



## Eco-friendly Edible Film from Chicken Bone Waste and Tapioca Starch

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### Abstract

The manufacture of edible film from chicken bone gelatin incorporated with starch is essential for Indonesia, where most Muslims are. This is related to Shari'a law which requires Muslims to consume only halal food. Gelatin made from chicken bones is guaranteed to be halal. This study aimed to determine the process of extracting chicken bone waste with acid solvents, making the edible film, and the characterization of chicken bone edible film. This research started with extracting gelatin from chicken bone waste. The 5 g of extracted chicken bones were mixed with 40% w/v glycerol, starch (0, 5, 10, 15% w/v), and distilled water, then heated at 50°C. The mixture was printed in a petri dish (15 cm in diameter) and dried for 24 hours. The edible films were evaluated for physicochemical and mechanical properties, such as tensile strength, elongation, thickness, water resistance, WVTR, and degradation test. Edible film characterization used FTIR, SEM, XRD, and TGA. The optimum condition of the extraction procedure was obtained by using 5% HCl, which produces 8.22172% yield of gelatin with pH of 6.0, water content of 8%, and ash content of 0.945%. In the thickness test, the more significant the starch concentration added, the greater the thickness of the edible film produced. The edible film exhibited a decrease in tensile strength and an increase in elongation along with increasing starch concentration. The results of the WVTR test were only starch concentrations of 0 and 15% that meet the standards, while all concentrations in the water resistance did. The results of FTIR chicken bones with variations in starch and the addition of glycerol as a plasticizer have functional groups N-H, O-H, C-O, C=O, C-H, C-N. Edible films without the addition of starch were utterly degraded within 30 days.

### 1. Introduction

One of the packaging materials often used is plastic; its usage has also contributed much waste that is difficult to decompose. Increased public awareness of health and environmental issues triggers an increase in demand for biodegradable packaging that can ensure the safety of food products. The edible film is a thin layer that coats food that is fit for consumption and can be degraded by microorganisms [1].

The essential ingredients utilized for edible films production are hydrocolloids, lipids (waxes, acylglycerols, or fatty acids), and composites. Several

hydrocolloids are commonly used, such as protein compounds, cellulose derivatives, alginates, pectins, starches, and other polysaccharides. Meanwhile, lipids and hydrocolloids were combined to form a composite [2].

The potential of chicken bones as main material for gelatin needs to be studied further, considering that the material is abundant and not many have used it. Chicken bones have more than 80% protein; therefore, boiler chicken bones can be used as an alternative raw material for halal gelatin manufacturing. Besides that, it can also reduce the buildup of boiler chicken bone waste that has not been processed further [3].

According to [4], the type of bone commonly used in the manufacture of gelatin is compact bone because it can be extracted more than once to produce more gelatin. In addition, compact bone is easier to separate from the surrounding tissue than hollow bone.

The addition of 20–30% gelatin and 10–30% plasticizer can improve the flexibility of edible films. The plasticizer used can be glycerin, sorbitol, palmitic acid, soy protein isolate, or other composite materials. The utilization of gelatin can be used as an edible film that protects food products from damage and as a raw material for coatings on pharmaceutical/drug products [5]. Starch-based films have a good ability to protect the product against oxygen, carbon dioxide, and oil and increase the unity of the product structure. Starch has high amylose content (35.34 %) [6]. Tapioca starch has several advantages, such as its water-soluble properties, can be used as a substitute for plastic polymers because it is economical, renewable, and provides good physical characteristics [7].

Country chicken feet gelatin using 3% acetic acid concentration with 24 hours curing time resulted in good quality gelatin, yield value of 12.31%, gel strength of 64.16 g/Bloom, the viscosity of 5.50 cP, 89.90% of protein, and 7.31% of water content. In other words, the gelatin obtained under the conditions of the extraction procedure can be used as a meat packaging material which functions to maintain weight and reduce the number of microorganisms that contaminate the surface of the meat [8]. Therefore, this study will utilize broiler chicken bone waste incorporated with tapioca starch as an environmentally friendly edible film.

## 2. Methodology

### 2.1. Tools and Materials

The tools and materials used in this study were digital scales (Shimadzu Compration Japan), hotplate (IKA Hs-7), water bath (MEMMERT), oven (Memmert UN55), fume hood (Merck), knife, spatula, cutting mat, beaker glass, watch glass, stirring rod, mortar, Universal tensile testing machine (Tensile and Elongation), FTIR (Prestige-21 Shimadzu), SEM (FEI: INSPECT-S50), XRD, TGA. The materials used were HCl (analytical grade), glycerol, distilled water, tapioca starch, and boiler chicken bones collected from restaurants in Pekanbaru, Indonesia.

### 2.2. Gelatin Extraction from Chicken Bones Waste

The chicken bones were washed, soaked in distilled water, then heated at 80°C for 1 hour to remove the fat adhering to the bones. The bones were cut into small pieces, soaked in HCl, and neutralized using distilled water. After neutral pH was achieved, the ossein (collagen) of the chicken bones was heated in a water bath at 90°C for 7 hours. The sample was filtered and dried in an oven at 50°C for 24 hours. The chicken bone extract was tested for water, ash, pH, and yield.

### 2.3. Edible Films Production

Films were prepared by mixing tapioca starch, chicken bone gelatin, and glycerol as a plasticizer with

some variations. Four variations of films with different starch ratios were: A (0%), B (5%), C (10%), D (15%). Glycerol (4.0%, v/w total solids) plasticized the film formation. Tapioca flour was dissolved in distilled water and heated with magnetic stirring in a glass beaker at 75°C until completely dissolved. Chicken bone gelatin powder was dissolved in distilled water at 45°C. After that, the gelatin solution was added into dissolved tapioca flour and then heated at 45°C with continuously stirring for 30 minutes, followed by the addition of plasticizer with constant stirring for 30 minutes. The solution was poured into petri dishes and dried in an oven at 50°C for 24 hours. The dry film obtained was stored in a tight container for further analysis.

### 2.4. Analysis

The yield, proximate characteristics (moisture and ash content), and the physicochemical properties of chicken bone gelatin were investigated. The characterization of the edible film used FTIR, SEM, XRD, and TGA. The physical and mechanical properties of the edible film were observed, such as the tensile strength, elongation, thickness, water vapor transmission, water-resistance test, and test degradation. Physicochemical characteristics included pH.

#### 2.4.1. Yield

The yield was obtained from the dry gelatin weight compared to the weight of the fresh material (washed bones). The yield was calculated based on the following equation:

$$\text{Yield (\%)} = \frac{\text{weight of gelatin}}{\text{theoretical yield}} \times 100\%$$

#### 2.4.2. Proximate Characterization of Moisture Content

The porcelain dish was dried at 105°C for 1 hour, cooled, and weighed. A 0.5 g gelatin was placed on the weighed crucible and heated at 105°C for 24 hours. Gelatin was cooled in the desiccator and weighed to constant weight. The moisture content is calculated as follow:

$$\text{Moisture content (\%)} = \frac{W_a - W_b}{W} \times 100\%$$

where  $W_a$  is the weight of container and initial sample (gram),  $W_b$  is the weight of container and sample after drying (gram);  $W$  is sample weight (gram).

#### 2.4.3. Ash Content

The sample was calcinated at 600°C, the dry crucible's weight and the weight of the sample were known. The evaporation process was carried out for 6 hours. After that, the sample was cooled and weighed. Ash content is calculated by the following equation:

$$\% \text{ Ash} = \frac{W_2 - W_1}{W} \times 100\%$$

where  $W_1$  is the weight of crucible (gram);  $W_2$  is the weight of crucible with ash (gram);  $W$  is sample weight (gram).

#### 2.4.4. Physicochemical Characterization of pH

For pH analysis, 0.2 grams of sample was dissolved in 20 mL distilled water at 25°C. The sample was homogenized with a magnetic stirrer, then the degree of

acidity was measured at room temperature with a pH meter.

## 2.5. Edible Film Characterization

The edible films were cut into 2 x 2 cm and characterized by FT-IR (Shimadzu) in the Riau University laboratory, SEM (FEI, Type: Inspect S50) in the Sepuluh Nopember Institute of Technology (ITS) laboratory, XRD and TGA at Gadjah Mada University laboratory.

## 2.6. Mechanical properties of edible films

### 2.6.1. Tensile Strength and Elongation

The tensile strength of edible films was measured using L & W Tensile Tester. The sample was cut into 2 x 15 cm, then clamped 1.5 cm on both sides of the length. After the sample was finished, the tensile and stretch resistance values were recorded. This tensile strength test was repeated twice (duplo). The tensile strength test value is obtained using the following equation:

$$T = \frac{F}{K}$$

where F is Force (Kg), K is conversion factor (0.65378), T is Tensile strength (Kg/mm<sup>2</sup>).

### 2.6.2. Thickness Test

The thickness of the edible film was measured using a screw micrometer with an accuracy of 0.01 mm. Measurements were made at five different points, namely the corner and middle of the films. The thickness value is obtained from the average measurement results.

$$\text{Thickness (mm)} = \frac{\text{point 1} + \text{point 2}}{2}$$

### 2.6.3. Soil Biodegradation Experiments

The edible films were cut into 5 x 1 cm. The films were dried in a desiccator and then weighed to a constant weight (W<sub>1</sub>). Samples were buried in the soil from a landfill for 30 days with a 5–10 cm depth. Then the sample was taken from the soil and cleaned the dirt attached to the edible film. After the burial, the final weight was weighed to obtain a constant weight (W<sub>2</sub>). The percentage of weight loss can be calculated using the following equation:

$$\text{Weight loss (\%)} = \frac{W_1 - W_2}{W_2} \times 100\%$$

where W<sub>1</sub> is the initial weight, W<sub>2</sub> is the constant weight (after burial).

### 2.6.4. Water Absorption

The edible films were cut into 2 x 2 cm and weighed with an analytical balance (W<sub>0</sub>). The weighed films were immersed in 15 mL of distilled water container for 10 minutes. The wet films were then removed from the container, dried with a tissue, and weighed to obtain the final weight (W). So that the percentage of water solubility is obtained using the following equation:

$$\text{Water absorption (\%)} = \frac{W - W_0}{W_0} \times 100\%$$

where W<sub>0</sub> is the initial weight before being immersed in the water and W is the weight of the wet films.

Then the percent water absorption is calculated based on the following equation to get the percent water resistance:

$$\text{Water resistance (\%)} = 100\% - \text{water absorption (\%)}$$

## 2.6.5. Water Vapor Transmission Rate (WVTR)

The edible films cut according to the surface diameter of the beaker glass were mounted onto beaker glass previously filled with 3 g of silica gel until completely closed. The water vapor that diffuses through the edible films would be absorbed by the silica gel and increase the weight of the silica gel. The glass beaker containing silica gel was weighed using an analytical balance from the 0th to the 24th hour. The WVTR can be calculated by the equation:

$$\text{WVTR} = \frac{\Delta W/t}{A}$$

where ΔW/t is the moisture gain weight per time (g/s), A is the surface area of the film (m<sup>2</sup>).

## 3. Results and Discussion

### 3.1. Physical and Chemical Analysis of Chicken Bone Gelatin

This research was started by degreasing the chicken bones from the remaining meat and fat attached to the bones. The results of % yield, proximate characteristics (moisture content, ash content), physicochemical characteristics (pH) of obtained films can be seen in Table 1.

**Table 1.** Results of Physical and Chemical Analysis of Chicken Bone Gelatin Extract

Parameter	Results (%)	Average (%)	SNI No.06-3735	British Standart 757
Moisture content	8.77 7.92	8.35	16% (maximum)	-
pH	6.0	-	-	4.5–6.5
Ash content	0.93 0.96	0.945	3.25 (maximum)	-
Yield	8.22	-	-	-

Yield is one of the essential parameters in gelatin production, and the more yields produced, the more efficient the treatment is given. Based on the results, the gelatin yield from chicken bones was 8.22172%, more significant than the study [9], which was only 5.0589%.

Moisture content aims to determine the water content in gelatin. The water content of gelatin is substantial on shelf life because it is closely related to the activity of microorganisms that occur while the gelatin is stored and can affect the appearance, texture, and taste of foodstuffs processed using the gelatin [10]. The water content of chicken bone gelatin was 8%, where the results still meet the gelatin quality standard, which is a maximum of 16% according to the Indonesian National Standard 06-3735-1995.

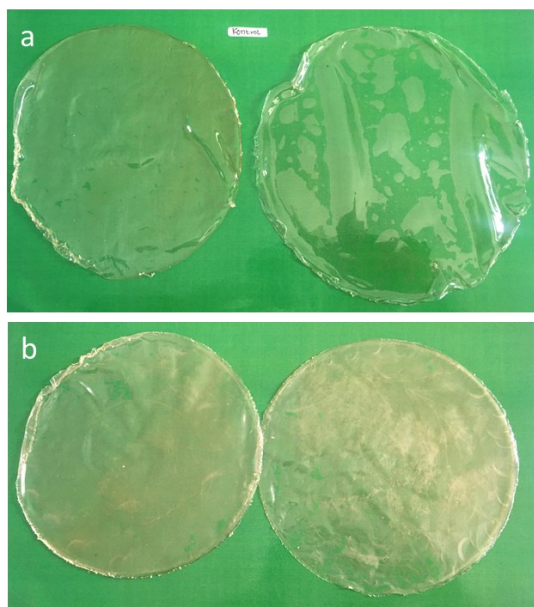
The ash content showed the number of minerals in the material. Generally, the minerals in gelatin extracted from bone consist of calcium, sodium, chlorine,

phosphorus, magnesium, and sulfur. Calcium is the most abundant mineral, causing the gelatin solution to have a cloudy yellow color. The ash content of chicken bone gelatin was 0.945%. According to the Indonesian National Standard (SNI) 06-3735-1995, the results still meet the gelatin quality standard, a maximum of 3.25%.

The pH of chicken bone gelatin in this study was 6. The results obtained still met the British standard 757 (1995) of gelatin which ranged from pH 4.5–6.5. The degree of acidity (pH) of gelatin was obtained by measuring the gelatin product dissolved in distilled water. The pH value of gelatin is related to the process carried out [1]. Gelatin with a neutral pH value tends to be preferred, so the neutralization process has an essential role in neutralizing chicken bone gelatin from acid and alkaline residues after immersing. The pH is highly dependent on the washing process after the demineralization. A good washing process will cause less acid trapped in the chicken skin; thus, the pH value will be closer to neutral.

### 3.2. Edible Film Production

The edible film made from chicken bone waste with tapioca starch has characteristics that are not too different from edible films without tapioca starch, which have the same brownish-yellow color. However, different elasticity, as shown in Figure 1a. Before adding starch, the edible film was more transparent, and the surface was even. After adding starch, the surface was more uneven because the starch was not completely dissolved, as seen in Figure 1b.



**Figure 1.** Edible Film from chicken bones (a) before adding starch (0%) (b) after addition of starch (15%)

### 3.3. Mechanical properties of Edible Film

The thickness of the film affects the physical and mechanical properties of the edible film produced as a food packaging material. When applied to the material, the thickness of an edible film will play an essential role in the permeability properties, drying speed, mechanical properties, and appearance. The ability of the edible film

to impede the rate of gas and water vapor to lengthen the films' shelf life is proportional to its thickness. However, if the film is too thick, it will affect the product's appearance, taste, and texture when eaten [7]. From table 2, the higher the starch concentration added, the thicker the edible film is.

**Table 2.** The Thickness of Edible Films

Starch (%)	Thickness (%)		Average (%)
	I	II	
0	0.218	0.224	0.221
5	0.225	0.231	0.228
10	0.293	0.305	0.299
15	0.325	0.320	0.322

According to [2], the factors that affect the thickness of the edible films were the properties and components of the edible films, the water content, and the concentration of dissolved solids. The process that involves much heat when making edible films is the gelatinization process, namely heating the gelatin and mixing the plasticizer in the mixture. It is characterized by a change in the viscosity of the film's solution, and this process will affect the thickness of the resulting films. The higher the viscosity of the solution, the higher the thickness [7].

Tensile strength is a mechanical test of edible films, which is related to the strength of the edible films in resisting damage to food packaging. The highest tensile strength value of edible films is expected to protect the packaged product from mechanical disturbances [11]. The tensile strength results decreased in concentration with the addition of more starch, as shown in Table 3.

**Table 3.** Tensile Strength of Edible Film

Starch (%)	Tensile Strength (MPa)		Average (MPa)
	I	II	
0	67.56	67.37	67.47
5	71.09	70.90	71.00
10	58.64	59.03	58.84
15	52.46	52.17	52.31

Factors that affect the tensile strength of edible films from chicken bone gelatin are the properties of the constituent matrix and additives. The more starch added, the lower the tensile strength. Plasticizers also affect reducing tensile strength because they can reduce intermolecular forces on the polymer chain to widen the distance between molecules and make the film more flexible [7].

Mechanical strength such as tensile strength and elongation at break is also affected by the homogeneity/heterogeneity of a film solution. The addition of starch at a very low concentration can reduce the elongation values because only a few bonds are formed. Meanwhile, high concentrations will cause an increase in the level of heterogeneity, and the formed sulfide bonds will be stronger, so there is no opportunity for plasticizers to form hydrogen bonds [7]. Table 4 shows that the elongation value in all variations increased with the increase in starch addition.



The addition of starch and glycerol as plasticizers caused the elongation of the edible film to increase. Plasticizers will produce films with lower tensile strength, reduce brittleness, and increase flexibility [12].

**Table 4.** The Elongation of Edible Film

Starch (%)	Elongation		Average (%)
	I	II	
0	28.11	28.09	28.10
5	24.90	25.30	25.10
10	26.44	26.47	26.45
15	30.24	30.25	30.24

Edible films with a higher thickness have a powerful ability to resist gas migration due to their denser structure. At the same time, the tensile strength is getting smaller because the thickness is positioned as a divider from the maximum stress in the equation for finding tensile strength. The elongation increases because the elongation is always inversely proportional to the tensile strength [13].

### 3.4. Water Vapor Transmission Rate Test (WVTR)

Measurement of the WVTR of a material is an essential factor in assessing the permeability of the film to water vapor or the ability of the film to inhibit the movement of water vapor. The low WVTR value indicates that the edible film can inhibit the occurrence of incoming water vapor; hence, it can prolong the product’s shelf life. The WVTR of the edible film is also influenced by the thickness value. Increasing the thickness of the edible film causes the water vapor to travel farther to diffuse through the film; thus, the WVTR value decreases, as shown in Table 5.

**Table 5.** WVTR Edible Film test results

Starch (%)	WVTR (%)		Average (%)
	I	II	
0	6.17	6.25	6.21
5	11.71	12.27	11.99
10	8.26	8.31	8.29
15	6.07	6.22	6.14

Increasing starch concentration will decrease the WVTR value. The presence of hydrophilic or hydrophobic groups in the primary materials for making edible films can affect the WVTR value. The plasticizer exerts an effect on hydrophilic polymers, such as gelatin proteins, to increase the permeability value. The high value of water vapor transmission is due to the use of hydrophilic glycerol plasticizer; thus, the transfer of water vapor from the environment to the surface of the film sample becomes faster.

### 3.5. Water Resistance

The water resistance test of the edible film was carried out by immersing the film for 10 minutes. The water resistance of edible films is determined by the ability of the films to absorb water or the percentage of swelling. The lower the water absorption value, the better the quality of the edible film, and vice versa. The percentage of water resistance is influenced by the

addition of starch, glycerol, and the thickness of the edible film. The results of the water resistance test can be seen in Table 5.

**Table 5.** Water Resistance of Edible Film

Starch (%)	Water resistance (%)		Average (%)	RPD (%)
	I	II		
0	9.33	10.07	9.70	7.63
5	28.99	28.55	28.77	1.53
10	35.63	33.11	34.37	7.32
15	58.06	57.28	61.37	1.35

Water solubility is affected by the thickness of the edible films. Increasing film thickness along with an increasing concentration (15% starch concentration) will cause a lower water solubility value. This is because the more time it requires to dissolve the edible films. However, the water solubility value of the edible film was high at a concentration of 15% due to the increased hydrophilicity associated with the addition of glycerol and starch concentration. The hydroxyl groups in the two materials cause the edible film to absorb water more efficiently. [12].

### 3.6. Biodegradability of the Edible Films

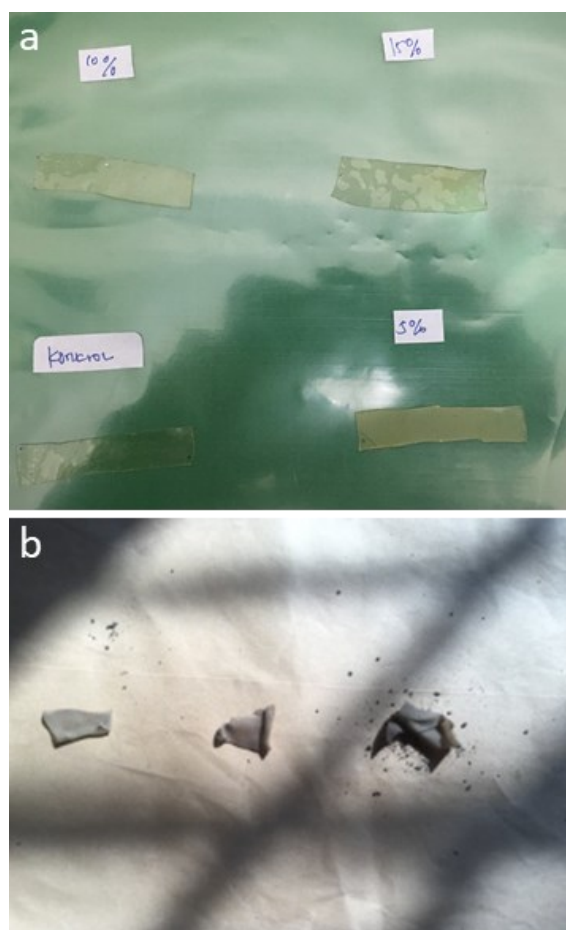
In order to determine the biodegradability of the edible film made, it was tested with soil media. The results can be seen in Table 6.

**Table 6.** The results of the edible film biodegradation test on soil media

Starch (%)	Weight Loss (%)		Average (%)
	I	II	
0	100	100	100
5	93.50	92.32	93
10	81.02	83.63	82
15	76.61	76.47	77

The mass reduction after burial was only slightly in the previous study [14] of samples without adding gelatin powder. Then gelatin was added with 5 g, 10 g, and 15 g. At the addition of 15 g, there was an increasing mass reduction. This shows that plastic degradation is getting more significant due to the addition of gelatin powder which can be easily degraded by the activity of microorganisms in the soil.

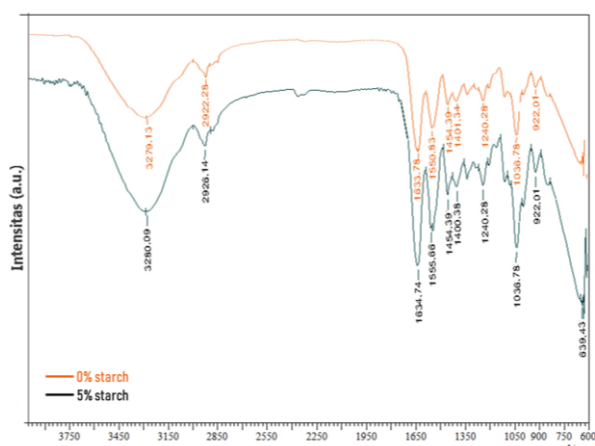
The edible film is easily degraded because the constituent components are natural materials. The resulting edible films contained a hydroxyl group (OH) and a carbonyl group (CO), which caused edible films to be appropriately degraded. In general, the factors that accelerate the process of biodegradation are the components of the constituent solution, bacterial activity, polymer structure, morphology, molecular weight, temperature, environment, and humidity [15], as shown in Figure 2.



**Figure 2.** Biodegradation Test Results (a) Edible film samples before being buried in the soil (b) Samples after being buried in the soil for 30 days

### 3.7. FTIR Analysis

FTIR spectroscopy is an analytical method used to characterize polymeric materials and functional group analysis. The FTIR results did not show a significant difference in the spectra between edible films without and with the addition of starch. This is because the composition of the functional groups of the two samples is almost the same, as shown in Figure 3.



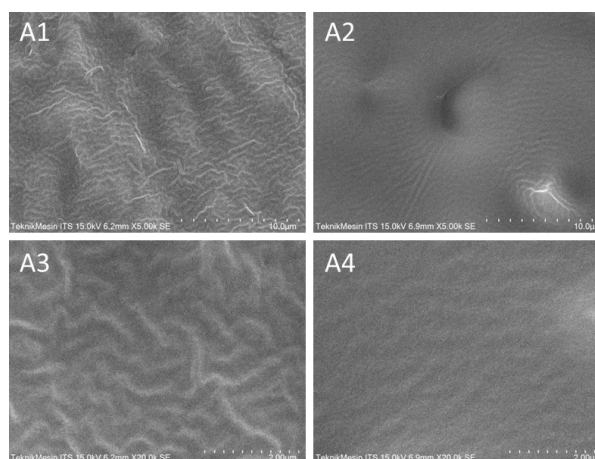
**Figure 3.** FTIR Results

Figure 3 shows that C-H with a sharp absorption band with weak intensity is present at wavenumbers of 2922.28 and 2926.14  $\text{cm}^{-1}$ , indicating the presence of

starch and glycerol, which also have C-H groups [14]. Broad absorption band with weak intensity at wavenumbers of 3279.13 and 3280.09  $\text{cm}^{-1}$ , wherein this absorption area there are N-H groups which indicate the presence of gelatin [16]. At wavenumbers of 1633.78 and 1634.74  $\text{cm}^{-1}$ , there is a functional carbonyl group (C=O) with a sharp absorption band and weak intensity, indicating the presence of a gelatin functional group [16]. The bands at 1550.83 and 1555.66  $\text{cm}^{-1}$  are associated with an N-H group [16]. The existence of the C-N group is evidenced by the absorption of the wavenumber 1454.39  $\text{cm}^{-1}$ . The peaks at 140.38 and 1401.34  $\text{cm}^{-1}$  indicate the presence of C-O vibrations from alcohol or ether groups of glycerol and starch in the mixture. The 1240.28  $\text{cm}^{-1}$  corresponds to an N-H group from gelatin and a C-H group from glycerol. The wavenumber 1036.78  $\text{cm}^{-1}$  is the C-O group from glycerol and gelatin. The peak at a wavenumber of 922.01  $\text{cm}^{-1}$  denotes the presence of the C-O-H functional group on glycerol [17]. The absorption region bands of the N-H group are at wavenumbers 1237.86, 1241.22, and 1241.26  $\text{cm}^{-1}$ , while the C-O group indicates at wavenumbers 1080.65, 1060.63, and 1080.50  $\text{cm}^{-1}$ . The peak at 639.43  $\text{cm}^{-1}$  shows the C-H group.

### 3.8. Scanning Electron Microscopy (SEM)

The results of the SEM can be seen in Figure 4. The edible film of chicken bone waste without starch appeared to have fine lines in the form of a hollow path, and no fractures were found in the microscopic structure of the edible film. Different results can be seen in the observation of edible films. With the addition of starch, there were no fine lines, and the surface of the edible film was more even, smooth and homogeneous.



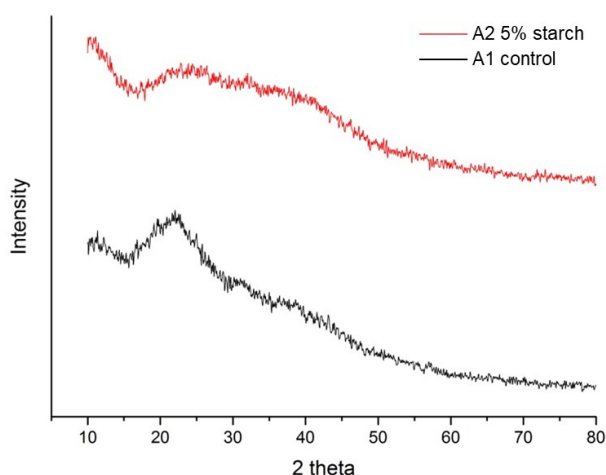
**Figure 4.** SEM of chicken bone gelatin+glycerol (A1), chicken bone gelatin+glycerol+ 5% starch (A2) at 5,000 and 20,000x magnifications

The structure of the edible film that uses gelatin has many cavities (pores) compared to the structure of the bioplastic without gelatin. The cavity in this plastic film is quickly filled with water, causing the plastic film in this formulation to absorb the most water compared to other film formulations. While the structure of biodegradable plastic films that do not use gelatin looks denser, this causes the biodegradable plastic films with this formulation to have a good elongation percentage [18].

The difference between these edible films can be seen from the flatness on the surface. Edible films without the addition of starch have many fine lines that make them more brittle than edible films added with starch.

### 3.9. XRD of Edible Films

Crystallinity analysis was carried out based on XRD diffraction measurements. The crystalline polymer material will show diffraction peaks as sharp peaks at a certain angle, while the amorphous part will appear as broad peaks. XRD test results can be seen in Figure 5.



**Figure 5.** XRD results of chicken bone gelatin+glycerol (A1), chicken bone gelatin+glycerol+5% starch (A2)

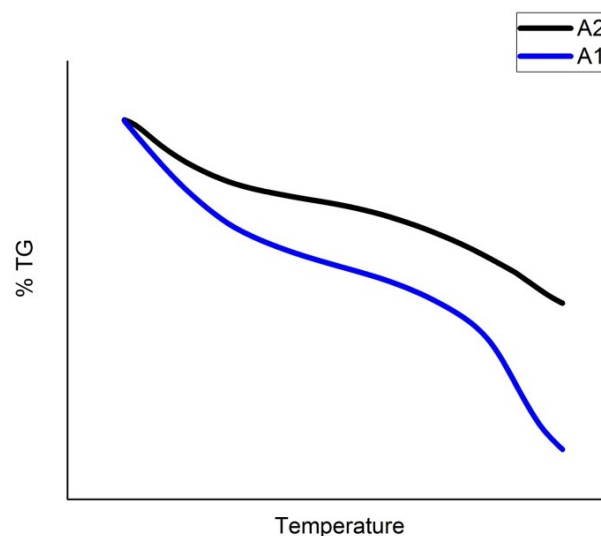
XRD spectra showed two combinations of edible films (gelatin+glycerol+water) and (gelatin+starch+glycerol+water) with a 5% starch concentration. The diffractogram pattern of the two samples has different intensities at each angle and has peaks marked by sharp curves. These peaks are known as Crystalline regions [19]. From Figure 5, it can be seen that the edible film of tapioca starch is an amorphous and crystalline material. Tapioca starch is a semicrystalline material, which is a material consisting of crystalline units and amorphous units. This is in accordance with research from [19] that cassava starch is a semicrystalline material, namely a material consisting of crystalline and amorphous units.

Based on the results obtained, it is known that the crystallinity value of bioplastics with a combination (gelatin+glycerol+water) is lower than combined bioplastics (gelatin+starch+glycerol+water) so that this bioplastic is better because of the fast of the decomposition process. This is in accordance with research [19], where one of the criteria for polymers that can decompose has low crystallinity.

### 3.10. TGA of Edible Film

Thermal properties analysis is intended to determine the thermal resistance of a material. The use of plastic films is strongly influenced by heat, so materials with higher thermal resistance are needed for specific purposes. The thermal resistance of a plastic film is also closely related to its mechanical properties, where the higher the tensile strength, the higher the thermal resistance. The TGA results can be seen in Figure 6.

Figure 6 shows that the TGA thermogram provides information about the decrease in mass due to increased temperature. The heat applied to the sample will increase with time, so the mass of the sample decreases. Samples with more dominant tapioca starch content have low thermal resistance.



**Figure 6.** TGA results of chicken bone gelatin+glycerol (A1), chicken bone gelatin+glycerol+5% starch addition (A2)

Weight loss of bioplastic samples occurred at a temperature of 475°C with a weight loss range of 41.39–71.03% by weight. The most negligible weight loss occurred in the sample without the addition of starch, while the most significant weight loss was the sample with the addition of 5% starch, which was the optimum condition. Thus, it can be said that the sample without the addition of starch has a more dominant low thermal resistance. However, the sample with the addition of starch has a higher thermal resistance. This might be caused by the polyblend structure, which has changed during mixing.

## 4. Conclusion

The optimum condition of the extraction procedure was obtained by using 5% HCl, which produces 8.22172% yield of gelatin with a pH of 6.0, water content of 8%, and an ash content of 0.945%. The results obtained are following SNI No. 06375. This study indicated that edible film made from chicken bone waste with the addition of tapioca starch has characteristics that are not too different, which have the same brownish-yellow color, but different elasticity. For the WVTR test, only starch concentrations of 0 and 15% meet the standards, while all concentrations in the water resistance did. The results of FTIR chicken bones with variations in starch and the addition of glycerol as a plasticizer have functional groups N-H, O-H, C-O, C=O, C-H, C-N. The functional groups of gelatin are N-H, O-H, C-H, C=O, C-N, and C-O. Chicken bone gelatin edible film with the starch variation of 0, 5, 10, and 15% in the gelatin edible film sample was degraded entirely for 30 days. Meanwhile, with each addition of starch, more weight was lost. For the XRD test results, the samples were semicrystalline, while the TGA

results showed broad peaks and had low thermal power without the addition of starch.

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