JOURNAL OF SUSTAINABLE MATERIALS PROCESSING AND MANAGEMENT
e-ISSN: 2821-2843

JSMPM

Vol. 4 No. 1 (2024) 40-45
https://publisher.uthm.edu.my/ojs/index.php/jsmpm

Modification of Gelatin by Ciprofloxacin for Industrial Applications

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DOI: https://doi.org/10.30880/jsmpm.2024.04.01.004

Article Info

Received: 29 January 2024
Accepted: 7 March 2024
Available online: 15 May 2024

Keywords

Gelatin, ciprofloxacin, food packaging

Abstract

Generally, gelatin resulting from collagen, a naturally occurring protein found in ligaments and tissues, is formed through the boiling of connective tissues, bones and animal skins, commonly sourced from cows. It has exceptional properties, including the ability to form strong, transparent gels and flexible films, easy digestibility, solubility in hot water and positive binding action, make gelatin a highly valuable resource in various industries such as food processing, pharmaceuticals, photography and paper production. It is regarded as non-toxic, non-degradable and biocompatible material. In this study we modified gelatin by ciprofloxacin compound, specifically we aimed gelatin to be used in different industries specifically in food packaging, then the synthesized materials were characterized by Fourier transform infrared (FTIR), the surface was imaged by scanning electron microscopy (SEM) furthermore, surface morphology was measured using atomic force microscopy (AFM). Overall, all analysis techniques confirmed the modification by the presence of ciprofloxacin coordinated with the gelatin molecule.

1. Introduction

Researcher have focused to finds an environmentally friendly material. Therefore, Gelatin is a good candidate and is a widely examined to be used in food packaging industry due to its characteristics as biodegradable materials and has low mechanical and economical production cost. Generally, petrochemicals can be utilized to produce plastic materials which are exploited in packing sector [1]. Petrochemicals considered environmentally unfriendly materials which are a high pollutant. Therefore, researchers have found biomaterials are much safer and more reliable to be used in this field [2,3]. Biopolymer can be degraded by microbe into CO_2, CH_3OH, H_2O and inorganic molecules [4]. Polymer degradation affected by type of microbe, humidity and temperature. Biopolymer converted into CO_2 and bio-mass from days to months depends on the nature of material structures [5,6]. Polysaccharide, lipids, proteins and/or mix of them are a vital source to produce biodegradable biopolymers [7–9]. Gelatin is a biopolymer with protein based, which is extensively used in food wrapping due to its capability to create film as a barrier to exclude temperature, oxygen and light and protect food from damaging [9]. Gelatin produce from collagen which is exists in mammals' tissues, tendons and ligaments. In general, gelatin cab be formed from decomposing of animal skins, boiled crushed bones, and the connective tissues of cows and pigs. Gelatin has the ability to form visible films that are soluble in hot water with high binding's abilities, which is important in photography, medications, food packaging [10]. Gelatin was used in the beginning as a biological adhesive material, then it is rapidly to be used in industrial field and other uses. Gelatin can be obtained by chemical and physical treatment of raw materials which include hydrolysis of these

materials. Gelatin hydrogels can be utilized as biodegradable materials for medication and in healthcare fields, and it is a main structure of different amino acids [12]. The amide bond is existing in different molecules and the bioactive of natural composition are considered a part of some industries specifically the pharmaceutical manufacturing [13]. Ciprofloxacin is a derivatives of 4-quinolone carboxylic acid with a wide range of biological activity. The medication orally, shown efficiency against infections of urinary, gastrointestinal tracts, gonorrhea, osteomyelitis, respiratory system and tissues [14]. In general, gelatin is a widely used in food as a biopolymer to enhance the elasticity and stability. Gelatin can be obtained from fish and insects rather than skin and bones of land animals which provide more confidential source accepted by many people. The acid and alkaline processes are two main methods to produce gelatin A and B [15]. Moreover, gelatin considered as biocompatible and biodegradable which is important in biomedical applications such as, tissue engineering and stent construction [16,17]. The aim of this work is to modify gelatin by ciprofloxacin compound and find the prospective uses in industry especially in food packaging as alternative of the synthetic material which considered environmentally non-friendly materials.

2. Experimental Procedures

2.1 Materials

Ciprofloxacin, reagents, and solvents were supplied from Sigma-Aldrich (Gillingham, UK).

2.2 Films Characterization

Fourier transform infrared (FTIR, Bruker) was used to characterized the absorption bands of synthesized compounds and were recorded in the range between (4000 – 200) cm^{-1}. Scanning electronic microscopy (SEM) was used to image the synthesized compounds and were carried out using Inspect S50 microscope (FEI Company, Czech Republic) at an accelerating voltage of 15 kV.

2.3 Films Preparation of Gelatin and Ciprofloxacin

Dissolve 2 g of gelatin/dissolve gelatin film (1 gm) with ciprofloxacin in tetrahydrofuran (THF) (20 ml). Then, the solution was heated for 1 hr to form a uniform solution. Then, the solution was transferred to Petri dish and left 24 hrs to evaporate and give gelatin-ciprofloxacin film (Fig. 1).

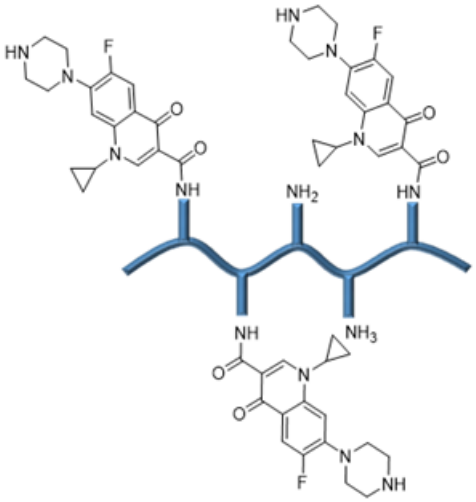

Fig. 1 *Modification of gelatin molecule*

2.4 Reaction of Gelatin with Ciprofloxacin

N-hydroxysuccinimide (NHS) and Dicyclohexylcarbodiimide (DCC), was mixed and dissolved in dimethylformamide (DMF) and stirred for 15 min. Gelatin (2 g) was dissolved in water and mix with the original solution and stir for 24 hrs. The product was filtered and washed with diethyl ether.

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3. Results and Discussion

Amide synthesis is an important organic reaction which is highlighted the synthesis of compounds with industrial and biological applications. The preparation includes ketone or aldehyde condensation with a primary amine to form carboxylic acid or imine to create amide bond, also known as (amino-lysis reaction). The prepared amide was analyzed by FTIR. FTIR is a powerful technique used for this purpose. In FTIR, a beam of infrared radiation is passed through the sample, and the absorption of the radiation is measured. The resulting spectrum provides information about the functional groups present in the compound. The amide compound contains carbonyl group give absorption band in the range between (1600-1800 cm^{-1}). The amino group reaction of gelatin with carboxylic group of ciprofloxacin to produce amide group was confirmed by the absorption band at 1622 cm^{-1}, and disappear of NH_2 group absorption band at 3276 cm^{-1} (Fig. 2).

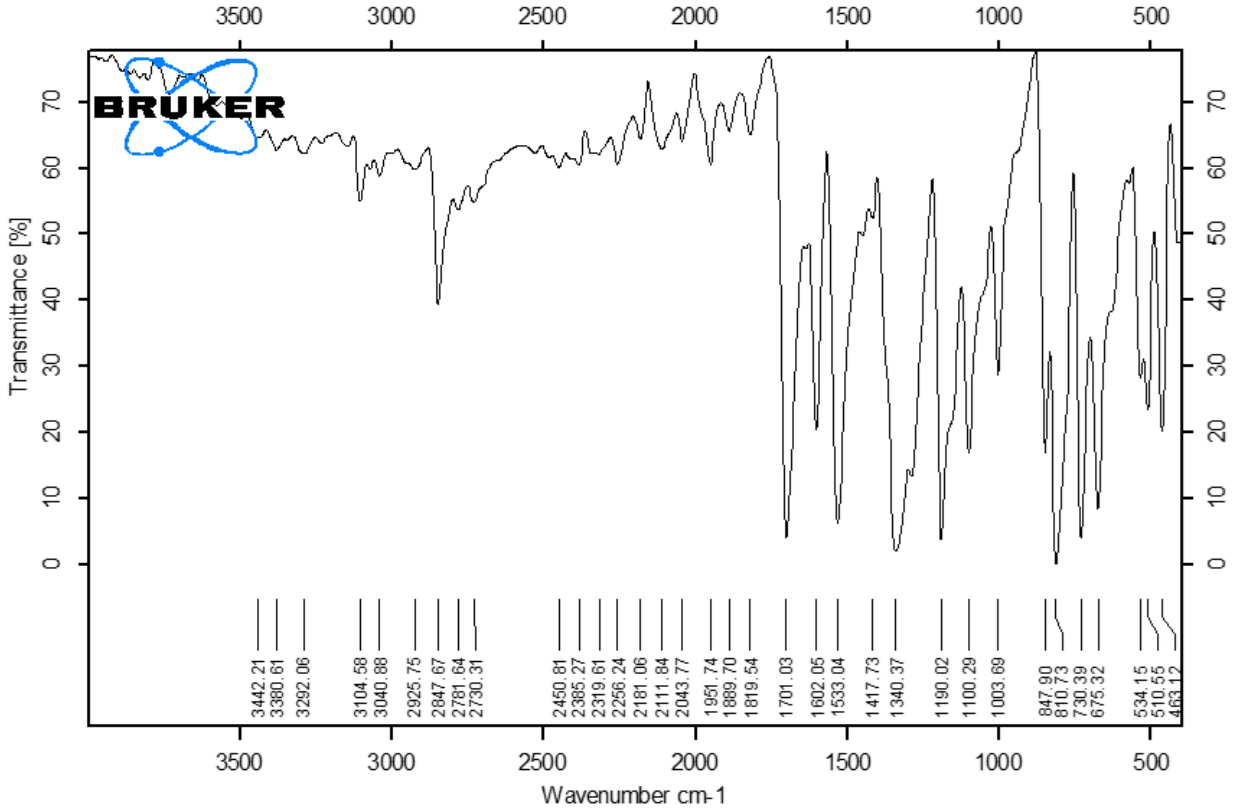
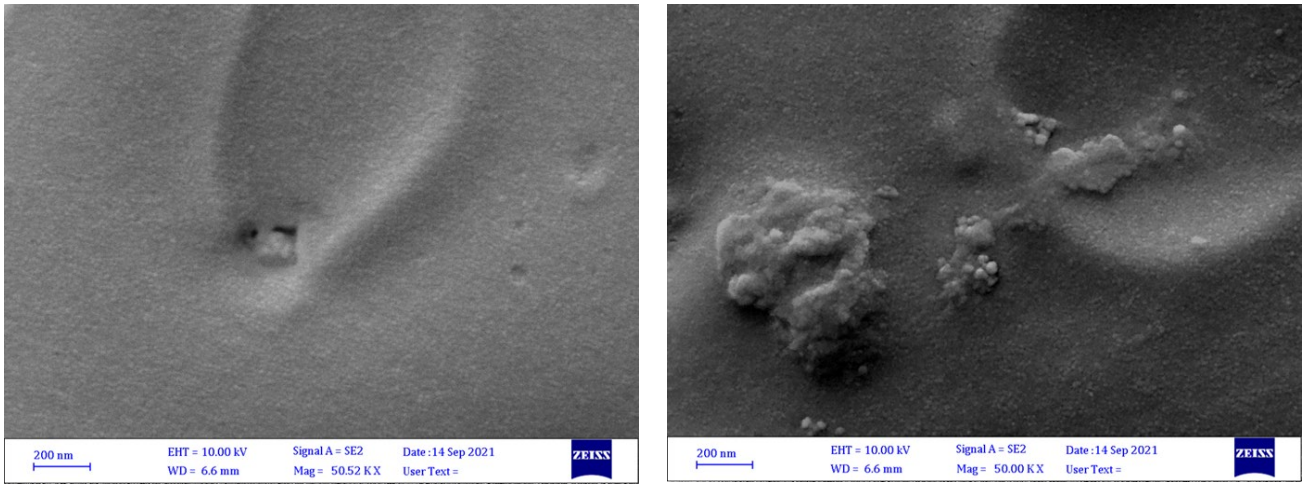


Fig. 2 *FTIR of modified gelatin*

The surface topography of prepared modified gelatin compound was scanned by SEM (Fig. 3). It is clear that, the roughness of modified gelatin surface increased according to the formation of gelatin polymer film [16,17]. The obtained surface morphologies provide visual confirmation of the successful crosslinking achieved through the utilization of ciprofloxacin. However, it is crucial to note that, at the highest concentration of gelatin, the Gel matrix exhibited significant heterogeneity. This heterogeneity is evident from the considerable variation observed in the distribution of pore sizes. Such variations can be attributed to the insufficient availability of ciprofloxacin to facilitate complete crosslinking reactions.

The surface roughness of modified gelatin is shown in Fig. 4 and Fig. 5. There is a significant difference that can be seen in surface morphologies, these differences attributed to the solvent evaporation, polymer solubility, film thickness, and surface composition. Furthermore, the composition of the modified gelatin film contains crosslinking agents and/or amended functional groups, which can affect the surface roughness. By understanding the surface morphology of modified gelatin, we can optimize the modification process and further amended of gelatin properties for specific applications. Such as drug release, mechanical strength, and bioactivity [20,21].



(a) **(b)**

Fig. 3 *SEM images of (a) gelatin and (b) Modified gelatin*

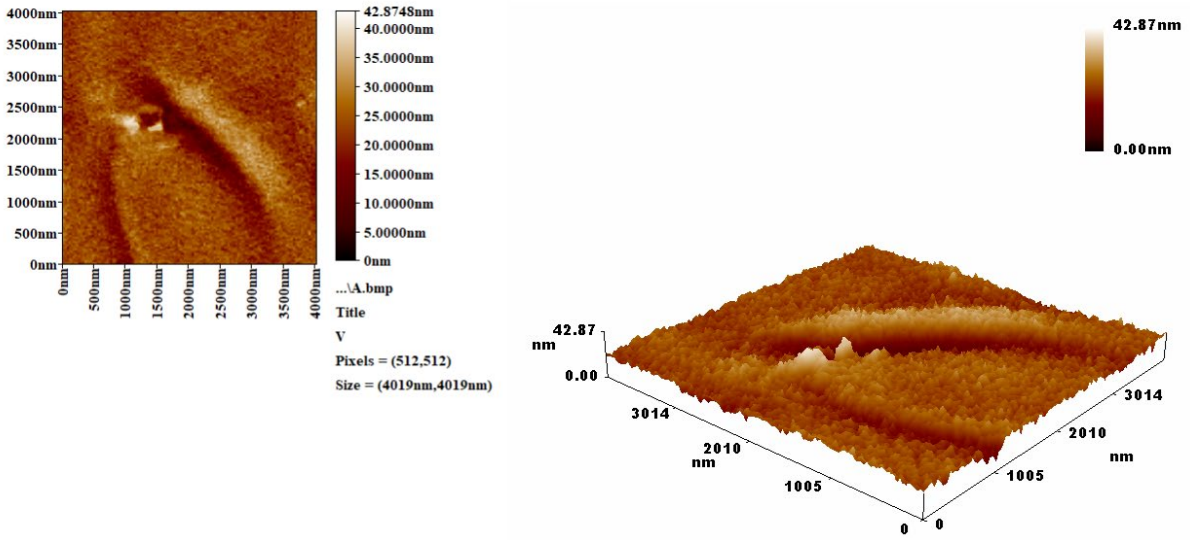


Fig. 4 *AFM image of gelatin*

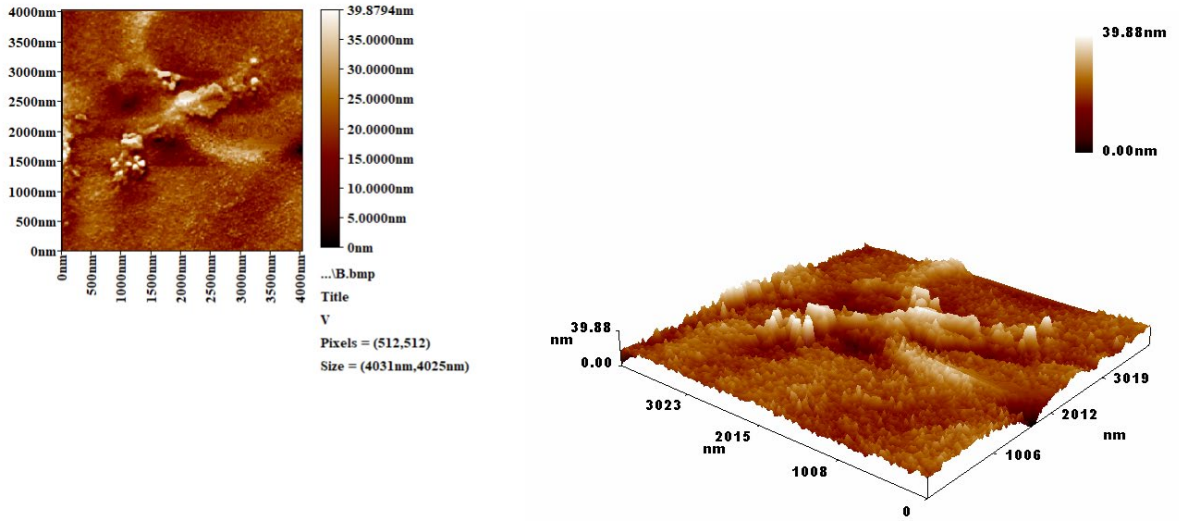


Fig. 5 *AFM images of modified gelatin*

4. Conclusion

Gelatin is generally used in biomedical and industrial fields; therefore, gelatin was improved through the reaction with ciprofloxacin to be used in food packaging as one of the more important industrial applications. The synthesized natural polymer was confirmed by FTIR, SEM and AFM. Furthermore, study needed to be tested the biological and chemical compatibility of the new polymer film with the food packaging criteria. Consequently, the results provided a valued visions into the essential properties of the modified gelatin, assisting the optimization for particular applications.

Acknowledgement

This research is made possible through monetary assistance by Department of Chemical Industries, Institute of Technology-Baghdad Middle Technical University, Baghdad, Iraq and Department of Chemistry, College of Science, Al-Nahrain University, Baghdad, Iraq.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Dina S. Ahmed and Emad Yousif;* ***data collection:*** *Dina S. Ahmed and Emad Yousif;* ***analysis and interpretation of results:*** *Dina S. Ahmed and Emad Yousif;* ***draft manuscript preparation:*** *Dina S. Ahmed, Ahmed Al-Ani and Mustafa Abdalla. All authors reviewed the results and approved the final version of the manuscript.*

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