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Characteristics of Biodegradable Film as Food Product Packaging Based on Casein, Chitosan and Gelatin

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ABSTRACT: The purpose of this study was to determine the best level of gelatin addition in the manufacture of edible film so as to produce good quality edible film as a food product packaging. The materials used were casein hydrolyzate and chitosan edible film with gelatin with different percentages. This research method is a complete randomized laboratory experimental design with five treatments including without gelatin (P0) and with gelatin 0.25% (P1), 0.5% (P2), 1% (P3) and 1.5% (P4) with four replications. The variables measured were solubility, swelling, moisture content, Water Vapour Permeability, Water Vapour Transmission Rate, thickness, tensile and Scanning Electron Microscopy. Data were analyzed using Analysis of Variance (ANOVA) and continued with Duncan's Multiple Range Test (DMRT) whether there was a real difference or a very real difference. The results showed that there were significant differences ($P<0.05$) in solubility and Water Vapour Permeability. There was a significant difference ($P<0.01$) in swelling, moisture content, Water Vapour Transmission Rate, thickness and tensile strength. SEM testing resulted in a flatter surface structure. The conclusion of this study is that the best result is edible film with the addition of 0.25% gelatin.

KEYWORDS: Edible film, Edible film quality, Gelatin

INTRODUCTION

Technological developments in all walks of life have an influence on people's consumption patterns. The food industry sector has a role in improving public health. Good food products contain high nutritional value and do not contain contamination so that preservation is needed through packaging to extend the shelf life without reducing the quality of food products. Packaging is a way to protect food products with the aim of maintaining food nutrition, protecting products from the surrounding environment, maintaining durability and avoiding chemical reactions caused by microbes to food products. Food product packaging materials are divided into two groups, namely non-biodegradable and biodegradable packaging materials. The majority of food industries in Indonesia use non-biodegradable plastics as the main ingredient in preserving food products through packaging. The use of non-biodegradable plastics in food products has an impact on global warming, pollutes the environment and has an impact on health (Khwaldia et al., 2010). The use of non-biodegradable plastics also has several disadvantages in terms of raw materials, health and environment. The weakness of using synthetic plastics in terms of raw materials is that plastics are made from petroleum which cannot be renewed and are not energy efficient. The aspect of plastic use has an impact on cancer caused by plastic materials (polyster) which easily degrade into monosteryne at high temperatures (Santoso, 2020). The disadvantages of using synthetic or non-biodegradable plastics in the environment are that they are not environmentally friendly and cannot be decomposed by microbes, thus disturbing soil fertility. Technology development towards natural biodegradable packaging materials needs to be done. In Indonesia, the development and research on biodegradable packaging technology to reduce the use of non-biodegradable packaging is still very limited. Biodegradable packaging is a plastic that is easily decomposed by microorganisms in the soil. Biodegradable packaging can inhibit water vapor transfer, easily degrade and reduce environmental problems (Indriyanto, et al., 2014). Biodegradable as a packaging must be able to act as a selective barrier to carbon dioxide, control oxygen transfer, reduce biological components and as a barrier to spoilage microbes (Thulasisingh, et al., 2021). Biodegradable packaging is divided into three namely, edible film, edible coating and encapsulation.

Edible film is a thin film made from natural and edible materials that is used as a surface coating for food components. The use of edible films as packaging for food products such as sausages, meat, fresh fruits and vegetables can slow down quality deterioration, maintain product safety and extend shelf life. Edible film has a function as a mass transfer barrier to inhibit the migration of moisture, oxygen, carbon dioxide, aroma and lipids, maintaining the quality and safety of food products (Manab, et al., 2017). The use of edible film as a food packaging is to extend the shelf life of the product and not pollute the environment. The constituent components of edible film consist of hydrocolloids, lipids and composites. Casein is an insoluble protein in milk that is used as a material for making edible films. Casein has properties that are difficult to split by heat, form good protection on nonpolar molecules and have low oxygen permeability (Bonnaille, et al., 2014). The disadvantage of using casein as an edible film material is that it does not have antimicrobial activity against bacteria that grow on the surface of food (Ngajow, et al., 2013). Chitosan is a polymer compound produced from the extraction of hard-shelled animals derived from the deacetylation of chitin. Chitosan has advantages such as biodegradable, biocompatible, can inhibit the activity of liquids in the surrounding environment, inhibit O_2 and CO_2, has antimicrobial properties and high viscosity (Felycia and Slamat, 2021). The presence of amine group compounds (NH_2) in chitosan causes chitosan to have a fairly high chemical reactivity, so that chitosan is able to bind water and can dissolve in acetic acid which causes water absorption to be maximized. Chitosan has good oxygen barrier properties so the addition of other compounds is needed to improve its quality as a natural coating for food products. Gelatin is a type of protein extracted from animal collagen tissue. Gelatin is used as food packaging and drug packaging. Gelatin-based edible film is water soluble, odorless, transparent, reversible, the best gas barrier, selective for heat transfer, water vapor and soluble materials and can be protective against mechanical damage. Gelatin edible film contains the most attractive protein compared to lipids and polysaccharides. The use of gelatin as a raw material for edible films has a high content of glycine, proline, hydroxyproline which results in edible films that are more flexible and easily applied to food ingredients (Wang, et al., 2021).

MATERIALS AND METHODS

The research was conducted in April at the Animal Product Technology Laboratory, Faculty of Animal Science, Universitas Brawijaya, sample preparation and microbiology room.

Research Materials and Equipment

The research materials used in the manufacture of edible film consisted of casein hydrolysate, chitosan, gelatin, glycerol, 2% acetic acid and distilled water. The equipment used in the manufacture and testing of edible film consisted of digital scales, magnetic stirrer, thermometer, beaker glass, measuring cup, laboratory spatula, stopwatch, petri dish, whatman paper no 41, oven, desiccator, analytical balance, 25 ml and 50 ml film pots, digital thickness micrometer, Universal Testing Machine, Uv-Vis Spectrophotometer, Fourier Transform Infrared Spectroscopy and Scanning Electron Microscopy.

Methods

The research method used was a completely randomized design (CRD) laboratory experiment with 5 treatments and 4 replications. The treatment given is the addition of gelatin P1 (0.25%), P2 (0.5%), P3 (1%), P4 (1.5%) on edible film based on casein hydrolysate and chitosan. Edible film without gelatin addition was used as control treatment (P0).

Edible Film Preparation Procedure

The process of making edible film was carried out by dissolving casein hydrolyzate for 30 minutes and chitosan solution for 1 hour at a temperature below 50°C using a magnetic stirrer, during the heating process 0.28% glycerol was added to each solution. After the addition of glycerol, the solutions were homogenized again using a magnetic stirrer at ≤ 50°C for 30 minutes. Gelatin solution was prepared by dissolving gelatin into distilled water with gelatin percentages of 0.25% (P1), 0.5% (P2), 1% (P3) and 1.5% (P4). The gelatin solution was homogenized using a magnetic stirrer at ≤ 50°C for 15 minutes and 0.28% glycerol was added. Casein hydrolysate solution, chitosan solution and gelatin solution were then homogenized together and heated at ≤ 50°C for 2 hours. The edible film solution was poured into a 95 mm diameter petri dish as much as 25 ml and dried at room temperature.

Variables Measured

1. Solubility

   The solubility of edible film determines the biodegradability value of the film as a food packaging. Solubility measurement aims to determine the ability of edible film to dissolve in water and retain water. The solubility analysis procedure is based on the procedure used by Silva, et al. (2019). The edible film sample is cut into 2.5×2.5 cm strips. The cut edible film samples were dried in an oven at 105°C for 24 hours. The edible film samples were weighed. Filter paper and sample were weighed separately, to determine the initial weight of the sample (DM_0). The samples were placed for 24 hours in a beaker containing 50 ml of distilled water and placed at room temperature. The wet edible film was placed back in the oven to dry at 105°C for 24 hours. The sample was weighed again to obtain the final weight (DM_{24}).

$$\text{Solubility (\%)} = \frac{DM_0 - DM_{24}}{DM_{24}} \times 100\ (\%)$$

Description:

DM_0 = Initial dry sample weight

DM_{24} = Final dry sample weight

2. Degree of Swelling

The swelling test is a test to determine the amount of edible film absorption of water expressed in percent swelling. The swelling degree test uses the procedure used by Gohargani, et al. (2020). The edible film sample is cut into 3×3 cm strips. The cut edible film samples were dried in an oven at 105°C. The edible film sample that has been in the oven is weighed (W_1). The edible film samples were then soaked in 50 ml of distilled water and placed at room temperature for 2 hours. After 2 hours the distilled water on the edible film sample was removed with filter paper and weighed (W_2),

$$\text{Swelling (\%)} = \frac{W2 - W1}{W2} \times 100\%$$

Description:

W_1= Initial dry sample weight

W_2= Final dry sample weight

3. Water Content

Testing water content using the drying method used by Harumarani, et al. (2016) with reference to AOAC, 2005. Measurement of moisture content was carried out using the oven drying method. The test procedure is the cup to be used is placed in an oven at 105°C for 24 hours or until a fixed weight is obtained. The cup is removed from the oven and cooled in a desiccator for 30 minutes and then weighed. Weighed edible film samples are then placed in a cup, dried in an oven at 105 °C until a fixed weight is reached or for 24 hours. The sample was cooled in a desiccator for 30 minutes and then weighed.

$$\text{Water Content (\%)} = \frac{BS - (BCS - BC)}{BS} \times 100\%$$

Description:

BS = Initial dry sample weight

BC = Weight of cup

BCS = Weight of sample and cup

4. Water Vapor Permeability

Water vapor permeability test using the gravimetric method conducted by Setijawati, (2017) with reference to ASTM E96, 1993. The edible film sample is cut into 5×5 cm strips and weighed. The edible film sample was attached to the lid of the film pot which contained 15 ml of distilled water. Edible film that has been attached to the lid of the film pot is put in a desiccator that already contains silica gel (which has been previously baked for 3 hours). Weighed the edible film after 24 hours of storage.

$$\textit{Water Vapour Permeability} = \frac{\Delta W}{t \times A}$$

Description:

ΔW = Weight change of Edible film after 24 hours

t = Time (24 hours)

A = Surface area of edible film

5. Water Vapor Transmission Rate

Water vapor transmission rate (WVTR) of edible film using the standard test method for water vapor transmission of materials conducted by Tavares, et al. (2021) with reference to ASTM E-96-95, 1995. The edible film sample is cut into 5×5 cm strips and weighed. The edible film sample was attached to the lid of the film pot which contained 15 ml of distilled water. Edible film

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that has been attached to the lid of the film pot is put in a desiccator that already contains silica gel (which has been previously baked for 3 hours). Weighed the edible film after 24 hours, 48 hours, and 72 hours of storage.

$$\text{Water Vapour Transmition Rate}=\frac{\Delta X}{T\times A}$$

Description:
ΔX = Weight change of edible film / weight of edible film - initial weight of edible film
T = Time (24 hours, 48 hours, and 72 hours)
A = Surface area of edible film

6. Thickness
Test the thickness of the dried edible film or edible film using a screw micrometer (Santacruz, et al., 2015). The edible film samples were measured for thickness using a Digital Thickness micrometer (SanSanMall) with an accuracy of 0.01 mm. Measurements were taken at several points or three different sides of the edible film to obtain the average thickness of the edible film.
7. Tensile Strength
The tensile strength of edible film was tested according to the procedure used by Wijayani, et al. (2021) with reference to ASTM, 1993. Cut 5x0.5 cm edible film. Measured the thickness of the edible film using a Digital Thickness micrometer. Pasted the edible film between the grips with an initial distance of 50 mm/min.

$$TS=\frac{F}{N}$$

Description:
TS: Tensile strength
F : Maximum force applied to the film until tearing
N : Unit of edible film area
8. SEM
Scanning Electron Microscopy (SEM) test aims to see the structure of edible film. Testing edible films using Scanning Electron Microscopy (SEM) (Sun, et al., 2021). The dried edible film was cut with a maximum diameter of 1 cm and glued to the sample plate. The morphology of the coating surface was recorded by SMI.A1. SEM at surface and cross section magnification.

Data Analysis
The data obtained was tabulated using Microsoft Excel. Data were analyzed statistically by calculating using analysis of variance (ANOVA) according to the method used, namely Completely Randomized Design. If there are results showing significant differences or highly significant different effects between treatments, then proceed with Duncan's Multiple Range Test (UJBD).

RESULTS AND DISSCUSION

Table 1. Average Results of Casein Hydrolysate and Chitosan Edible Film with or without gelatin addition

Treatment	Solubility (%)	Swelling (%)	Water Content (%)	WVP (g/cm^2 .24 hours)	WVTR (g/cm^2 /day)	Thickness (mm)	Tensile (MPa)
P0	58,69 ± 8,34^a	48,79 ± 4,23^a	20,57 ± 1,53^c	0,000238 ± 0,000051^b	0,000065 ± 0,000009^b	0,06 ± 0,010^a	9,44 ± 2,44^a
P1	59,55 ± 13,41 ^{a}	60,93 ± 9,04^b	16,48 ± 2,77^b	0,000133 ± 0,000098^{ab}	0,000050 ± 0,000011^{ab}	0,08 ± 0,010^b	10,95 ± 3,08^a
P2	60,30 ± 5,81^a	61,85 ± 4,68^b	15,70 ± 1,21^b	0,000115 ± 0,000057^{ab}	0,000047 ± 0,000006^a	0,09 ± 0,005^b	11,10 ± 1,13^a
P3	60,52 ± 5,17 ^{a}	77,45 ± 2,50^c	14,81 ± 3,06^b	0,000110 ± 0,000022^a	0,000040 ± 0,000003^a	0,11 ± 0,005^c	12,06 ± 1,89^{ab}
P4	77,09 ± 4,23^b	81,06 ± 1,60^c	6,59 ± 1,31^a	0,000105 ± 0,000019^a	0,000039 ± 0,000007^a	0,12 ± 0,008^c	18,61 ± 5,45^b

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[a,b,c] : Different superscripts indicate that the concentration of added gelatin provides a significant difference ($P<0.05$) to solubility and WVP and provides a very significant difference ($P<0.01$) to swelling, water content, WVTR, thickness and tensile strength of edibles. casein hydrolyzate and chitosan films.

Solubility

The solubility of edible film is an important factor in determining the biodegradability value of edible film as food packaging and packaging for direct consumption (Bourtoom and Manjeet, 2008). Casein hydrolysate and chitosan edible film without the addition of gelatin and with the addition of gelatin (0.25%, 0.5%, 1% and 1.5%) gave a significant effect ($P<0.05$) on the solubility of edible film. The higher concentration of gelatin resulted in a high solubility value. Edible films with low solubility values are good for packaging food products that have high water content values, while high solubility values are good for ready to eat food products. Edible films with high solubility show lower water resistance and show the hydrophilicity of the film. The highest average value of solubility in edible film with gelatin addition treatment of 1.5% (P4) is 77.09%. Edible films with high solubility values dissolve easily in water so they cannot retain water (Pitak and Rakhsit, 2011). The solubility of an edible film is influenced by the material components in the manufacture of edible film, namely the hydrophilic component which is the component of the material that can dissolve in water. The hydrophilic value of an ingredient causes high film solubility (Zulferiyenni et al., 2014). The addition of gelatin to the edible film of patient hydrolysate and chitosan resulted in a high solubility value. Gelatin contains hydrophilic amino acids which include lysine, serine, arginine, hydroxyproline, aspartic acid and glutamate in large quantities rather than hydrophobic amino acids (Flores, et al., 2012). The use of chitosan with the addition of gelatin produces electrostatic bonds with hydrogen when chitosan is positively charged and gelatin is negatively charged (Hamzah, et al., 2019). The increase in solubility value is caused by hydrogen bonding which is an interaction between hydroxyl groups (OH) in gelatin with amine groups (NH_2) in chitosan. The high solubility of edible films with the addition of gelatin can be applied to directly edible food products such as candy, ready to eat food packaging and instant noodle seasoning packs (Wijayani et al., 2021). The lowest solubility value in edible film with the addition of gelatin was found in treatment P1 (0.25% gelatin). The low solubility value is caused by the denaturation of proteins contained in gelatin. Protein denaturation causes loss of physiological and biological activity that can reduce solubility. High temperature heating causes the protein to denature quickly, in addition to the stirring process during edible film making causes the protein to clump. High temperature heating has the ability to denature proteins and form complex electrostatic interactions between polysaccharides in chitosan and proteins. Edible film with low solubility value is found in the treatment with the addition of gelatin which can be used as an important requirement for food packaging and serves as a food product protector (Atef, et al., 2015).

Swelling

The swelling test is a test of the ability of edible film to pass water vapor and gas particles on a unit area of food material. The swelling degree test is conducted to determine the amount of water that can diffuse into the edible film membrane expressed in percent (Gustian et al., 2013). The degree of swelling in edible film is influenced by the diffusion of water into the polymer structure, the number of hydrogen bonds, polymer relationships, ionic groups on polymers and interactions between molecular chains in edible film materials (Moradi, et al., 2012). The average swelling degree of casein hydrolyzate and chitosan edible films with the addition of 0.25%, 0.5%, 1% and 1.5% gelatin increased by 60.94-81.06%. Edible films with a high degree of swelling have high water absorption (Susilowati and Lestari, 2019). The lowest average value of swelling degree was found in treatment P1 with the addition of 0.25% gelatin. The swelling value produced is influenced by the materials used in the manufacture of edible film. The composition and concentration of the ingredients used affect the absorption of water which results in swelling of the edible film. The addition of gelatin with a high concentration produces edible film characteristics that are thicker, stronger and not easily broken which has an impact on increasing total solids. The increase in total solids causes water to enter more easily resulting in increased swelling of the edible film. Gelatin is composed of amino acids glycine-proline, glycine-proline-hydroxyproline which are connected by peptide bonds that are arranged over time resulting in greater gel strength produced by gelatin (Febriana, et al., 2021). The addition of gelatin with a high concentration in edible film can increase the swelling degree value. Gelatin has reversible properties from sol to gel, expands in water and forms a film so that it can prevent water molecules from moving freely. The addition of gelatin with a high concentration causes the edible film to swell in water (Zahro and Fithri, 2015). Edible films of casein hydrolysate and chitosan with the addition of gelatin show a higher swelling capacity due to the porosity in the tissue structure that allows water vapor to enter the film (Xu, et al., 2021). A high swelling degree value results in the greater amount of water absorbed, so the film's resistance to water decreases (Rahmiati, et al., 2022).

Water Content

Moisture content is an important parameter that affects the quality and durability of products that are coated or applied as product packaging (Diova, et al., 2013). High moisture content in edible films affects food durability. Edible film with high moisture content is easy to become a medium for microbial growth (Zahwa, et al., 2020). The highest average water content was found in the treatment without the addition of gelatin. The difference in the value of water content produced is due to the addition of hydrocolloids. The higher the concentration of hydrocolloids, the more water is bound in the hydrocolloid network (Rosida and Arumsaka, 2019). The highest average value of water content in edible film is in the treatment without the addition of gelatin at 20.57%. Chitosan contains non-polar amino acids that are hydrophobic in nature, thus affecting the value of water content (Rosida et al., 2019). Chitosan has hydrophobic properties so that the more the addition of chitosan the water content in edible film decreases (Kusumawati and Widya, 2013). The addition of protein material in edible film is able to bind water because it has hydrogen groups. Protein undergoes changes when heated, the conformation of the hydrophobic groups in the protein is exposed out which results in hydrogen bonds being broken and results in the ability of protein to bind water getting lower (Lindriati et al., 2014).

A good edible film has a low moisture content so that its application as a packaging material does not have an impact on the damage to the coated product and the impact on reducing the shelf life. The low value of water content occurs due to the interaction between chitosan and protein (gelatin and casein hydrolysate) which results in heating and increasing the stability of protein and polysaccharide components so that the water content becomes low. The lowest moisture content value in casein hydrolyzate and chitosan edible film with the addition of 1.5% gelatin was 6.59%. The decrease in moisture content in the treatment of the addition of gelatin in edible film is due to the reduced water content in edible film because water molecules can be bound through strong hydrogen bonds so that free water in edible film is reduced. Kusumawati and Widya, (2013) stated that the decrease in edible film moisture content is caused by the high concentration of gelatin which is able to bind water molecules through strong hydrogen bonds thereby reducing the amount of free water in the film. The addition of gelatin with a high concentration results in an increase in the number of polymers and viscosity that make up the network. The quality standard for edible film moisture content according to Japannese Industrial Standard (1975) is a maximum of 13%. Based on the research, the moisture content of edible film with 1.5% gelatin addition of 6.59% meets the Japannese Industrial Standard (1975) standard, but the moisture content of edible film without and with the addition of 0.25%, 0.5% and 1% gelatin does not meet the Japannese Industrial Standard (1975) standard. The lowest moisture content value indicates that the edible film is the best and able to longer protect a product that is packaged or coated. Edible films with low moisture content will be more resistant to microbiological damage, and do not provide additional water to the product and reduce product shelf life.

Water Vapor Permeability

The results of the average analysis of water vapor permeability of casein hydrolysate and chitosan edible film without the addition of gelatin and casein hydrolysate and chitosan edible film with the addition of gelatin (0.25%, 0.5%, 1% and 1.5%) gave a significant effect ($P<0.05$) on the Water Vapor Permeability of edible film. Factors that affect the water vapor permeability of edible film are temperature, relative humidity, food type, water activity and characteristics of the materials used (Olivas and Gustavo, 2009). The average water vapor permeability of edible film in this study ranged from 0.000238-0.000105 g/cm^2.24 hours. The highest average water vapor permeability in the treatment without gelatin addition was 0.000238 g/cm^2.24 hours. Chitosan has hydrophilic properties and casein has barrier properties against water vapor. The addition of casein protein to the chitosan matrix slightly decreased the permeability of the film to oxygen (Pierro, et al., 2006). The average value of water vapor permeability was low in the treatment of 1.5% gelatin addition which was 0.000105 g/cm^2.24 hours. The decrease in film permeability occurs because the water vapor entering the edible film matrix is getting smaller. The addition of gelatin to edible film can reduce the value of water vapor permeability caused by the hydrophilic nature of gelatin. High hydrophilicity in a material causes the water vapor permeability of the film to decrease (Dwimayasanti, 2016). The value of water vapor permeability is low or closer to zero, the absorption of edible film to water vapor is smaller and better (Fitriana et al., 2017). The smaller the water vapor migration that occurs in the product packaged by the edible film, the better the edible film properties in maintaining the shelf life of the packaged product.

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Permeability to water vapor transmission rate is an important factor of edible film because it affects the quality, safety and shelf life of food products (Mellinas, et al., 2016).

Water Vapor Transmission Rate

The water vapor transmission rate of edible film is measured to determine the ability of edible film to inhibit water vapor transmission from the coated material. The water vapor transmission rate of casein hydrolysate-chitosan edible film without the addition of gelatin and with the addition of gelatin (0.25%, 0.5%, 1% and 1.5%) gave a very significant effect ($P<0.01$) on the water vapor transmission rate of edible film. The water vapor transmission rate is influenced by the hydrophilic nature of the material used in the manufacture of edible film, the combination of constituent materials and the thickness of the edible film (Setyaningrum, et al., 2017). The average analysis results of edible film with the addition of gelatin 0.25%, 0.5%, 1% and 1.5% 0.000050-0.000039 g/cm^2/day. In Mudaffar's research (2018) the water vapor transmission rate with the addition of 1%, 2% and 3% gelatin decreased by 0.078 g/cm^2/day, 0.041 g/cm^2/day and 0.034 g/cm2/day. The addition of gelatin to edible film has a significant effect ($P<0.05$) on the water vapor transmission rate of edible film. The addition of gelatin can form a denser and more cohesive network that results in a thicker film. According to Supeni and Irawan (2012), the thickness value affects the water vapor transmission rate and the permeability value of edible film to water vapor. The addition of gelatin in treatment P4 produced the lowest water vapor transmission rate of 0.00039 g/cm^2/day. Gelatin contains hydrophilic and hydrophobic amino acids such as alanine, valine, leucine, isoleucine and methionine. Amino acids in the material cause disulfide bonds and hydrophobic interactions to form more and more, so that the amount of film matrix formed increases. Edible films that have a compact structure and network can increase the film's ability to retain water vapor (Poeloengasih and Djagal, 2003). The decrease in water vapor transmission rate is caused by an increase in hydrophobicity in the edible film. The ratio between hydrophilic and hydrophobic will affect the water vapor transmission rate value of the film. The lower the hydrophilic or hydrophobic ratio in the edible film, the lower the water vapor transmission rate. In the treatment with or without the addition of gelatin, the average value of water vapor transmission rate meets the value of water vapor transmission rate of edible film according to Japanese Industrial Standard. The lower the water vapor transmission rate value, the better the quality of edible film in protecting the product, slowing down the oxidation reaction, and maintaining the moisture content of the applied product.

Thickness

Thickness is one of the characteristics of edible film that affects water vapor, product shelf life and one of the parameters that affect edible film on the product to be packaged or coated. High edible thickness minimizes the permeability value and protects the packaged product (Setijawati, 2017). Thickness is a physical property of edible film that determines the properties of edible film such as tensile strength, elongation and ability to withstand water vapor transmission (permeability) (Jacoeb, et al., 2014). The addition of material composition in the manufacture of edible film causes an increase in film thickness. Thickness affects the transmission rate of water vapor, gas and volatile compounds and other properties (Wang, et al., 2010). The average value of edible film thickness during the study ranged from 0.06-0.12 mm. The maximum edible film thickness according to Japan Industrial Standard is 0.25 mm. The thickness of edible film in the study has met the requirements based on the thickness of edible film according to Japanese Industrial Standard 1975. The lowest average value in the treatment without the addition of gelatin was 0.06 mm. The thickness of edible film is influenced by the nature, concentration and composition (Singh, et al., 2015). Factors that influence the manufacture of protein-based edible film include the form of protein (globular and fibrous), type of amino acid and pH. Based on research conducted by Santoso, et al. (2016) showed that the higher the concentration of protein added to the manufacture of edible film formed a thick edible film. The thickness of edible film during the study increased along with the addition of gelatin concentration. The addition of 0.25% to 1.5% gelatin increased between 0.08 to 0.12 mm. The increase in the concentration of gelatin added to the edible film resulted in an increase in total solids due to the increase in the concentration of ingredients that produced a stiff and fairly thick edible film. The high thickness of the edible film affects gas transmission which affects the durability of the packaged product. The high edible film thickness value results in the edible film having increasingly rigid and hard properties. The thickness of the edible film affects the packaged product, the thicker it is, the better its function as a food ingredient and resistance to microbial contamination (Kweon and Jung, 2023).

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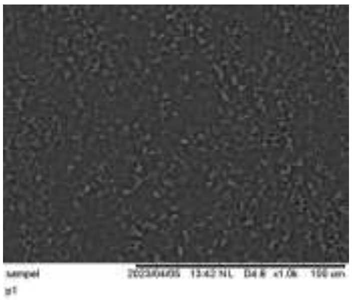
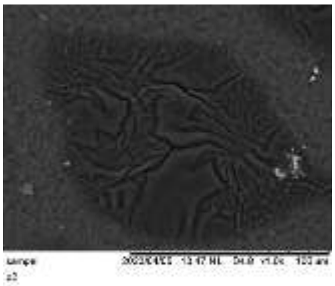
Tensile Strength

The average value of the tensile strength of the edible film of patient hydrolysate and chitosan with or without the addition of gelatin ranged from 9.44-18.61 MPa. A high tensile strength value of edible film can protect the packaged product from physical damage. The lowest average tensile strength value of casein hydrolysate and chitosan edible film in the treatment without the addition of gelatin was 9.44 MPa. The use of chitosan affects the number of hydrogen interactions (intermolecular and intramolecular), so that a crystalline phase is formed which can provide stiffness and hardness (Pitaloka, et al., 2021). The increase in the tensile strength value of edible films is influenced by the formulation of materials used in the manufacture of edible films (Cahyo, et al., 2021). The use of natural polymers such as chitosan and alginate can increase the tensile strength of edible films. Chitosan has the ability to form hydrogen bonds with other materials in the film matrix such as gelatin, starch or other natural polymers. The interaction that occurs between chitosan and other materials such as gelatin can strengthen the film structure and increase the overall tensile strength. Gelatin is a protein that can provide strength and elasticity to edible films. The addition of gelatin to edible film can form a strong polymer network that increases the tensile strength of the film. Research conducted by Qotimah (2020) showed the tensile strength value of edible film with the addition of gelatin ranged from 14.70-26.00 MPa. The highest average value of edible film tensile strength of casein hydrolyzate and chitosan with the addition of 1.5% gelatin was 18.61 MPa. Based on the results of the study, the higher the addition of gelatin concentration in the manufacture of edible film produces high tensile strength. The high tensile strength value is due to the large amount of protein content in gelatin collagen and the network structure formed affects the tensile strength produced. According to Hasdar (2011), the more protein contained in gelatin, the greater the tensile strength value produced. The amount of protein in edible films that contain large amounts of hydrophobic amino acids results in bonding between polymers resulting in higher and stronger concentrations. Edible films with high tensile strength values are good for products that require high protection while edible films with low tensile strength can be used for lightweight food products (Katili, et al., 2013). A high tensile strength value indicates that the edible film is good to use as a packaging material.

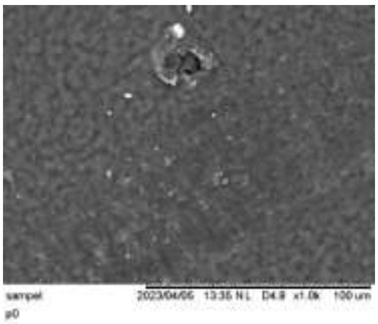
Scanning Electron Microscopy



Edible film With Gelatin 0,25% (P1)



Edible Film With Gelatin 0,5% (P2)



Edible Film Without Gelatin (P0)

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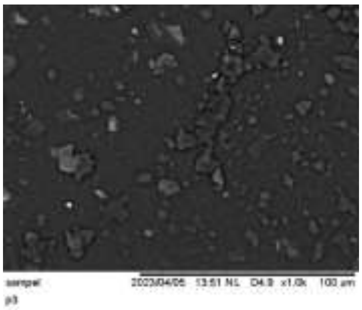
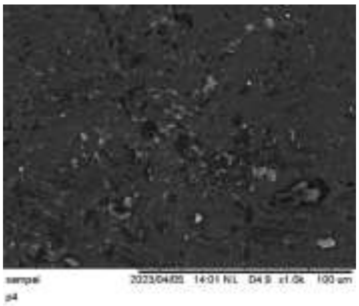


Edible Film With Gelatin 1% (P3)



Edible Film With Gelatin 1,5% (P4)

Figure 1. Edible Film Morphology Test Results Using Scanning Electron Microscopy

Scanning Electron Microscopy is a morphological test of casein hydrolysate and chitosan edible film with the addition of gelatin. The results of the Scanning Electron Microscopy (SEM) edible film test show that the edible film treatment without the addition of gelatin has a surface structure that is not too flat, less smooth and visible large white pores on the surface of the film. The polymer structure of chitosan edible film is in the form of long fiber polymer and large pores (Supeni, et al., 2015). Edible film treatment with the addition of 0.25%, 0.5%, 1% and 1.5% gelatin has an increasingly flat surface structure, there is a latitude in the addition of 0.5% gelatin and visible white molecules in each treatment. The white macro molecules found on the edible film surface indicate that the casein hydrolysate and chitosan edible film solution with the addition of gelatin during the homogenization process is not perfectly homogenized. Scanning Electron Microscopy (SEM) results of edible film treatment with 0.25% gelatin addition showed that the addition of gelatin caused the film surface to be smooth, but there were many granules. The results of Scanning Electron Microscopy (SEM) edible film treatment with the addition of 0.5% gelatin produced a smooth edible film surface, textured in the middle and there were white pores from the treatment of 0.25% gelatin addition, the results of Scanning Electron Microscopy (SEM) edible film treatment with the addition of 1% gelatin produced a smoother film surface and there were white pores and in the treatment with the addition of 1.5% gelatin produced a smooth surface but there were many white pores. The irregularity of the edible film surface is caused by the presence of macromolecules in the edible resulting from starch, fat and protein contained in the edible film polymer (Muslimah, et al., 2021). The surface of edible film treated with 1.5% gelatin addition produces a more textured surface than edible film treatments with 0.25%, 0.5% and 1% gelatin addition. Based on the results of the Scanning Electron Microscopy (SEM) test, the edible film treatment with 0.25% gelatin addition is the best for coating food products because the edible film surface produced has a relatively smooth texture and there are no large white pores. Edible films with smooth surface morphology without phase segregation and no cracks are desirable edible film characteristics to be applied to food products (Saiz, et al., 2020).

CONCLUSION

Based on the results of the study, it can be concluded that the addition of different concentrations of gelatin 0.25% to 1.5% produces a solubility value of 58.69-77.09%, swelling 48.79-81.06%, moisture content 20.57-6.59%, Water Vapour Permeability 0.000238-0.000105 g/cm2.24, Water Vapour Transmission Rate 0.000065-0.000039 g/cm2/day, thickness 0.06-0.12 mm and tensile strength 9.44-18.61 MPa. Edible film with the addition of 0.25% gelatin gives the best results to be used as a food product packaging based on physical, chemical quality testing variables and Scanning Electron Microscopy (SEM) results.

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