**Effect of acetic and citric acid solvent combination with cinnamon oil on quality of edible packaging from chitosan**

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**Abstract.** Chitosan is one of the fishery by-products, which is extracted from shrimp and crab carapace. Chitosan can be processed into edible packaging. The nature of chitosan edible packaging is depended on the type of solvent used while extraction. Acetic acid produces a strong coating with good barrier properties but less elastic, while citric acid produces an elastic layer but has relatively low barrier properties and weak coating. Cinnamon essential oil can inhibit bacterial growth. This study aimed to obtain the best proportion combination of acetic and citric acid solvents which can improve mechanical properties and permeability of the edible packaging, also determine the effect of cinnamon essential oil in inhibiting *Salmonella* and *S. aureus* bacteria. The experimental design used a completely randomized design (CRD), with solvent combination treatment in preliminary research initially followed by chitosan and cinnamon essential oil addition in the subsequent research. Data showed that the best edible packaging properties were obtained from a combination of acetic and citric acid (2:2) with 30.67 MPa tensile strength, 65.35% elongation, 0.0422 mm thickness, and moisture permeability 3.02x10^{-10} g.m.m^{-2}.s^{-1}.pa^{-1}. The concentration of 1.5 g of chitosan with 1.5% cinnamon essential oil can produce an antibacterial with 10.15 mm inhibition zone diameter in *Salmonella* sp. and 9.53 mm in *Staphylococcus aureus*

1. **Introduction**

Food products are never separated from the packaging. The function of food packaging is other than to protect food from environmental contamination, it can also improve an attractive appearance. Food packaging is often made from a synthetic plastic. The use of synthetic plastics can cause environmental problems as pollution. Indonesia's waste piles are recorded at 37,490,381 tons per year with a percentage of plastic waste of 16.97% from total waste in Indonesia in 2021 [1]. Because synthetic plastic materials cannot be decomposed, therefore it is necessary to develop environmentally friendly plastics that can be biodegraded [2]. Edible packaging is one type of packaging that is environmentally friendly, can protect food products, and can be eaten immediately [3]. Coating food products with edible packaging can extend the shelf life and improve the quality of food products. Edible packaging based on its function is divided into edible coatings and edible films [4].

One of the potential ingredients in producing edible packaging is chitosan. Chitosan is a natural polysaccharide produced from the deacetylation process (removal of the COCH$_3$ group) from chitin [5]. The main source to produce chitosan is chitin where the raw material is available in quite abundant quantities in Indonesia, especially crab shells and shrimp shells [6]. In addition, the skeletons of other crustaceans such as lobsters, marine zooplankton exoskeletons, including corals, and jellyfish
also contain chitin or chitosan [7]. Chitosan is non-toxic, has biological activity, biocompatibility, biodegradability, and can be modified chemically and physically [8]. Chitosan also has the potential to be used as edible film [9].

Edible films from chitosan were extracted with various acid solvents, namely acetic acid, formic acid, lactic acid, propionic acid, malic acid, and citric acid [10]; [11]; [12]. The nature of chitosan edible packaging is depended on the type of solvent used while extraction. Acetic acid has advantages as a solvent for chitosan, produced strong film (high tensile strength), good barrier properties (low water vapor permeability), but less elastic (low elongation) [13]. Chitosan solvent with citrate acid produces an elastic film but has relatively low and not strong barrier properties [11].

Additional materials such as antimicrobials and antioxidants can be added to the edible film’s production. Spices in powder form and essential oils such as cinnamon, pepper, cloves, oregano, basil oil, lemongrass oil, garlic, and volatile oil components can be added to edible films as antimicrobials [14]. Cinnamon contains essential oils, tannins, saponins, and flavonoids have an antiseptic effects and work by damaging cell membranes [15]. Based on this, research is needed to determine the effect of the combination of citric and acetic acids in the production of edible films and the addition of cinnamon essential oil to the anti-bacterial activity of the edible film.

2. Method

2.1 Material

The materials used to produce edible films were shrimp carapace, benzoic acid, NaOH, HCl, 0.2 N acetic acid, concentrated H$_2$SO$_4$, citric acid with a technical grade, distilled water, and ethanol. The materials used for the antimicrobial analysis were cinnamon essential oil, filter paper, aluminum foil, PCA media, and NaCl.

2.2 Tool

The equipment used for making edible films includes a basin, electric stove, blender, analytical scale, 500 mL beaker glass, 30 X 30 cm$^2$ glass, 30 mL Erlenmeyer, dropper pipette, 10 mL volume pipette, 100 mL measuring cup, petri dish, desiccator, clamp, crucible tank, desiccator, suction cup, beaker, weighing bottle, porcelain exchanger, muffle, oven, statif, Kjedalh instrument, Kori brand micrometer, Lloyd instrument.

The equipment used to analyze the antimicrobial activity was 100 mL measuring cup, 250 mL beaker glass, 50 mL beaker glass, digital scale, oven, pH meter, spatula, hot plate, magnetic stirrer, serological pipette, volume pipette, petri dish, triangle, autoclave, test tube, Erlenmeyer 250 mL, test tube rack, tweezers, Bunsen, incubator, and suction bulb

2.3 Research methods

2.3.1 Preliminary research. In a preliminary study, chitosan was extracted using the Toan method [16]. 4% citric acid solution and 2% acetic acid will be combined with different volume ratios in dissolving chitosan. Treatment A, chitosan was dissolved in 1 L of 4% citric acid solution. Treatment B, chitosan was dissolved in 1 L solution of citric acid and acetic acid with a volume ratio of 1:3. Treatment C, chitosan was dissolved in 1 L solution of citric acid and acetic acid with a volume ratio of 2:2. Treatment D, chitosan was dissolved in 1 L solution of citric acid and acetic acid with a volume ratio of 3:1. Treatment E, chitosan was dissolved in 1 L solution of citric acid and acetic acid with a volume ratio of 4:0. The chitosan solution was then stirred for 30 minutes and filtered through a filter cloth. A total of 250 mL of chitosan solution was poured on a glass plate measuring 30 x 30 cm$^2$. Then dried in an oven at 27°C for 24 hours. The edible films obtained were stored in a container containing silica gel until the time for analysis.

2.3.2 Further research. The best quality of chitosan that extracted with different solvent volume ratios from preliminary research then added with cinnamon essential oil. Chitosan edible coating was made by means of chitosan with a concentration of 1.5 grams put in 50 ml of acetic acid and 50 ml of acetic
acid. Then stirred using a magnetic stirrer for one minute. Furthermore, 0.75 ml of glycerol, 0.2 ml of tween 80, and cinnamon essential oil with a concentration of 1.5% were added and stirred again for one minute [17]. The resulting edible coating was then tested for antibacterial. Antibacterial testing in this study used *Salmonella* sp. and *Staphylococcus aureus*. The parameters of the test carried out are quantitative parameters based on the area of the resulting inhibition zone. This aims to determine the effect of cinnamon essential oil in inhibiting *Salmonella* sp. and *Staphylococcus aureus*.

2.4 Research Design
The experimental design used in this study was a completely randomized design, with the proportion of acid mixing as a single factor (A, B, C, D, E) and was repeated three times. If the results of the analysis of variance at the 5% confidence interval show that there is an effect of the proportion of mixing acids on the edible film properties, then proceed with the Least Significant Difference Test (BNT) with a 5% confidence interval. The best treatment is determined by multiple attributes [18]. The research design can be seen in Table 1.

| Code | Chitosan (g) | Proportion of mixing volume of acid (1000 mL) |
|------|-------------|-----------------------------------------------|
| A (0:4) | 2 | Acetic acid 0 | Citric acid 4 |
| B (1:3) | 2 | 1 |
| C (2:2) | 2 | 2 |
| D (3:1) | 2 | 3 |
| E (4:0) | 2 | 4 |

Edible film with the best quality that extracted using a combination of acetic and citric acid then added with cinnamon essential oil with a ratio of 1.5 grams : 1.5%.

2.5 Test Parameters
The test parameters in this study include thickness, elongation, tensile strength, and water vapor permeability for preliminary research and antibacterial for further research.

2.5.1 Thickness [19]. Samples were measured using a Kori brand micrometer at five different places. Then the measurement results are averaged as the thickness of the edible film. The thickness is expressed in mm. Kori micrometer with an accuracy of 0.001.

2.5.2 Tensile strength [19]. Edible film tensile strength test was obtained from the graph of the percent elongation test using the same procedure. The test results on the graph are calculated by the formula:

\[
\text{Tensile strength} = \frac{\text{Compressive force (N)}}{\text{Surface area (mm}^2)} \times 100\%
\]

(1)

2.5.3 Elongation [19]. Using Lloyd Instruments first, the instrument is turned on for 30 minutes to warm up, the computer enters the Lloyd program, it is turned on, press the number 1 enter, then insert the diskette into drive B. The cursor is placed in the Installation enter. The cursor is placed in the machine control enter. After the connection between the machine and the computer is established, the standard instrument Lloyd program will appear on the screen. The cursor is placed on the break detector, turned on by pressing the plus sign (+). Then the cursor is placed above the auto-return, the auto return is activated if there is more than one sample with the same size. The cursor is placed at auto-zero and turned on so that between load and extension shows the number 0.0 at the time of testing. When the cursor is placed in the Cycle, when it is ON, it will display count : 1 for the tensile
test. The cursor is placed on the internal select extensometer meaning the computer will automatically record the distance travelled by the plunger or drag. The cursors are placed on the Y axis and X axis, so that the speed of the push or pull movement is recorded at the time of the test. The cursor is placed in inch speed (mm/min), width (sample width, mm), depth (sample thickness, mm). Gauge length (sample length, mm). Put towing accessories. Putting the sample in the towing accessories. Press F9 to go to the graphics screen. Pressing F7 for testing. After the test is complete press the letter S to save the data. The measurement results are in the form of a graph then the percent elongation calculation is carried out with the formula:

\[
\text{Elongation} = \frac{\Delta t \text{ (minute)} \times \text{test speed (mm/minute)}}{\text{film length (mm)}} \times 100%
\]  (2)

2.5.4 Water vapor permeability/WVTR [19]. The edible film was cut into a circle with a diameter of 4 cm. The cup is filled with 30 mL of saturated salt. The edible film was placed in the mouth of a circular cup with an inner diameter of 3 cm. The cup is placed in a desiccator containing silica gel. Then weighed after 24 hours. Weight changes indicate the rate of diffusion of water vapor through the edible film. The rate of transmission of water vapor and water vapor permeability can be calculated by the formula:

\[
WVTR = \frac{\Delta W}{A \times \Delta T}
\]  (3)

\[
WVP = \frac{WVTR \times x}{\Delta P}
\]  (4)

Information
WVTR : Water vapor transmission rate  
WVP : Water vapor permeability  
\(\Delta W\) : Weight change after 24 hours  
x : Edible film thickness  
A : Edible film wide area (m²)  
\(\Delta T\) : Time (24 Hours)  
\(\Delta P\) : Difference in water vapor pressure on the inside and outside of the cup (Pa)

2.5.5 Antibacterial. Antibacterial testing in this study used Salmonella sp. and Staphylococcus aureus bacteria. The parameters of the test carried out are quantitative parameters based on the area of the resulting inhibition zone. This aims to determine the effect of cinnamon essential oil in inhibiting Salmonella and S. aureus bacteria. The diameter of the inhibition zone according is the difference between the diameter of the clear area formed and the diameter of the borehole [20]. The diameter of the inhibition zone was calculated in millimeters (mm) using a caliper. Then the diameter of the inhibition zone can be categorized as its antibacterial power based on the classification of [21] as follows:

a. The diameter of the inhibition zone above 20 mm means that the inhibition is very strong  
b. Inhibition zone diameter 11 - 20 mm means strong inhibition  
c. Inhibition zone diameter 5 - 10 mm means moderate inhibition  
d. Inhibition zone diameter 0-4 mm means weak inhibition

3. Result and discussion
Based on the results of research conducted on the properties of the edible film from chitosan due to the mixing proportion of acetic and citric acid, the average values of thickness, tensile strength, elongation and water vapor permeability are presented in Table 2.
Table 2. Average properties of chitosan edible film

| Treatment (Acetic acid : Citric acid) | Physical properties | Permeability properties |
|-------------------------------------|---------------------|------------------------|
|                                     | Thickness (mm)      | Tensile strength (Mpa) | Elongation (%) | Water vapor permeability (g.m.m^-2.s^-1.pa^-1) |
| A (0:4)                             | 0.0437 ± 0.00100    | 6.19 ± 1.45            | 117.00 ± 10.08 | 3.90 x 10^-10 ± 4.68 x 10^-11 |
| B (1:3)                             | 0.0435 ± 0.00050    | 13.22 ± 2.62           | 83.42 ± 9.25   | 3.79 x 10^-10 ± 4.14 x 10^-11 |
| C (2:2)                             | 0.0422 ± 0.00126    | 30.67 ± 2.73           | 65.35 ± 5.64   | 3.02 x 10^-10 ± 3.22 x 10^-11 |
| D (3:1)                             | 0.0420 ± 0.00050    | 42.32 ± 3.26           | 18.07 ± 3.17   | 2.70 x 10^-10 ± 4.32 x 10^-11 |
| E (4:0)                             | 0.0415 ± 0.00087    | 43.59 ± 0.75           | 9.71 ± 2.32    | 2.29 x 10^-10 ± 3.39 x 10^-11 |

### 3.1 Thickness

The results showed that the average thickness of the chitosan edible film due to the proportion of acid mixing ranged from 0.0415-0.0437 mm. The results of statistical analysis showed that the proportion of acid mixing had a significant effect on the thickness of the chitosan edible film (P<0.05). The average elongation of chitosan edible film due to the proportion of acid mixing with different tests can be seen in Figure 1.

In Figure 1 it can be seen that there is a decrease in thickness with an increase in the proportion of acetic acid and a decrease in the proportion of citric acid. The highest thickness value was obtained in treatment A (acetic acid : citric acid 0:4) and the lowest thickness value was obtained in treatment E (acetic acid : citric acid 4:0).

In treatment A, the solvent used was entirely citric acid. Citric acid has the ability to form multiple salt bridges with the amino groups of chitosan. This causes the chitosan solution to undergo gel formation before the polymer molecules become straight and perfectly close during the drying process, so that the edible film is formed thick [22]. In treatment B (acetic acid : citric acid 1:3), C (acetic acid : citric acid 2:2), and D (acetic acid : citric acid 3:1), acetic acid results in a neater and more complete arrangement of polymer chains, because acetic acid does not form layered salt bridges like citric acid. This causes the chitosan edible film produced to be thinner as the proportion of acetic acid increases [23]. Treatment E obtained the thinnest edible film of chitosan, because acetic acid resulted in the polymer of chitosan being neatly and straightly arranged before forming a gel when drying the chitosan solution so that the resulting chitosan edible film was thinner [13].
Edible film which has a thickness of 0.0415-0.0437 mm is quite thin. Edible film which has a thickness of 0.201-0.583 mm was used as a wrapper for apples [24]. Chitosan edible film with a thickness of 0.047-0.059 mm was also used as an edible coating and wrapping material for meat [25].

### 3.2 Tensile Strength

The results showed that the average tensile strength of the chitosan edible film due to the proportion of acid mixing ranged from 6.19-43.59 Mpa. The results of statistical analysis showed that the proportion of acid mixing had a significant effect on the tensile strength of the chitosan edible film (P<0.05). The average tensile strength of chitosan edible film due to the proportion of acid mixing with different tests can be seen in Figure 2.

![Figure 2. Average tensile strength of chitosan edible film.](image)

In Figure 2 it can be seen that there is an increase in tensile strength with an increase in the proportion of acetic acid. The lowest value of tensile strength was obtained in treatment A (acetic acid:citric acid 0:4), while the highest value of tensile strength was obtained in treatment E (acetic acid : citric acid 4:0). Treatment C (acetic acid : citric acid 2:2) has a tensile strength value in the middle of all treatments.

In treatment A, where all the proton sources (H+) which bind to the amino groups of chitosan came from citric acid and produced chitosan edible films which had low tensile strength. This happens because the volume of ions (in this case related to molecular weight) of citric acid is greater so that it provides a distance between the amine group of the glucosamine chain and the carboxyl group of the acid, which makes the bond between the amine group and the carboxyl group unstable and produces edible film. which has low tensile strength. In treatment C the proportions of acetic and citric acids were comparable, it turned out that the tensile strength value of the edible film medium was obtained. This happens because the use of acetic and citric acid as solvents will form acetate and citrate ions, acetate ions react more easily with NH3+, so that the remaining NH3+ that has not captured ions will react with citric acid ions. So here it is seen that there is an increase in acetic acid, the tensile strength will increase even though it is not too high because it is still influenced by citric acid. Treatment D and E had the highest tensile strength. This is in accordance with the results of research, acetic acid will form an edible film of chitosan which has high tensile strength, which is due to the smaller volume of ions released from acetic acid [22].

Classification of edible films based on tensile strength by [26], edible films with strengths from 1 Mpa into the "bad" group, 1-10 Mpa in the "enough" group, 10-100 Mpa in the "good" group, greater than 100 Mpa group "very good". So treatment A belongs to the "enough" group, while groups B, C, D, E belong to the "good" group. If high tensile strength is not followed by high elongation, the edible film will be brittle when used [11]. The ideal edible film must have high tensile strength and high elongation [26]. Thus, the tensile strength of treatment C, 30.67 Mpa is considered good, although the
value is not the highest, this edible film is better because the elongation of the edible film is also relatively high, which is 65.35%. So that this edible film will be better seen from its mechanical properties.

3.3 Elongation

The results showed that the average elongation of the chitosan edible film due to the proportion of acid mixing ranged from 9.71-117.00%. The results of statistical analysis showed that the proportion of acid mixing had a very significant effect on the elongation of the chitosan edible film (P<0.01). The average elongation of chitosan edible film due to the proportion of acid mixing with different tests can be seen in Figure 3.

![Figure 3. Average elongation of chitosan edible film.](image-url)

In Figure 3 it can be seen that in general there is a decrease in elongation with an increase in the proportion of acetic acid. The lowest elongation value was obtained in treatment E (acetic acid : citric acid 4:0), while the highest elongation value was obtained in treatment A (acetic acid : citric acid 0:4). Treatment C (acetic acid : citric acid 2:2) had a medium tensile strength value.

In treatment A which has the highest elongation value, all proton sources that bind to the amine group of chitosan come from citric acid because the citrate ion volume (molecular weight) is larger, making the bond between the amine group and the carboxyl group of the acid unstable so that the polymer used produced has high elongation [22]. In treatment C the proportion of acetic acid was proportional to citric acid, it turned out that the elongation value of the medium edible film was obtained. This happens because the use of acetic and citric acids as solvents will form acetate and citrate ions. The acetate ion will easily react with NH3+ with chitosan polymer, while the remaining NH3+ which has not captured the ion will react with citric acid ion. The interaction of NH3+ with acetic acid ions will form a tighter bond which causes a decrease in the elongation of the edible film, while the interaction of NH3+ with citric acid ions will give a looser bond [23], this condition makes the elongation of the edible film not possible. too high and too low. Treatments D and E had relatively low elongation, the low elongation of chitosan edible films using acetic acid is due to the fact that the acetate ion has a large volume of ions. small, thus forming a higher bond density, so that the resulting edible film becomes stiff with low elongation [22],[23].

Grouping of edible films based on elongation by [26], edible films with small elongation of 1% into the "bad" group, 1-10% in the "enough" group, 10-100% in the "good" group, greater than 100 % group “very good”. So treatment A belongs to the "enough" group, while treatment B, C, D belongs to the "good" group, and treatment E belongs to the "very good" group. The high elongation value of the chitosan edible film in treatments A and B showed that the edible film produced was flexible, but the edible film was too soft because the flexibility was not followed by high tensile strength (Figure 2). Based on the elongation, this edible film belongs to the “very good” group, because the elongation value is more than 100% [26]. Treatments D and E which have relatively low elongation make this
edible film stiff, so it is brittle. Good edible films have high tensile strength and high elongation [27]. The elongation value of the chitosan edible film from treatment C was moderate, although the elongation value was not the highest, this edible film was better because the tensile strength of the edible film was also moderate.

3.4 Water vapor permeability /WVTR

The results showed that the average water vapor permeability of the chitosan edible film due to the proportion of mixing acid ranged from 2.29 x 10^{-10} to 3.90 x 10^{-10} g.m.m^{-2}.s^{-1}.pa^{-1}. The results of statistical analysis showed that the proportion of acid mixing had a very significant effect (P<0.01) on the water vapor permeability of the chitosan edible film. The average water vapor permeability of the edible film of chitosan due to the proportion of mixing acid with different tests can be seen in Figure 4.

![Figure 4. Average water vapor permeability of chitosan edible film.](image)

In Figure 4 it can be seen that treatment A (acetic acid: citric acid 0: 4) and B (acetic acid: citric acid 1:3) had the highest relative water vapor permeability, while treatment E (acetic acid: citric acid 4:0) has the lowest water vapor permeability value. Here it is seen that there is a decrease in water vapor permeability with a decrease in the proportion of citric acid and an increase in the proportion of acetic acid.

In treatments A and B, where the proportion of citric acid was greater than the proportion of acetic acid, a relatively high water vapor permeability was obtained. This happens because citric acid has a hydroxyl group instead of hydrogen, which is more hydrophilic [28]. Treatment D and E with the proportion of acetic acid greater than the proportion of citric acid, will obtain relatively low water vapor permeability. This happens because acetic acid does not have a hydroxyl group like citric acid, which causes the hydrophilic group to only come from the carboxyl acid group, so that the water vapor permeability of the chitosan edible film is lower. Treatment C with balanced proportions of acetic and citric acid obtained lower water vapor permeability than treatments A and B, but higher than treatments D and E. This is because in this treatment the presence of citric acid will contribute more hydrophilic groups than treatment D and E, but lower than treatments A and B which used more citric acid.

Classification of edible films based on water vapor permeability by [26] edible films with water vapor permeability greater than 116 x 10^{-9} gmm^{-2}.s^{-1}.pa^{-1} into the "hunt" group, 116 x 10^{-9} to 11.6 x 10^{-9} gmm^{-2}.s^{-1}.pa^{-1} into “enough” groups, 11.6 x 10^{-9} to 1.16 x 10^{-9} gmm^{-2}.s^{-1}.pa^{-1} into “good” group, less than 1.16 x 10^{-9} gmm^{-2}.s^{-1}.pa^{-1} into “very good” group. So all treatments belong to the "very good" group. Even though the water vapor permeability of all treatments was classified as "very good", treatments C, D and E actually had better protective properties than treatments A and B, because they had relatively lower water vapor permeability. According to [29], the lower the water vapor
permeability of the edible film, the lower the amount of water vapor coming out of the material. The water vapor permeability value which ranges from $2.29 \times 10^{-10}$ to $3.90 \times 10^{-10}$ gmm$^{-2}$.s$^{-1}$.pa$^{-1}$, indicates that the edible film of chitosan produced is suitable for use as an edible coating formula material to prevent loss of water vapor from pre-cooking meat products, where [25] used an edible film formula that has a water vapor permeability greater than $2.39 \times 10^{-8}$ gmm$^{-2}$.s$^{-1}$.pa$^{-1}$ as an edible coating material.

3.5 Antibacterial
The antibacterial activity test in this study used method to determine the diameter of the inhibition zone of chitosan edible coating with the addition of cinnamon essential oil against Salmonella sp. and Staphylococcus aureus bacteria. Based on the results of the study, inhibition zone it was found in media treated with chitosan and cinnamon essential oil (1.5 g : 1.5%). The picture of Inhibitory Zone Against Salmonella sp. and Staphylococcus aureus bacteria can be seen in Figure 5.

![Figure 5. Inhibitory Zone Against Bacteria a) Salmonella sp. and b) Staphylococcus aureus.](image)

The clear zone formed indicates that chitosan and cinnamon essential oil can inhibit bacterial growth. From the measurement of the bacterial inhibition zone, it was found that it was 10.15 mm for Salmonella bacteria and 9.53 mm for S. aureus bacteria. Based on the classification, the diameter of the inhibition zone is in the range of 5-10 mm, which means moderate inhibition [21]. Chitosan can be active and interact with cells, enzymes, or polymer matrices that are negatively charged and as an antibacterial agent [30]. Chitosan provides antibacterial activity against bacteria such as Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa and Salmonella paratyphi B [31]. Cinnamon bark essential oil can inhibit the growth of Bacillus subtilis, Escherichia coli, Staphylococcus aureus, and Pseudomonas aeruginosa [32].

4. Conclusion
a. The best treatment of chitosan edible film is treatment C (acetic acid: citric acid 2: 2) as the best treatment, which has a tensile strength of 30.67 Mpa, elongation of 65.35%, thickness of 0.0422 mm, and water vapor permeability. $3.02 \times 10^{-10}$ gmm$^{-2}$.s$^{-1}$.pa$^{-1}$.

b. From the measurement of the bacterial inhibition zone, it was obtained 10.15 mm in Salmonella sp. and 9.53 mm in Staphylococcus aureus bacteria. The diameter of the inhibition zone is in the range of 5-10 mm, which means moderate inhibition.

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