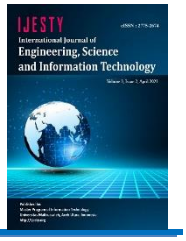
International Journal of Engineering, Science & InformationTechnology (IJESTY)
Volume 3, No. 2 (2023) pp. 66-71
ISSN 2775-2674 (online)
Website: http://ijesty.org/index.php/ijesty
DOI: https://doi.org/10.52088/ijesty.v1i4.447
Research Paper, Short Communication, Review, Technical Paper



Synthesis and Characterization of Chitosan-Pectin-Citric Acid-Based Hydrogels for Biomedical Applications (Primary Wound Dressings)

Suryati*, Rizka Mulyawan, Sulhatun, Muhammad, Nikmat Wanda

Department of Chemical Engineering, Faculty of Engineering, Universitas Malikussaleh, Aceh, Indonesia

**Corresponding author Email: suryati@unimal.ac.id*

Manuscript received 30 May 2023; revised 2 June 2023; accepted 14 June 2023. Date of publication 14 June 2023

Abstract

This study aims to analyze the processing of chitosan-pectin biocomposite hydrogel with the addition of citric acid to improve the quality of the biocomposite for primary wound dressing applications. The method is printing the biopolymer solution in a glass mold, then drying at 50oC. Chitosan 90.2% DD and pectin dissolved in 1% acetic acid with a ratio (w/w) of 50:50. The two ingredients were mixed using a magnetic stirrer at room temperature for 30 minutes until completely dissolved, then added citric acid crosslinking agent with various concentrations of 2,4, 6,8,10 (%). The test results for the characteristics of the chitosan-pectin-acid biocomposite Citrate obtained the best thickness in the composition variation (50:50:8) of 0.31 mm. The analysis results of the best absorption of the chitosan-pectin-citric acid biocomposite on the composition variation (50:50:6) were 185%. In the swelling analysis of the chitosan-pectin-citric acid biocomposite, the variation in composition (50:50:10) was 403%. The tensile strength test results of the chitosan-pectin-citric acid biocomposite decreased with the addition of citric acid, the best obtained was 20.76 MPa, and the best elongation was 76.0%. Test results for the functional group of the chitosan-pectin-CaCl2 biocomposite for the presence of O-H, C-H, N-H bonds in the fact of O-H, C-H, N-H bonds at a wavelength of 4000-2500 cm-1, C=O, C=N, C=C at a wavelength of 2000 -1500, and the specific absorption of the chitosan-pectin-citric acid biocomposite 400-1400 cm-1 indicates that the resulting membrane tends to be polar, hydrophilic and environmentally friendly because it can be degraded. Based on the expected test results, it was shown that the chitosan-pectin-CaCl2 biocomposite has the potential to be applied as an ideal primary wound dressing for wound healing and protection.

Keywords: *Hydrogel, Chitosan, Pectin, Citric Acid, Primary Wound Dressing.*

1. Introduction

Hydrogel is a sheet-shaped wound dressing that can absorb wound fluids and has good stability at acidic pH, so it can be used for treating burns. Current wound dressing techniques apply modern wound care methods by maintaining the isolation of the wound environment in a closed and moist state. Several types of wound dressings have been developed, one of which is in the form of a hydrogel [1] [2] [3] [4]**.**
A good wound dressing has several characteristics, such as biocompatibility, low toxicity, anti-bacterial activity, and good chemical stability to accelerate healing. However, no single material can achieve all these conditions. For this reason, much research has been carried out to find the ideal biocomposite for a primary wound dressing. Chitosan has been studied and has the ability in terms of quality, hemostasis, anti-bacterial activity, biocompatibility, and biodegradability. Recently, chitosan has been widely developed for biomedical applications. Chitosan has been widely used as a wound dressing in hydrogel form. However, to get better results, chitosan has been created by mixing various polymers such as alginate, gelatin, pectin, and others [5] [6] [7].
The research results conducted by [8] and [1] in 2020 demonstrated that hydrogels made with pectin and gelatin were successfully joined using citric acid as a crosslinking agent. This was proven by the hydrogel characterization tests that had been carried out, that citric acid could improve the limited mechanical characteristics of hydrogels. Based on the characterization test results, 4% pectin-gelatin-citric acid (CA4) hydrogel has the ideal features compared to other hydrogel variables. The tensile strength, elongation, and swelling values of the CA4 hydrogel were 0.05 MPa, 200%, and 890%, respectively [1]**.**

Pectin is a natural polysaccharide and biopolymer found in the primary cell walls of plant tissues. Therefore, citrus fruits, apples, pears, and other fruits extract pectin. The type of pectin contained in the fruit is differentiated based on the level of ripeness of the fruit. Pectin is proto-pectin in immature fruit [9] [10] [11]. As the fruit ripens, the proto-pectin turns into pectin. The pectin enzymes convert it to pectic

acid if it becomes overripe. However, proto-pectin can be converted into pectin by heating it with water. Therefore, the pectin extract is more critical when fully ripe fruit. Pectin has been evaluated for its toxicity by JECFA (FAO/WHO Joint Committee of Experts on Food Additives). Pectin, according to JECFA, is distinguished by standard analytical methods for experimentation and trade. Pectin is derived from linear polysaccharides, such as chains containing hundreds to thousands of saccharide units with an average molecular weight ranging from 50 to 150 kDa. Pectin is a heteropolysaccharide consisting of three main building subunits, namely homogalacturonan (HG), rhamnogalacturonan-I (RG-I), and rhamnogalacturonan-II (RG-II). The ratio of esterified galacturonic acid groups to total galacturonic acid groups, known as the degree of esterification (DE), significantly affects pectin's characteristics, particularly its solubility and gel formation. Pectin has been reported to have various bioactive properties, including anti-cancer, anti-inflammatory, anti-oxidant, anti-diabetic, anti-cholesterol, anti-tumor, chemopreventive activity, and others. Many researchers are interested in investigating and using pectin as a medicinal product [12]. This study aimed to obtain a hydrogel product based on chitosan-pectin, which can be used as a biomedical material (primary wound dressing) and can replace the use of synthetic flavorings which are non-biodegradable, not anti-bacterial, have low absorption and swelling capabilities and have good mechanical properties [10] [13].

2. Literature Review

Citric Acid is an organic acid compound with the chemical formula C6H8O7 [2] [14]. Besides being used as a sour taste enhancer in food and soft drinks, this compound is a good and natural preservative. This substance can also be an environmentally friendly cleaning agent and an anti-oxidant. At room temperature, citric acid is in the form of a white crystalline powder. The crystalline powder may be in the anhydrous (water-free) form or the monohydrate form containing one molecule of water for each citric acid molecule [15]. Chemically, citric acid is like other carboxylic acids. When heated above 175 °C, citric acid decomposes, releasing carbon dioxide and water [16] [17].

3. Method

3.1. Research Tools and Materials

The equipment used to conduct this research consisted of glassware, glass molds (7cmx7cmx5mm), a vacuum oven, and a centrifuge (Hettich type EBA 20). Equipment for biocomposite characterization that will be carried out are functional group tests using Fourier-Transformed Infra-Red Spectroscopy (FTIR), thickness tests (screw micrometers), swelling tests, absorption tests, tensile strength, and strain tests. The materials used in this study were chitosan (shrimp shells), pectin (DSM Nutritional Products Ltd), glacial acetic acid (Analytical grade 0.5M, VWR, Int.), Aqua bides, citric acid, plastic seals, filter paper.

3.2. Research Stages

3.2.1. Chitosan-Pectin Biocomposite Processing

The chitosan solution was poured into the biocomposite with various volume ratios and stirred homogeneously to obtain chitosan-pectin blending [18]. Variation of crosslinking agents: Citric acid %v: 2,4,6,8,10. The solution was injected into the glass mold and left at room temperature until solidified for 48 hours. The biocomposite was then dried for 48 hours at 50oC. The biocomposite was released from the mold slowly, after which it was washed with distilled water every 10 minutes five times and dried again before being stored in an airtight place and ready to be tested [19] [20].

4. Results and Discussion

4.1. Thickness Of The Chitosan-Pectin-Citric Acid Biocomposite

The membrane thickness test was carried out to determine the effect of variations in adding material composition to the biocomposite. The thickness test was carried out using a screw micrometer with an accuracy of 0.01 mm. Measurements were made by taking measurements of the thickness of the biocomposite from different sides, namely the top, middle, and bottom sides. The graph of the relationship between additive concentration and thickness can be seen in Figure 1.

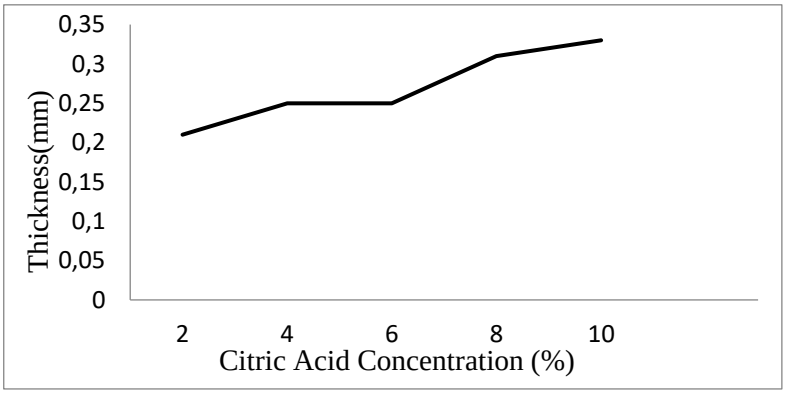


Fig 1. Graph of the relationship between the average thickness of the chitosan-pectin biocomposite against variation citric acid concentration (%)

From the thickness test, the thinnest biocomposite was the addition of 2% citric acid, which was 0.21 mm. Biocomposite thickness measurement can be used as quality control for wound dressing applications, namely having a thin thickness but not easily torn. Biocomposites with 2% and 4% citric acid additives are physically more homogeneous, lighter, clear, transparent, robust, flexible, and dry. The chitosan-pectin-citric acid biocomposite is in the form of thick sheets, not transparent, yellowish, slightly elastic, and non-porous. The addition of

6% citric acid was the most homogeneous, yellowish, strong, pliable, and dry composition. Adding citric acid on top of 6% of the biocomposite sheet makes it wrinkled and thicker. The form of these two types of biocomposites is ideal for wound dressings because they adhere to the wound surface. Wound dressings that are stiff, brittle, and dry on the surface cause discomfort to patients because an ideal wound dressing must have elastic properties and be easy and comfortable when used or removed.

4.2. The Effect Of Adding Additives On The Absorption Test Of The Chitosan-Pectin-Citric Acid Biocomposite

The absorption ability test aims to determine the absorption capacity of the chitosan-pectin-citric acid biocomposite. The liquid used in the absorption test was a solution of PBS (Phosphate Buffer Saline) with a pH of 7.3 for 12 hours. Before immersing the wound dressing, its dryness was weighed, after which it was soaked in a PBS solution, which was obtained by dissolving one PBS tablet in 100 ml of distilled water. After drinking, the wound dressing is weighed again to get the final weight.

Figure 2 shows that the percentage of water absorption decreased with increasing concentrations of citric acid in the biocomposite. At a citric acid concentration of 2%, the absorption rate is 133% and increases with increasing citric acid concentration in the biocomposite.

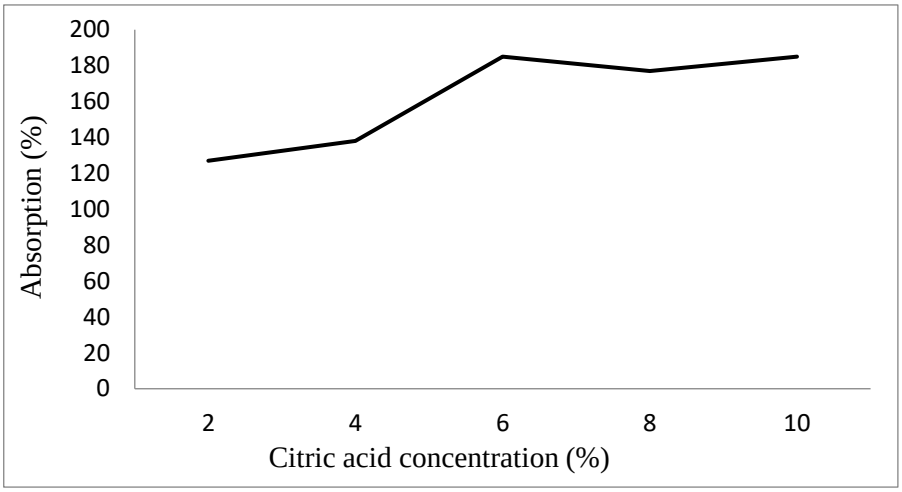


Fig 2. Graph of the relationship between the absorption capacity of the chitosan-pectin biocomposite against variation citric acid concentration (%)

The research results show that the percentage of biocomposite produced is excellent because all samples can absorb above 100%. The existence of a high membrane absorption capacity of the wound dressing causes the wound exudate content to decrease to reduce the possibility of infection in the wound. The research results show that the % absorption of the resulting biocomposite membrane is very good because all samples can absorb above 100%.

4.3. Effect Of Adding Additives On The Swelling Properties Of The Chitosan-Pectin-Citric Acid Biocomposite

Swelling analysis was conducted to determine the amount of fluid absorbed so that the wound dressing expands. Streaming analysis was carried out by weighing the dry biocomposite, soaking it in NaCl liquid used as a body fluid analog for 4 hours, and then considering the wet weight of the chitosan-pectin-citric acid biocomposite. The effect of the percent citric acid composition on the % swelling can be seen in Figure 3. The swelling test of the chitosan-pectin biocomposite with the addition of 200% citric acid concentration increases with increasing citric acid concentration.

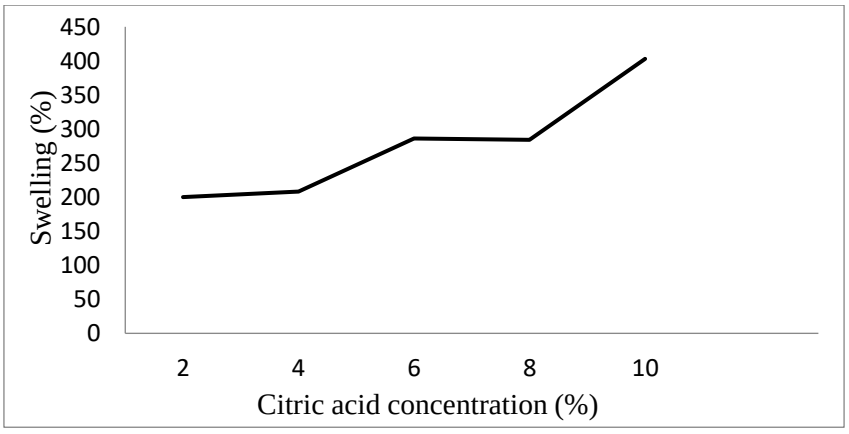


Fig 3. Graph of the relationship between the swelling power of the chitosan-pectin biocomposite against variations in citric acid concentration (%)

The highest percent swelling of the chitosan-pectin citric acid biocomposite was 403%. Biocomposites with more excellent citric acid composition can hold liquids well. A high swelling ratio indicates that the hydrogel material is suitable for application as a wound dressing. Besides that the chemical structure of the hydrogel constituent polymers influences the swelling character of the hydrogel. Hydrogels containing hydrophilic groups (OH) have good swelling characteristics compared to hydrogels containing hydrophobic groups. Increasing the citric acid concentration causes the biocomposite's polar nature [1].

4.4. Effect Of Adding Additives On The Mechanical Properties Of Chitosan-Pectin-Citric Acid Biocomposite

Tensile strength is the maximum tensile strength that the composite can achieve before tearing. The effect of the addition of citric acid on the tensile strength of the biocomposite can be seen in Figure 4.

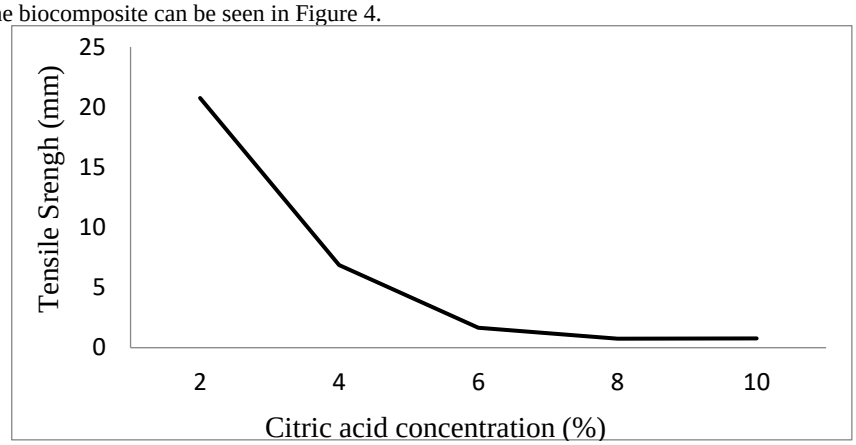


Fig 4. Graph of tensile strength relationship of chitosan-pectin biocomposite to variation citric acid concentration (%)

The desired results in this study were to find chitosan-pectin compositions and additives that met the absorption ability test but also had good mechanical properties. Table 3 shows that the biocomposite's tensile strength decreased with adding 2 grams of citric acid. The tensile strength of the biocomposite decreased from 20.76 to 0.77 MPa. This happens because citric acid can cause the polymer matrix to be expected to produce lower intermolecular tensile strength so that the stretchability of the film also decreases and the tensile strength will decrease due to the reduction of intermolecular interactions of protein chains so that the film matrix that is formed will be smaller.

4.5 Addition Of Additives To The Elongating Properties Of The Chitosan-Pectin-Citric Acid Biocomposite

Elongation shows the maximum change in length of the biocomposite when the tensile force is applied until the biocomposite breaks. The elongation value indicates the film's ability to elongate. This property depends on the type of film-forming material, which will affect the cohesive properties of the structure.

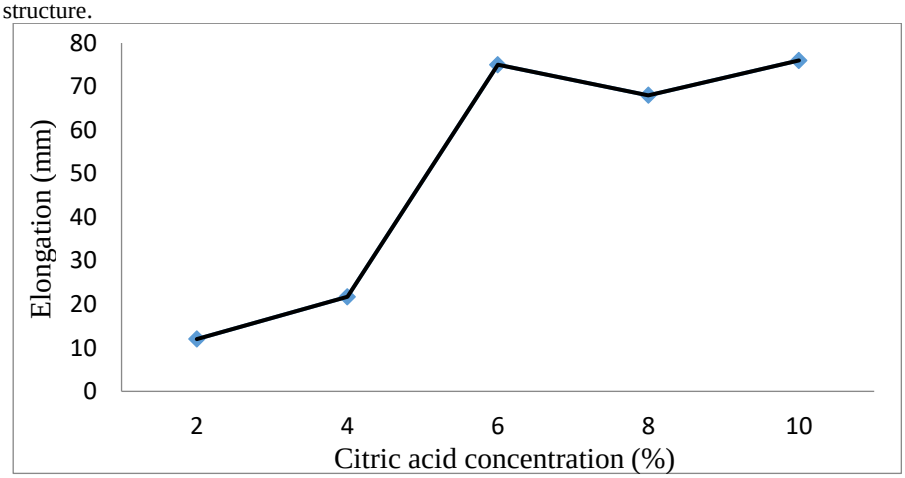


Fig 5. Graph of tensile strength relationship of chitosan-pectin biocomposite to variations in citric acid concentration (%)

In Figure 5, the elongation value increases as more CaCl2 is added, where at the addition of 2% citric acid, the percentage of elongation is 12.0%, and at the addition of citric acid up to 10%, the elongation value is 76.0%. This is because the added citric acid can reduce inter-molecular so that the cohesive force of the bioplastic structure increases.

Based on standard medical materials have an elongation between 17% and 207%, while the tensile strength values are between 1 Mpa and 27 MPa. Based on these criteria, the strength and elongation value of the results of this study is included in the standard medical criteria. Based on these criteria, the citric acid chitosan-pectin biocomposite is still included in traditional medical measures. Meanwhile, for the chitosan-citric acid pectin biocomposite above, the use of 2 g meets standard medical criteria.

4.6. The Effect Of Adding Citric Acid Additives To The Functional Groups Of Biocomposites

From Figure 6 below, there is a shift in peaks and the addition of new mountains, indicating an interaction between chitosan-pectin and citric acid.

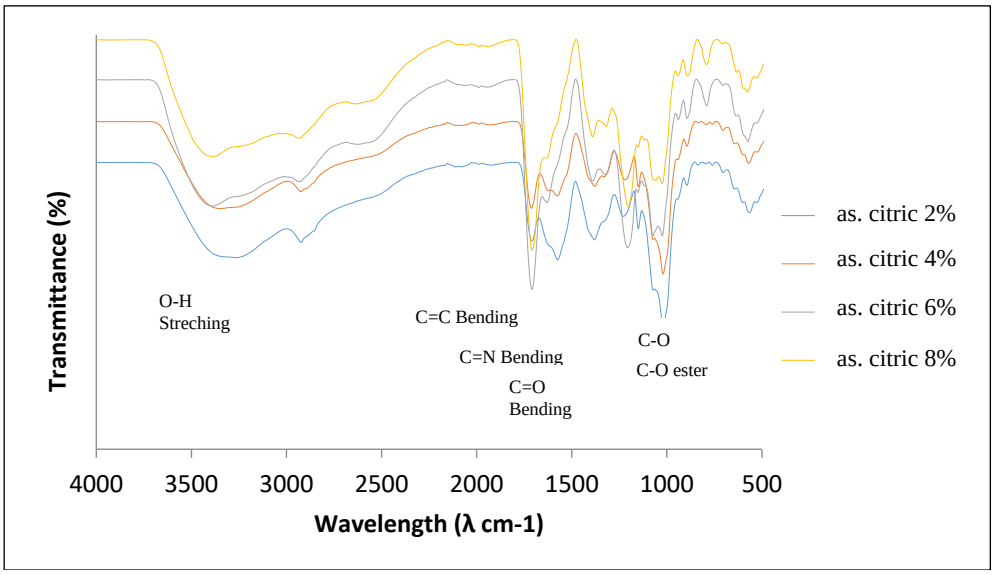


Fig 6. Spectrum graph of chitosan-pectin biocomposite with citric acid additives

According to Dompeipen, the specific functional groups of chitosan are hydroxyl groups (OH) and amide (NH2) in the infrared absorption spectrum range of 3200–3500 cm-1 and 1660–1500 cm-1 (Nurinayatullah 2022). Typical absorption of pectin can be seen at wave numbers 1732.42 cm-1 and 1637.36 cm-1 which are C=O bond vibrations. The absorption band at 1051 – 1074 cm-1 indicates the presence of C–O vibrations and C–H bending vibrations in the FT-IR spectral field, showing that pectin contains OH groups, aliphatic C-H, carbonyl C=O and C-O (Ningsih AS, 2019).

In Figure 6, the ratio of chitosan-pectin-citric acid has peaked at several wavelengths, namely: 3264-3386 cm-1, which is a broad absorption of O-H alcohols, N-H amines, and amides. The addition of citric acid concentration in the hydrogel causes the bond intensity of these two groups to increase. Strong absorption at wave numbers 1573-1630 cm-1 is the amide carbonyl group C=O, imine C=N, and alkene C=C with increasing citric acid concentration. The C-H alkane group is found at wave numbers 1379-1390 cm-1. The C-O groups of alcohols, ethers, carboxylic acids, and esters are present in wave numbers 1018-1059 cm-1. The C-H alkene groups are present in wave numbers 891-894 cm-1. The C-Cl group is present in wave numbers 704-791 cm-1. The C-O groups of alcohols, ethers, carboxylic acids, and esters are present in wave numbers 1708-1711 cm-1. The alkene group C=H is found at wave numbers 894-891 cm-1.

Figure 6 shows a shift in peaks and the addition of new mounts, indicating an interaction between chitosan-pectin-citric acid. The presence of O-H, C-H, and N-H bonds at a wavelength of 4000-2500cm-1, C=O, C=N, C=C at a wavelength of 2000-1500, and the specific absorption of chitosan-pectin-citric acid biocomposite 400-1400 cm-1.

5. Conclusion

The conclusion in this study was the thickness test, biocomposite made from chitosan-pectin-citric acid, which was the best in the composition variation (50ml:50ml:8ml) of 0.31 mm. For the results in the absorption analysis, the best biocomposite made from chitosan-pectin-citric acid was obtained at 185% with variations in composition (50:50:8). In the swelling analysis, the best chitosan-pectin-citric acid biocomposite was 403% in various documents (50:50:10). The tensile strength of the biocomposite decreased with the addition of 2% and 10% citric acid of 20.76 MPa decreased to 0.77 MPa. The elongation properties increased as more citric acid was added, whereas with the addition of 2% citric acid, the elongation percentage was 12.0%. With the addition of up to 10% citric acid, the elongation value was 76.0%. (Standard medical criteria for elongation between 17% and 207%). The presence of O-H, C-H, and N-H bonds at a wavelength of 4000-2500 cm-1, C=O, C=N, C=C at a wavelength of 2000-1500, and the specific absorption of chitosan-pectin-citric acid biocomposite 400-1400 cm- 1.

References

[1] F. Muhammad Tarmidzi, I. Kresna Maharsih, T. Raihatul Jannah, and C. Sari Wahyuni, “Sintesis Hidrogel Pektin-Gelatin dengan Penambahan Ekstrak Kulit Buah Naga Sebagai Kandidat Pembalut Luka Bakar,” vol. 2020, no. 1, pp. 53–60, 2020.

[2] F. M. Tarmidzi, I. K. Maharsih, T. R. Jannah, and C. S. Wahyuni, “Sintesis Hidrogel Pektin – Gelatin dengan Penambahan Ekstrak Kulit Buah Naga Sebagai Kandidat Pembalut Luka Bakar,” *J. Tek. Kim. dan Lingkung.*, vol. 4, no. 1, p. 53, 2020, doi: 10.33795/jtkl.v4i1.128.

[3] R. A. Sheldon, "Enzyme immobilization: The quest for optimum performance," *Advanced Synthesis and Catalysis*. 2007, doi: 10.1002/adsc.200700082.

[4] M. F. Firmansyah and H. Z. Maulana, "Empirical Study of E-Learning on Financial Literacy and Lifestyle : A Millenial Urban Generations Cased Study," *Int. J. Eng. Sci. Inf. Technol.*, vol. 1, no. 3, pp. 75–81, 2021.

[5] J. Su, J. Li, J. Liang, K. Zhang, and J. Li, "Hydrogel preparation methods and biomaterials for wound dressing," *Life*, vol. 11, no. 10, pp. 1–22, 2021, doi: 10.3390/life11101016.

[6] D. Noviana *et al.*, "In vivo study of hydroxyapatite-chitosan and hydroxyapatite-tricalcium phosphate bone graft in sheep's bone as animal model," 2011, doi: 10.1109/ICICI-BME.2011.6108636.

[7] L. Ghasemi-Mobarakeh, D. Kolahreez, S. Ramakrishna, and D. Williams, "Key terminology in biomaterials and biocompatibility," *Current Opinion in Biomedical Engineering*, vol. 10. 2019, doi: 10.1016/j.cobme.2019.02.004.

[8] M.-S. Kim, P. Chandika, and Jung Won-Kyo, "Recent advances of pectin-based biomedical application potential of marine pectin," *J . Mar . Biosci. Biotechnol.*, vol. 13, no. 1, pp. 28–47, 2021.
[9] P. Barbaro *et al.*, "Safety Data Sheet," *J. Am. Chem. Soc.*, 2009, doi: 10.1021/jm701266y.
[10] A. Teleman *et al.*, "Altered Growth and Cell Walls in a of Arabidopsis Fucose-Deficient Mutant," *Plant Physiol.*, 2012, doi: 10.1104/pp.110.160051.
[11] C. Lara-Espinoza, E. Carvajal-Millán, R. Balandrán-Quintana, Y. López-Franco, and A. Rascón-Chu, "Pectin and pectin-based composite materials: Beyond food texture," *Molecules*, vol. 23, no. 4. 2018, doi: 10.3390/molecules23040942.
[12] L. Hiremath, S. Vantagodi, S. S. Hegde, G. S. Anitha, and E. Keshamma, "Development and characterization of pectin and chitosan based biocomposite material for bio-medical application," vol. 10, pp. 9–12, 2021.
[13] A. Kaczmarska, P. M. Pieczywek, J. Cybulska, and A. Zdunek, "Structure and functionality of Rhamnogalacturonan I in the cell wall and in solution: A review," *Carbohydrate Polymers*, vol. 278. 2022, doi: 10.1016/j.carbpol.2021.118909.
[14] N. Paramita, A. Soufyan, B. Irawan, and M. Damiyanti, "Effect of gum Arabic (Acacia Senegal) topical gel application on demineralized enamel hardness," in *Journal of Physics: Conference Series*, 2018, vol. 1073, no. 3, doi: 10.1088/1742-6596/1073/3/032016.
[15] S. Spinella *et al.*, "Concurrent Cellulose Hydrolysis and Esterification to Prepare a Surface-Modified Cellulose Nanocrystal Decorated with Carboxylic Acid Moieties," *ACS Sustain. Chem. Eng.*, vol. 4, no. 3, pp. 1538–1550, 2016, doi: 10.1021/acssuschemeng.5b01489.
[16] B. S. Börekçi, G. Kaban, and M. Kaya, "Citric acid production of yeasts: An overview," *Eurobiotech Journal*, vol. 5, no. 2. 2021, doi: 10.2478/ebtj-2021-0012.
[17] C. S. V. Ramirez, F. Temelli, and M. D. A. Saldaña, "Carboxylic acid-catalyzed hydrolysis of rhamnogalacturonan in subcritical water media," *J. Supercrit. Fluids*, vol. 175, 2021, doi: 10.1016/j.supflu.2021.105268.
[18] F.-C. Tsai *et al.*, "Adsorptive removal of methyl orange from aqueous solution with crosslinking chitosan microspheres," *J. Water Process Eng.*, vol. 1, pp. 2–7, 2014.
[19] M. A. Smirnov *et al.*, "Self-healing films based on chitosan containing citric acid/choline chloride deep eutectic solvent," *Polym. Test.*, vol. 97, 2021, doi: 10.1016/j.polymertesting.2021.107156.
[20] S. Jeong, H. J. Jeon, K. J. Jang, S. Park, H. S. Choi, and J. H. Chung, "Injectable thermosensitive chitosan solution with b-glycerophosphate as an optimal submucosal fluid cushion for endoscopic submucosal dissection," *Polymers (Basel).*, vol. 13, no. 11, 2021, doi: 10.3390/polym13111696.