Preliminary Studies on Making Antibacterial Latex-Chitosan Film Composite

Sudirman Habibie, Mohamad Hamzah, Herri Susanto, Muslim E Harahap

Received: August 27, 2020; Accepted: September 10, 2020; Published: September 30, 2020
*Corresponding author: Sudirman Habibie, Center of Technology for Material, Agency for the Assessment and Application of Technology, E-mail: shabibie54@gmail.com

Abstract

Research on the application of chitosan as an edible film and coating has been developed. However, its hydrophilic nature causes edible films and coatings to be sensitive to air humidity so that they have a low moisture barrier. In addition, chitosan also has low thermal stability. This research combines natural rubber which is hydrophobic with relatively high thermal stability with chitosan which is antibacterial. The composite film between latex and chitosan was made by using the pour solution method. The occurrence of composites between latex and chitosan was proven from the results of FTIR and SEM characterization. The results of TGA characterization showed that the latex film (sample L1) had the highest thermal stability and the latex-chitosan composite (sample L1C3) had the lowest thermal stability. In the antibacterial test, it was concluded that the latex-chitosan film composite did not have bacteriocidal properties which was thought to be caused by the amine group in chitosan which could not diffuse on the media because it had formed a composite with latex. Based on the results of characterization and tests that have been carried out, it is concluded that the latex-chitosan composite film has thermal stability, optimal morphology in oxygen exchange with carbon dioxide, and has unmissable bacteriostatic properties. Bacteria, liquid droplets, and moisturizers are samples of the L1C1 formula which is a sample with a 1% chitosan content.

Keywords: Latex; Chitosan; Chitosan Latex Composite Film; Solution Casting; Thermal Stability; Antibacterial

Introduction

Indonesia as a country with the largest rubber plantations in the world has enormous potential to develop a natural rubber-based industry. According to Ditjenbun 2015, [1] the total area of rubber plantations in Indonesia in 2014 was around 3,606 million ha with a production of 3,153 million tonnes, so that Indonesia can be said to be one of the largest natural rubber producing countries in the world.

Natural rubber sap is a yellowish-white liquid obtained from rubber trees (Havea brasiliensis) and is a polyisoprene macro molecule with cis-1,4-polyisoprene molecular structure configuration and has high molecular chain flexibility. Natural rubber latex products generally have several disadvantages such as other polymers which are susceptible to oxidation or degradation due to heat and low mechanical strength, especially after being formed into thin films. Therefore, in the processing, it is necessary to add fillers in the form of inorganic fillers and organic fillers.

Rubber latex (latex) is a white liquid derived from natural rubber which is obtained by carving a knife into the layer of rubber tree bark (tapping). The rubber sap from the stems is collected in a bowl, so that the latex remains liquid to be used as raw material for making concentrated latex. It needs to be added to the ammonia solution when tapping. The sap content of rubber trees after tapping ranges from 20% -45%, non-rubber components around 5% and the rest is water [2]. Latex is a natural polymer of isoprene (cis 1,4-polyisoprene) with a molecular weight of 100,000 to 1,000,000 [3]. Latex is a suspension of rubber particles that must be coagulated to obtain rubber [4].

Garden liquid latex can be concentrated through a bleaching process (cream latex) and via centrifuged latex. Garden sap when concentrated is separated into rubber phase, serum and lower fraction [5]. The centrifugation process and the use of surfactants in the concentration process of natural latex will reduce the non-rubber fraction [6,7]. Increasing the concentration of latex derived from natural rubber can be done by developing a downstream industry made from latex [8]. The development of the concentrated latex-based industry can be improved by studying the physical and chemical properties of the latex to be engineered, including composite films as packaging for various industries such as the food industry, pharmaceutical industry, and so on.

Indonesia is a maritime country with abundant marine resources. This makes Indonesia one of the exporters of peeled shrimp, which is estimated to produce waste in the form of shrimp shells and heads weighing up to 50-60% of the weight of whole shrimp, causing waste to the environment [9]. Based on data from the Central Bureau of Statistics, Indonesia exported 2,646,101 tons of shrimp in 2016. From the shrimp waste, a biopolymer called chitosan can be produced, which process technology has been developed in the last 20 decades [10].

Chitosan is a polysaccharide, which is available in the second
largest amount after cellulose which can be derived from shrimp and/or crab shells [11]. Chitosan has a very reactive amine functional group, namely antibacterial and the production process is inexpensive [12]. Chitosan is a natural polycationic polymer that is biodegradable, biocompatible, safe, non-toxic, can form a thin layer, and has adsorption ability [13]. Chitosan has high thermal stability [14]. From its availability and properties, chitosan has the potential to be used as filler for latex films.

Based on the description above, this research will create and characterize a latex-chitosan composite film which is expected to produce a material with high thermal stability and antibacterial properties. In previous research by the author, latex-chitosan composites were used as nitrification inhibitors in agricultural fertilizer products [15].

Research Methodology

Materials Used

Materials used in this study are fresh latex with Dry Content (DC) of 60% and chitosan derived from Biotech Surindo Indramayu. Acetic acid used to dissolve the chitosan was 1% acetic acid solution.

Raw Material Preparation

The composition of chitosan used was 1%, 2% and 3%. Prepare a chitosan solution with a mass content per volume of 1%, 2%, and 3%. To make a solution of chitosan weigh chitosan powder as much as 1%, 2% and 3% (g/L) respectively dissolved in a 500 ml 1% (v/v) acetic acid solution using a magnetic stirrer at 700 rpm for +2 hours ago filter and put into a closed bottle. The 1%, 2%, and 3% chitosan solutions that have been made are left for at least 24 hours before use with the aim of removing air bubbles. After the chitosan solution was ready for use, the raw material was characterized.

Likewise, the latex solution was prepared with 2 concentrations of solution in different plates respectively 5% and 10% and diluted with distilled water to reach the desired volume. After that, mixing is carried out between the latex solution that has been ready and the chitosan solution that has been prepared in advance. (Figure 1) shows the solution of latex and chitosan powder.

Making latex-chitosan film composites

The latex-chitosan composite film was made by dispersing latex into chitosan solution. Before the experiment is carried out, it is necessary to know how to mix latex with an alkaline pH with chitosan solution with an acidic pH. This is done to prevent clumping when mixing is done directly between the latex and the chitosan acetate solution. For this reason, before mixing, the latex is diluted with distilled water to reduce the pH of the latex solution and increase the pH of the chitosan solution, then the diluted latex solution is poured gradually into the chitosan solution, so that it reaches a neutral pH mixture and does not clot.

Modifying variables are variables that are varied in the study in order to obtain optimal results. The variables that changed in this study were the mass/volume levels of 1%, 2% and 3% chitosan solution. While the concentration of latex used is 5% and 10% per volume.

Weigh the latex and add distilled water according to the formula that has been determined into a 50 ml beaker. In a different container, 500 ml beaker glass was put into a solution of chitosan and distilled water according to the predetermined formula. Stir in a spatula, mix latex with distilled water. Stir the chitosan solution with distilled water using a magnetic stirrer at a speed of 500 rpm for 1 minute. After 1 minute, the latex solution was dispersed into the chitosan solution using a magnetic stirrer at a speed of 500 rpm. The time for pouring the latex solution into the chitosan solution is 1 minute. Stirring is stopped when all the latex solution has been poured and visually the latex and chitosan solutions have been evenly mixed.

Figure 1: Latex (a) and Chitosan Powder (b)
The procedure was repeated for 1%, 2% and 3% chitosan concentrations respectively so that 3 portions of 50 ml each were obtained and poured into the mica container. So there will be 6 different dry masses for each formula \((L_1C_1, L_1C_2, L_1C_3, L_2C_1, L_2C_2, L_2C_3)\). For the L_0 sample formula that did not contain chitosan solution, the latex that had been added with distilled water was stirred with a spatula then weighed to determine the wet mass then poured into the mica. After that, samples L1C1, L1C2, L1C3, L2C1, L2C2, and L2C3 were dried in an oven at 55°C for 48 hours.

The dry formula is removed from the oven and removed from the mica. Place the sample in a plastic strip and store in a desiccator for 24 hours. Weigh the dry mass of the obtained chitosan-latex composite film. The sample is ready to be characterized.

**Results and Discussion**

**Raw Material Characterization**

Characterization of dry rubber content aims to determine the quality of the latex used. The higher the dry rubber content, the better the rubber quality. Based on the SOP of latex research in the PTM-BPPT laboratory, the dry rubber content was obtained by dividing the dry mass by the wet mass of latex multiplied by 100%. The wet latex mass is the mass of latex before drying. Dry latex mass is the mass of latex after drying in an oven at 100%. The wet formula is removed from the oven and put in a desiccator for 24 hours. In this characterization, three repetitions (triple) were carried out to determine the Dry Rubber Content (DRC). From the results of drying latex, the average dry rubber content (DRC) was + 62.36% as shown in table 1.

<table>
<thead>
<tr>
<th>Sample</th>
<th>DRC (%)</th>
<th>DRC Rata-Rata (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>62.1891</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>62.2926</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>62.6083</td>
<td>62.3633</td>
</tr>
</tbody>
</table>

The dry rubber content of latex used was 62.36% with a viscosity at 27°C 62.2679 cP, see table 2. The latex used had an acidity (pH) of 10 and a density of 1.0691. According to Loo (1980), [16] the minimum quality standard for DRC-based latex is 60-62%, while the maximum viscosity is at 25°C 50 cP so that the latex used is in accordance with existing DRC standards but not according to viscosity standards.

In Table 2, it can be seen that the degree of acidity (pH) of the chitosan solution with a concentration of 1-3% is 4 and the density for each 1% chitosan solution is 1.1484, 2% chitosan solution is 1.1510 and the chitosan solution is 3% is 1.1513. However, the significant difference is the viscosity, for the 1% chitosan solution the viscosity is 50.9163, the chitosan solution has 2% viscosity 1031.7296 and the viscosity 3% chitosan solution is 5388.6136.

As is known, chitosan has certain properties that are not shared by other types of biopolymers, such as anti-bacterial properties [17,18], chelate [19] and a unique molecular structure because it is similar to cellulose but contains an amine group in each glucosamine monomer. Several research results indicate that the properties of chitosan will be very beneficial for several industries such as the medical industry (medicine), beauty, toothpaste, textiles and others. For this reason, it is hoped that the addition of chitosan to the latex will provide composite properties that are beneficial to other industries.

**Characterization of Latex-Chitosan Composite Film Samples**

**FTIR**

The FTIR test results are in the form of wavelength absorption. The wavelength absorption is interpreted according to the table and steps from Pavia (2009) [20] in the book Introduction to Spectroscopy.

The results of FTIR spectra of latex (L) before mixing with chitosan solution can be seen in Figure 2. In the figure, it is known that there is a carbonyl group (C = O) with an absorption wavelength of 1663.01 cm\(^{-1}\) and is strengthened by the presence of a hydroxyl (OH) bond with absorption wavelength of 3299.55 cm\(^{-1}\) to 2914.25 cm\(^{-1}\) it is suspected that there are carboxylic acid groups. The carboxylic acid that was detected was suspected as a sign of protein content in latex. The cis isomer in latex is indicated by the presence of absorption waves of 2851.92 cm\(^{-1}\) and 2724.96 cm\(^{-1}\) which are aldehyde (C-H) bonds. Whereas in the fingerprint area there is absorption at wavelengths of 1444.75 cm\(^{-1}\) and 1375.24 cm\(^{-1}\) which is thought to be a hydrocarbon bond as the main bond in natural rubber.

In Figure 3, you can see the results of latex FTIR spectra (5%) after mixing with 1%, 2%, and 3% chitosan solutions. When we observe the FTIR spectra results of L_1C_0, L_1C_1, L_1C_2, and L_1C_3 they are not much different, especially in the region of the main functional groups.

To ensure the effect of chitosan on the spectra of latex-chitosan composites, the samples with greater chitosan levels were tested by FTIR first (sample L1C3). The FTIR results of the composite film (L1C3) showed the presence of a carbonyl group (C = O) which was detected at the absorption wavelength between 1663.20 cm\(^{-1}\) to 1662.28 cm\(^{-1}\). There is also a hydroxyl (O-H) bond that is absorbed at a wavelength of 2960.64 cm\(^{-1}\) so that it is suspected that there is a carboxylic acid group is present. Then the absorption at a wavelength of 2851.63 cm\(^{-1}\) is thought to be the cis isomer of latex which is an aldehyde (C-H) bond. In the fingerprint area it is suspected that there is a bending hydrocarbon bond in the presence of absorption at a wavelength of 1375.31
used is 3%, because chitosan above 3% can increase the viscosity of the solution, making it difficult to react between chitosan and latex. In Figure 5, the FTIR graph of Latex is coincided with the FTIR graph of the composite film.

From the results of this FTIR characterization, it can be concluded that latex-chitosan composites have occurred. This is indicated by the difference in the spectra of the latex film before the addition of chitosan (L) to the spectrum of the L₃C₃ composite film where chitosan has been added specifically to the fingerprint area (Figure 4), because the hydrocarbon bonds are bent with absorption at a wavelength of 1375.31 cm⁻¹ to 1444.63 cm⁻¹. To strengthen this, we will also discuss SEM-EDS characterization related to the formation of latex-chitosan composites. To obtain a comparison of the results, the FTIR spectra of Latex-chitosan composites (sample L₂C₃), where the latex content is greater than the L₁C₃ sample, see Figure 5.

After overlapping the FTIR graph of latex sample (L₁), chitosan sample (C) and latex-chitosan composite sample (L₁C₃), see Figure 5, the chitosan spectra curve is less visible when compared to the L₁ (latex) curve, this is possible because the ratio of the amount of chitosan in the composite film was very small (± 1% -3%). For this reason, FTIR for L₁ samples (10% Latex concentration) was not tested considering that with a concentration of 5% latex (L₁) alone the effect of chitosan on the FTIR graph did not look significant. Meanwhile, the highest concentration of chitosan

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**Figure 2:** FTIR Spectra of Latex (L₁)

**Figure 3:** FTIR spectra of the latex-chitosan sample composite (L₁C₃) cm⁻¹ to 1444.63 cm⁻¹. The group appears due to a mixture of latex and chitosan solution as a constituent. Chitosan 1%, 2%, and 3% have the same FTIR spectra. Chitosan is thought to have amine stretching bonds (N-H) at the absorption area of 3244.15 cm⁻¹ to 3217.31 cm⁻¹ (Figure 4). The presence of absorption medium at a wavelength of 1543.73 cm⁻¹ and 1544.19 cm⁻¹ indicates that chitosan is thought to have an aromatic ring. In the absorption area of 1405.89 cm⁻¹ to 1404.43 cm⁻¹, chitosan is thought to have a hydrocarbon chain.

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**Figure 4:** FTIR Spectra of Sample Chitosan (C)

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**Figure 5:** FTIR Spectra of Latex, Chitosan and Composites (Sample L₁C₃)
Thermogravimetry Analysis (TGA)

Analysis of the thermal properties of the latex-chitosan composite film was carried out using TGA. In Figure 6 it can be seen that the TGA curve of pure chitosan occurs in 3 stages of decomposition. In the first stage, chitosan began to decrease in mass at a temperature of 38°C after heating for 2.1 minutes, this is likely to begin to evaporate the water content and stop the mass decline at 191°C after heating for 16 minutes with the remaining mass after heating (residue) 17.874 mg. In other words there was a mass reduction of 11.6%. This indicates the evaporation of water from chitosan. In stage 2, chitosan begins to decompose at 203°C after heating for 17.1 minutes and stops decreasing its mass at 402°C after heating for 35.6 minutes with the remaining mass after heating (residue) 11,324 mg. In other words there was a mass reduction of 43.995%. At this stage the breakdown of the chitosan polymer has occurred during heating, which causes a mass decrease. Then the temperature was continued to 760°C, the third decomposition occurred, where the chitosan began to decompose further at + 588°C after heating for 53.5 minutes and stopping the mass decline at + 750°C after heating for 70.1 minutes with the remaining mass after heating (residue) of 12,935 mg. In other words there is a mass reduction of 36.026%.

In Figure 7 you can see the TGA curve of the crude latex (sample L). It can be explained that solid latex contains no water or so little that there is no visible reduction in mass weight during preheating to about 280°C. Latex begins to decompose at + 289°C after heating for 25 minutes. Latex stopped experiencing mass decline at + 499°C after heating for 45 minutes with the sample mass (residue) after heating only 0.16 mg. In other words, there was a mass decrease of 99.166%. When compared with the TGA curve of chitosan and latex-chitosan composites, it can be seen that chitosan has a small effect on the formation of residues at temperatures above 450°C. This is most likely due to the chitosan content in the small composite sample or perhaps because of the reaction between latex and chitosan which dominates the properties of latex.

The latex film began to decompose at +289°C, while the latex-chitosan composite film began to decompose at 223°C, resulting in a decrease in the decomposition time of the composite film around 50°C. This is probably due to the water content factor in chitosan as described in Figure 5 which contains a Relative Humidity (RH) of 11.6%, so that at a temperature of 223°C, there appears to be a decrease in weight earlier than latex film. This perception may be debatable because prior to characterization...
with TGA, the latex film and chitosan-latex composite film were dried for approximately 30 hours using an oven at a temperature of 55°C, so that the impurity content of the composite film, such as water, acetic acid, and ammonia can be said to be low or absent from samples.

It can be concluded that the higher the chitosan content in the composite film, the faster the composite film will undergo decomposition, which is indicated by the decreasing initial decomposition temperature. This is because the more chitosan is contained in the film, the more amine groups the film will have. According to Satrio, Pramono, and Purnawan (2012) [21] the amine group will decompose at a temperature of 250°C. From this statement, chitosan which contains amine groups has a lower decomposition temperature than natural rubber.

In line with the statement of Rao and Johns (2008) [22], chitosan has lower heat stability than natural rubber. In addition, Rao and Johns explained that in the temperature range 200-300°C there was a decrease in the mass of volatile substances and amino groups. In contrast, at a temperature of 300°C cis-1,4-isoprene, the main constituent of natural rubber is still stable and undergoes mass reduction at 350°C.

**SEM-EDS TEST**

The SEM-EDS results were used to see the shape and size (morphology) of the latex film before and after mixing with 1%, 2%, and 3% chitosan solutions and to strengthen the suspicion of latex-chitosan composites. In Figure 9 it can be seen that the morphology of the chitosan polymer with an uneven surface tends to be wavy, while in Figure 10 it can be seen the morphology of the latex formula L1, namely the latex film without a mixture of chitosan solution. The morphology of latex as a matrix of chitosan-latex composite film has a flat surface (Figure 11).

When the observations were only on sample L₃C₁ (1% chitosan composite) and sample L₃C₄, to do if chitosan will affect the morphology and / or properties of the latex-chitosan composite?

In this study, SEM results from sample C (chitosan 1%) with sample L₃C₄ (chitosan 3%). In Figures 11 and 12, it can be seen that the morphology of the latex-chitosan composite film with chitosan content of 1% and 3% as measured by three different magnifications, namely 5000x, 10,000x, and 20,000x. The mixture of latex and chitosan showed a tendency that the higher the chitosan content, the more wavy the surface of the chitosan composite film formed. With the tendency to form a wavy surface on the latex-chitosan composite film, it can be neglected that chitosan as a filler has been mixed with latex as a matrix. According to Surdia and Saito (1999) [23] a composite is a combination of two or more than three materials which have a number of properties that cannot be possessed by each component. From this understanding, the understanding of the latex-chitosan composite in the film is felt to have been fulfilled. In this study, the differences in the properties of latex before and after being composited with chitosan can be seen from the thermal analysis using TGA.

From the SEM-EDS results, it can be seen that the pore size formed on the surface of the chitosan-latex composite film so that each particle can or cannot pass through the film. Overall, the morphology of the latex-chitosan composite film at 5000x magnification tends to be wavy and the pores appear to vary in number for each sample, at 10,000x magnification it can be seen that the surface of the film has scratches where at 20,000x the scratches appear more obvious.

In the sampling area, sample L₃C₃ (composite film with 1% chitosan content) had a higher pore number than sample L₃C₄ (composite film with 3% chitosan content) and sample L (latex film). The pore diameter L₃C₃ and L₃C₄ are estimated to be the same, namely 0.2 µm. In sample L₃C₃ the pore diameter was estimated at 0.3 µm. The composites L₃C₃ and L₃C₄ were estimated to have an average stroke length and width of 1 µm and 0.1 µm.

The particle size according to the engineering toolbox, liquid droplets measuring 0.5-5 µm, humidifier 0.9-3 µm, bacteria 0.3-60 µm, oxygen 0.0005 µm, and carbon dioxide 0.00065 µm. This shows that the L₃C₃ and L films are considered impassable by bacteria. On the other hand, all films, L₃C₃, L₃C₄ and L and Latex, are considered impassable to liquid droplets and humidifiers. But in all films, gas and carbon dioxide exchange can occur. This suggests that the resulting thin composite film can be used as a wound dressing to prevent bacteria and fluid from the wound, but still release evaporation. While the composite film (L₃C₃) has a large enough pore (0.3 µm) and latex film (L) although it has small pores (0.2 µm) but does not contain anti-bacterial, so it cannot be used for wound dressings.

According to the Ministry of Fisheries, Plantations and Livestock of Guyana (2004)[24] waxing on fruits and vegetables has several drawbacks, one of which is the potential for changes in the taste of the fruit and causing the skin to become damaged due to limitations. gas exchange between oxygen and carbon dioxide. In addition, the film used for food packaging must be able to prevent the mass transfer of water content from both inside and outside to the package so that the quality of the food in the package is maintained [25]. So from the results of morphological characterization using SEM-EDS, it can be concluded that the L₃C₃ composite film is more optimal in exchanging oxygen with carbon dioxide because it has more pores and cannot be passed through.
by bacteria, liquid droplets, and a humidifier.

**Antibacterial Test**

Antibacterial activity test was carried out to prove the antibacterial ability of chitosan in the latex-chitosan composite film layer against Escherichia coli bacteria. The antibacterial properties of chitosan can be classified as bacteriocidal or bacteriostatic. Bacteriocidal means that chitosan can kill bacteria while bacteriostatic means that chitosan inhibits bacterial growth without killing bacteria [26].

The selected test bacteria is Escherichia coli. These bacteria are bacteria that usually live in the digestive tract in animals and humans. Even so, the Escherichia coli bacteria are the most common bacteria found to cause diarrhea cases. One of the causes of diarrheal disease is food or drink that has been contaminated with uncontrolled amounts of Escherichia coli bacteria [27].

Chitosan has a higher inhibitory effect on Escherichia coli which is a Gram negative bacteria compared to Gram positive bacteria [28]. This is because chitosan has an amine functional group (-NH\(_2\)) which is positively reactive and highly reactive, so that it can bind to the bacterial cell wall which is relatively negatively charged. This bonding can occur at the electronegative site on the surface of the bacterial cell wall. In addition, amines also have a lone pair of electrons so that this group can attract Ca\(^{2+}\) minerals present in the bacterial cell wall by forming coordinate covalent bonds. Gram-negative bacteria with lipopolysaccharide in the outer layer have a negative pole which is very sensitive to chitosan [29]. According to Herliana (2010), [30] this interaction causes changes in the permeability of the bacterial cell wall which results in an imbalance of internal cell pressure and causes leakage of intracellular electrolytes, such as potassium. In addition, other low molecular weight proteins such as nucleic acids and glucose also leak out. The bacterial cell will eventually undergo lysis.

On the other hand, according to Liu et al. (2006), [31] chitosan with 90% deacetylation showed antibacterial activity up to 84% and chitosan-g-MAP showed antibacterial activity up to 95%. This indicates that the greater the deacetylation degree of chitosan, the greater the antibacterial ability it has. In other words, the inhibition (activity) of antibacterial compounds is influenced by the level and degree of deacetylation of chitosan.

Based on the results of the antibacterial activity test, in the latex-chitosan composite film samples, both L\(_1\)C\(_1\), L\(_1\)C\(_2\), and L\(_1\)C\(_3\) from two repetitions (duplo) there were no clear zones or resistance areas (Figure 12 and Figure 13), as well as latex samples (L) of the two repetitions (duplo) there is no visible zone or area of resistance (Figure 13). There were no clear zones or resistance areas showing that the latex-chitosan composite films L\(_1\)C\(_1\), L\(_1\)C\(_2\), and L\(_1\)C\(_3\) and L did not have bacteriocidal properties. Positive control with chloramphenicol showed a clear zone or resistance area (Figure 12 and 13).

![Figure 10: Morphology of Sample Latex Film (L1). Magnification (a) 5000x (b) 10,000x (c) 20,000x](image1)

![Figure 11: Morphology of Composite Films (Sample L1C1). Magnification (a) 5000x (b) 10,000x (c) 20,000x](image2)
According to Panczyk et al (2015), [32] although clear zones were not formed on the chitosan film, the growth of bacteria, especially Escherichia coli in the medium was inhibited or the chitosan film was bacteriostatic. Panczyk further added that the bacteriostatic ability of the chitosan film was determined by the degree of deacetylation of the chitosan raw material. Chitosan with 90% deacetylation level can completely inhibit the growth of Gram negative bacteria Escherichia coli and Pseudomonas fluorescens as well as Gram positive bacteria Staphylococcus aureus and Listeria innocua in the media. Whereas in some Gram-positive bacteria cells with chitosan containing 73% deacetylation can grow.

Furthermore, in a study conducted by Darmanto et al in 2011 [33], the diffusion method so that the positive Staphylococcus
 aureus film plug against Gram bacteria from a mixture of gelatin and chitosan was found to form 0.1 cm clear zones in samples containing 4% gelatin and 3% chitosan. According to Davis and Stout (1971), [34] argued that the provisions of antibacterial strength, including resistance of 2 cm or more, means that the antibacterial ability is very strong, the resistance area of 1-2 cm shows strong. Antibacterial ability, resistance area 0.5-1 cm means moderate antibacterial ability, and resistance area 0.5 or less means that antibacterial ability is weak so that it is not optimal in inhibiting the number of bacterial growth.

The absence of clear zones in sample Latex [L] is considered reasonable because the sample does not contain chitosan. Meanwhile, the absence of clear zones in the latex-chitosan composite film samples L,C, L,C, and L,C indicates that the amine group in chitosan cannot diffuse into the media because it has a composite form with latex and is possible because the percentage of chitosan used is very small (1-3%), antibacterial activity is not seen.

Paying attention to the characterization of latex-chitosan composites, especially the results of the characterization of antibacterial properties, it can be said that latex-chitosan composites can be used as a dressing / wound covering that can function to protect bacterial growth in wounds, so as to accelerate wound healing due to bacteriostatic properties. The role of latex or rubber, which is designed like a thin film, is expected not to stick to wounds and to be easily opened or replaced. To get the results of latex-chitosan composites in the medical field, it is necessary to carry out a more detailed study, especially the latex-chitosan composite formula and optimal processing conditions. In addition, latex-chitosan composites can be used as food packaging to prevent bacterial contamination.

Conclusion

Based on the research conducted, it can be concluded that the manufacture of latex-chitosan composite film by pouring solution method produces new materials, namely composites in the form of films as evidenced by the results of FTIR and SEM-EDS characterization. The variation of the concentration of chitosan used 1%, 2%, and 3% (m/v) affected the morphology of the sample in SEM-EDS characterization and the thermal stability of the sample in the TGA characterization.

FTIR characterization showed differences in latex spectra before and after mixing with chitosan in the fingerprint area. TGA characterization showed that samples with higher chitosan composition had lower thermal stability. Meanwhile, SEM-EDS characterization showed that there was a tendency for more corrugation of the morphology of the latex-chitosan composite film, the chitosan concentration was higher than the chitosan-latex composite film at the lower chitosan concentration. From the results of these characterizations, the L,C formula is considered to have optimal thermal and morphological stability in the exchange of oxygen with carbon dioxide, cannot be passed by bacteria, liquid droplets, and a humidifier.

Based on the results of the antibacterial test against the Escherichia coli bacteria, all samples of the latex-chitosan composite film had no clear zone on the test media, so the film did not have bacteriocidal properties or killed bacteria. However, the latex-chitosan composite has the inherited bacteriostatic properties of chitosan, which inhibits the growth of bacteria without killing the bacteria. It is possible that latex-chitosan composites can be used as a wound covering film.

Suggestion

This research is an early stage research that produces new materials so that it needs a lot of refinement in further research. Further research is recommended to conduct research on several things such as: variations in the content of chitosan and latex which are more varied and their characterization, refining of raw materials, and testing the bacteriostatic properties of the film.

Acknowledgment

First of all thank you to the Director of the Material Technology Center, BPPT for the permission of this research to be conducted at the PTM Laboratory, and also thanks STMI Polytechnic for its trust in giving permission to the students to work on this research in the PTM Laboratory.

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