Muhammad Tariq Saeed Chani, Fabrication and characterization of chitosan-CeO2-CdO nanocomposite based impedimetric humidity sensors International Journal of Biological Macromolecules,Volume 194,2022,Pages 377-383,
[37]. Alireza Foroughnia, Aliakbar Dehno Khalaji, Eskandar Kolvari, Nadiya Koukabi, Synthesis of new chitosan Schiff base and its Fe2O3 nanocomposite Evaluation of methyl orange removal and antibacterial activity, International Journal of Biological Macromolecules,Volume 177,2021,Pages 83-91
[38]. Rashid, S., Shen, C., Yang, J., Liu, J., & Li, J, Preparation and properties of chitosan–metal complex: Some factors influencing the adsorption capacity for dyes in aqueous solution. Journal of Environmental Sciences, 2018, 66, 301–309.
[39]. Huang, C., & Peng, BPhotocatalytic degradation of patulin in apple juice based on nitrogen-doped chitosan-TiO2 nanocomposite prepared by a new approach. Lwt, . 2021,140.
[40]. Midya, L., Sarkar, A. N., Das, R., Maity, A., & Pal, S., Crosslinked chitosan embedded TiO2 NPs and carbon dots-based nanocomposite: An excellent photocatalyst under sunlight irradiation. International Journal of Biological Macromolecules, 2020, 164, 3676–3686.
[41]. Alimard, P. Fabrication and kinetic study of Nd-Ce doped Fe3O4-chitosan nanocomposite as catalyst in Fenton dye degradation. Polyhedron, 2019, 171, 98–107.
[42]. Zhao, M.; Liu, Y.; Yin, C. Gold Nanorod-Chitosan Based Nanocomposites for Photothermal and Chemoembolization Therapy of Breast Cancer. Int. J. Biol. Macromol. 2024, 259, 129197.
[43]. Geeta, Shivani, Neeru Devi, Shayoraj, Neha Bansal, Sanjay Sharma, Santosh Kumar Dubey, Satish Kumar,Novel chitosan-based smart bio-nanocomposite films incorporating TiO2 nanoparticles for white bread preservation, International Journal of Biological Macromolecules, 2024,Volume 267, Part 2, 131367.