Mini Review

BIOMEDICAL Journal of Scientific & Technical Research

ISSN: 2574 -1241

DOI: 10.26717/BJSTR.2022.46.007286

Recent Advancement of PVA/Chitosan-Based Composite Biofilm for Food Packaging

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ARTICLE INFO

Received: August 27, 2022

Published: September 07, 2022

Citation: Md. Hasinur Rahman, Md. Sofiuzzaman, Md. Ibrahim H. Mondal, Afia Rahman, Firoz Ahmed, et al. Recent Advancement of PVA/Chitosan-Based Composite Biofilm for Food Packaging. Biomed J Sci & Tech Res 46(1)-2022.

ABSTRACT

The recent increased concern for environmental problems caused by plastic packaging has stimulated interest in alternative and sustainable packaging materials. This new trend favours the development of industry knowledge of bio-based packaging materials, such as chitosan-based films for food packaging. Although there are some shortcomings in thermal stability, barrier properties, mechanical properties, and high sensitivity to moisture, chitosan has been widely studied and used due to its unique biological and functional properties. Blending chitosan with other natural and/or synthetic polymers (e.g. PVA) is an effective way to overcome these limitations. In this study, we tried to summarize the application of various strategies to overcome the inherent deficiencies and enhance the properties of chitosan/PVA-based biofilms, especially when mixed with natural and synthetic film-forming agents.

Keywords: Sustainable; Packaging; PVA; Chitosan; Biofilm

Introduction

Food packaging is an essential part of the food industry because food safety, shelf life and quality are directly dependent on the materials used for packaging. If foods are exposed to moisture, which is a good environment for the growth of bacteria and mould, and at an inadequate storage temperature, they can easily contaminate and spoil, therefore, in order to maintain the quality of the food for a longer period, adequate protection against external influences and factors is required [1]. Biodegradable films are used as packaging materials to extend the shelf life of foods & food products without causing a negative impact on food materials as well as on the environment. The most commonly used ingredients are cellulose, starch, alginate, carrageenan, pectin and chitosan. Chitosan (β-(1,4) 2-amino-2-deoxy-d-glucosamine) is a polysaccharide obtained by deacetylation of chitin. It exists in the exoskeletons of insects, the shells of crustaceans and various fungi [2]. Chitosan is a low-cost natural polysaccharide and has unique properties such as non-toxicity, biodegradability, renewability and biocompatibility. Due to these characteristics, the production of chitosan alone or chitosan-based composite films have received great attention in different fields of application, especially in food packaging [3]. To improve the biological (mainly antibacterial and antioxidant) and physiological (mainly mechanical, thermal and barrier) properties of chitosan films, various support polymers have been mixed into chitosan films [4]. Polyvinyl alcohol (PVA), being non-toxic, water-soluble, semi-

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crystalline, biodegradable and biocompatible polymer is one of the most commonly used synthetic polymers blended with chitosan [3]. PVA and chitosan have good compatibility, but chitosan reduces the crystallinity of the mixture. In addition, chitosan significantly reduced the strain capacity of the film and simultaneously increased the film stiffness.

Another advantage of using chitosan together with PVA film is its ability to both reduce UV transmission and at the same time provide antibacterial activity. However, the properties of the film have been found to be satisfactory, but additional efforts, such as crosslinking are required to meet all requirements for food packaging materials. Bonilla et al. [5] studied the mixing of PVA with chitosan in different preparations to obtain biodegradable films, the structural, thermal, mechanical, barrier properties, as well as antibacterial activity were examined. This study aims to describe an effective strategy to meet the requirements of PVA/chitosan film for food packaging applications.

Physiochemical & Biological Properties of Chitosan/PVA Composite Film

Mechanical Properties

By using glycerol and low molecular weight PVA as plasticizers, the mechanical properties of chitosan films can be substantially improved. Adding gallic acid and natural phenolic acid derived from protocatechuic acid, The tensile strength and elongation at break of the chitosan-based composite film are higher [6]. According to reports, the cellulose/zinc oxide nanocrystal (CNC/ZnO), TiO_2 nanopowder, silicon carbide nanocomposite and graphene oxide filler dispersed in the PVA/chitosan mixture can significantly improve the tensile strength and modulus of the mixture [7]. They increase the tensile strength and Young's modulus and have good potential for food packaging applications [6]. The process of chitin extraction from natural resources and its conversion into chitosan has been outlined in Figure 1.

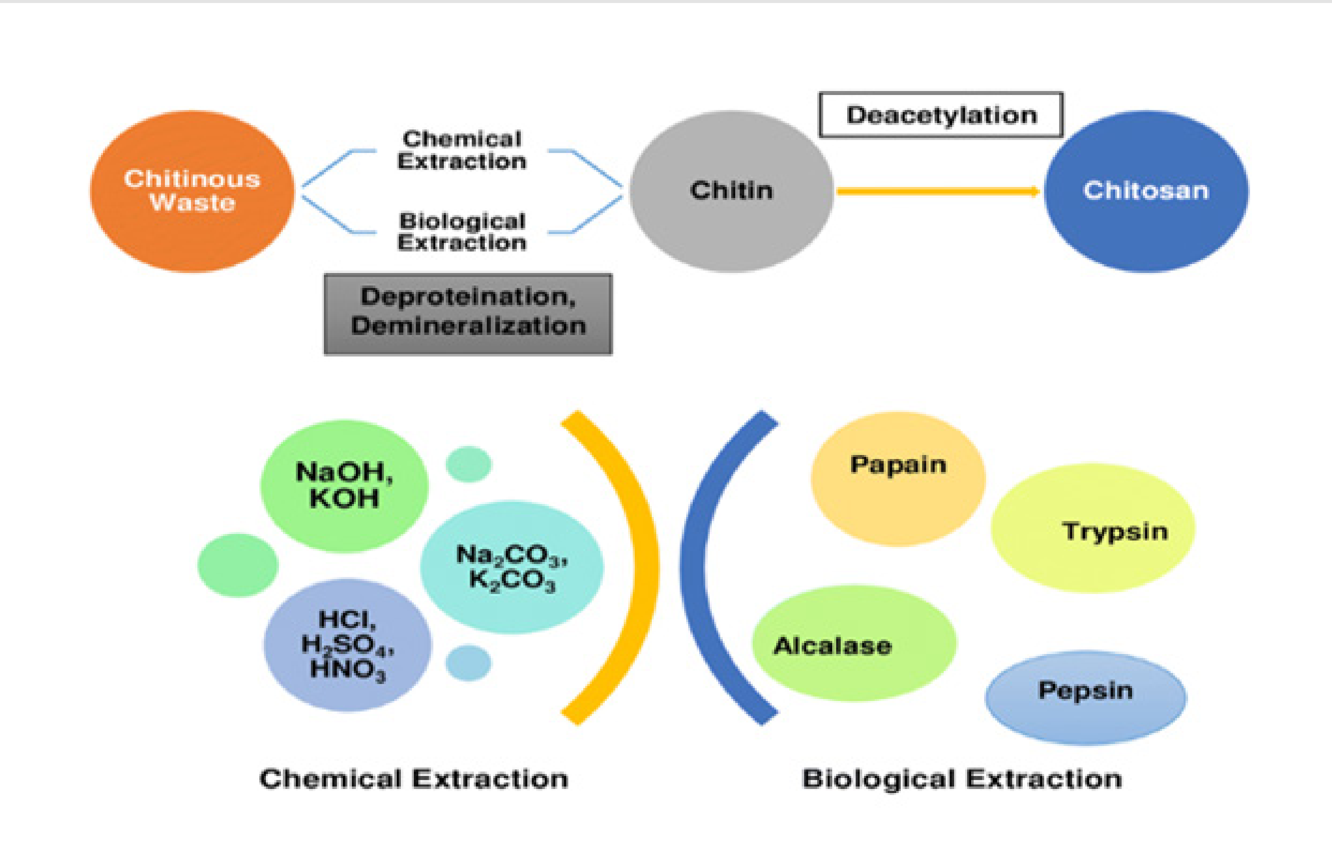

Figure 1: Chitin and chitosan extraction from chitinous marine waste [15].

Barrier Properties

The barrier properties of chitosan-based coatings contribute to maintaining continuity of storage, nutritional value, and prolonging the shelf life of vegetables and fruits. Recently, the water vapor permeability and oxygen permeability of chitosan films have been reported to decrease with increasing propolis concentration. In the chitosan / PVA blend film, the moisture content was observed to increase with the increasing concentration of polyvinyl alcohol [8]. Adding olive oil and corn oil as plasticizers to chitosan will reduce its barrier properties, such as water absorption, moisture, and

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oxygen permeability. The addition of sorbitol to the chitosan film will reduce its total moisture content and permeability to water vapour [9].

Antimicrobial Properties

Chitosan film has been used extensively in food packaging materials, which can be attributed to its inherent antibacterial properties. Sodium lactate-enhanced PVA/montmorillonite chitosan film exhibits excellent antibacterial activity against E. coli, making it a potential component of food packaging [6]. The mixed PVA and chitosan film containing bifunctional cellulose/zinc oxide filler nanocrystals & propolis has antibacterial activity against the bacterial species Salmonella cholera, S. aureus, E. coli and Pseudomonas [7]. It has shown that silver nanocomposite film containing chitosan has good antibacterial activity. By adding turmeric extract and diluted young apple polyphenols and TiO_2 nanoparticles to the film-forming solution, the antibacterial properties of the chitosan film have been greatly improved [6]. The antimicrobial action of chitosan has been outlined in Figure 2.

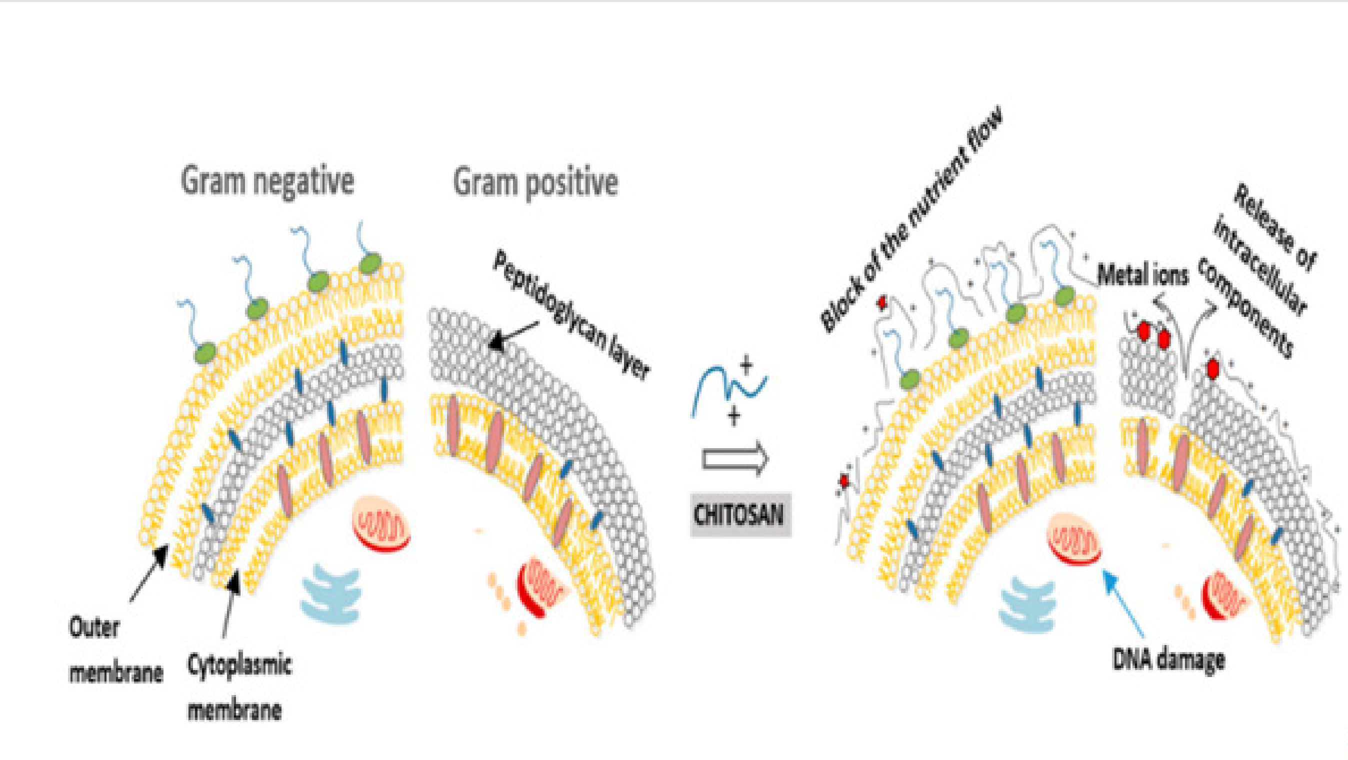

Figure 2: The proposed action of chitosan on Gram-positive and -negative bacteria. [16].

Meat Packaging

Meat packaged with traditional plastic and PVA nano-layers showed a rapid increase in the number of microorganisms when the microbial growth was evaluated a week later (Figure 2). This indicates that there are conditions suitable for the growth of microorganisms, and due to the action of micro-organisms, this may lead to the degradation of packaged meat. In the case of PVA (70%)-Chitosan (30%)-Nano-layers and PVA (70%)-Chitosan (30%)-silver (Ag) Nano-layers, there was no initial growth, but after 16-17 hours, bacterial growth was observed. This may be because the bacteria reside on a deeper surface and are not in close contact with the packing layer. These bacteria must have eliminated the antibacterial effect of fibrous composite nano-layers (FCNL). Compared with the bacterial growth observed in convective plastics and PVA nanolayers, the bacterial contamination observed in PVA-CH-Ag nanolayers is negligible [10]. The PVA-CH-Ag nano-composite layer showed the highest antibacterial activity among the tested packaging materials. Also, when the meat is ground in a mincer after 7 days, if the meat is packed in a PVA-CH-Ag composite nanolayer, the sensory quality (i.e.vision and smell) is much better [11].

Antioxidant Properties

Chitosan film can be used as an active container to prevent the oxidation of food. The antioxidant properties of the chitosan/nanoclay nanocomposite active film containing a sodium montmorillonite film are enhanced by the incorporation of milk thistle extract [10]. The chitosan-based edible film is mixed with polyphenolic starch containing thyme extract, which has stronger

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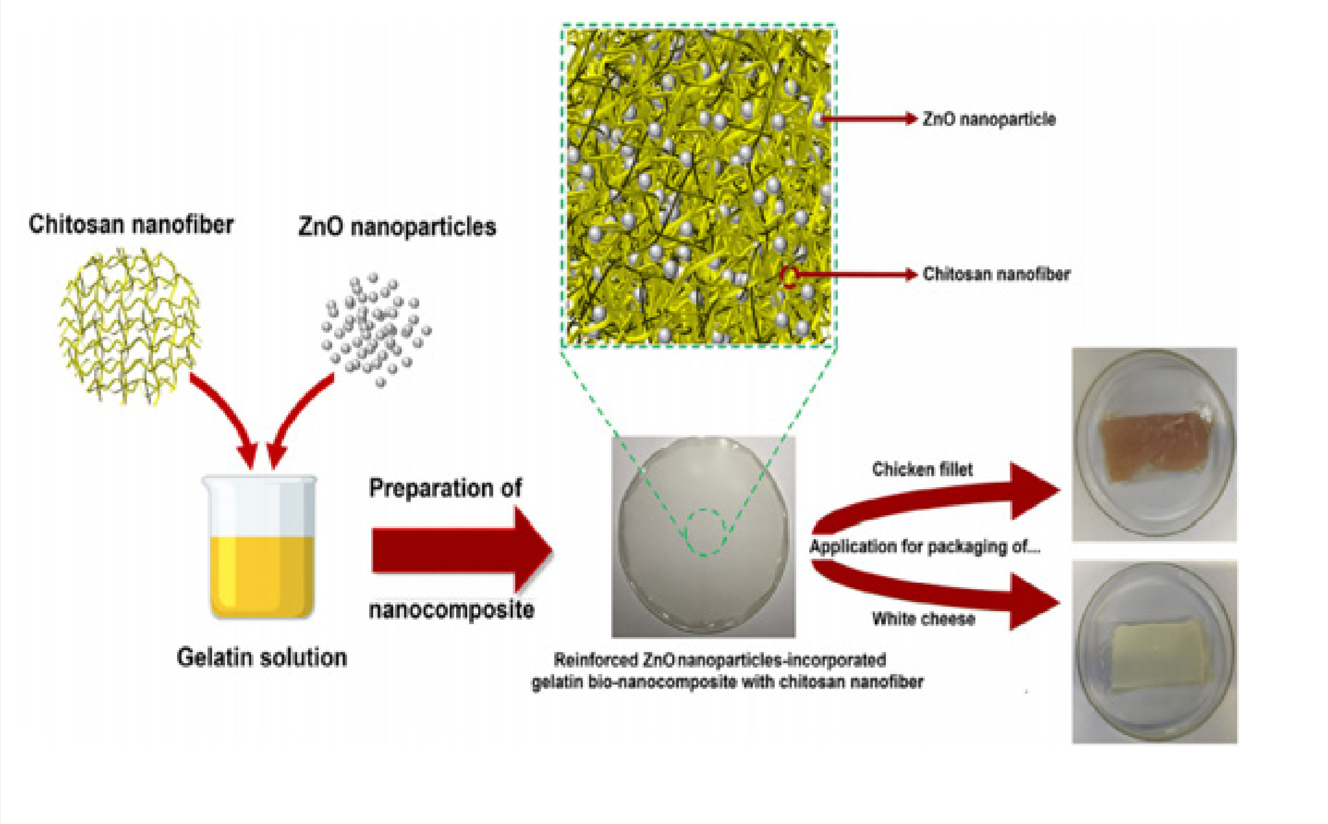

Figure 3: Schematic diagram showing the mode of action of antioxidant activity of chitosan via interruption of free radical chain reaction [17].

Food-Related Application PVA/Chitosan Film

PVA/Chitosan nanocomposite films have a synergistic antioxidant reaction that protects food from ultraviolet light and further comprises the ability to inhibit gram-negative bacterial growth. It is an important food contact material for bottles and fresh products [13]. The film of the polyvinyl sodium laminated lactate/montmorillonite solution (NaCl/ PVA / MMT) showed a decent antimicrobial movement against E. coli and was used as a decent limit membrane towards a dynamic food beam. Chitosan/ PVA biocomposite films supported by thiabendazolium-Montmorillonite have amazing potential as antibacterial food bundling things [14].

Conclusion & Future Outlook

Chitosan is the second most abundant material on the earth after cellulose. It has extraordinary film-forming ability. The chitosan/ PVA-based biocomposite film has sufficient structure, mechanics, morphology and antibacterial properties. It can resist degradation by bacteria and help to extend the shelf life of food. Therefore, the chitosan/PVA film can be used as an active container to prevent food oxidation. Furthermore, adding PVA to the chitosan film can greatly change the flexibility and swelling behaviour. The addition of PVA greatly improves the solubility, tensile strength, and elongation at the break of the composite film. In the future, chitosan/PVA film can replace traditional plastic packaging reducing its environmental footprint.

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ISSN: 2574-1241

DOI: 10.26717/BJSTR.2022.46.007286

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