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Research Article

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Preparation and characterization of edible film from the belitung taro starch (*Xanthosoma sagitifolium*) and chitosan

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ABSTRACT

Edible film can be used as packing material alternative that does not give negative impact to the environment since it uses cheap and renewable sources. Belitung taro starch (Xanthosoma sagitifolium) and chitosan are used as the ingredients in the making process of edible film with glycerol as the plasticizer. The characterizations of edible film includes thickness, tensile strength, maximum strain, Scanning Electron Microscopy (SEM), and Fourier Transform Infrared Spectroscopy (FT-IR). The obtained result was addition of chitosan 0.5% (PK1) is the best edible film if observed from tensile strength of 84.34 MPa and chitosan 1.5% (PK5) from maximum strain of 49.1%. SEM morphologic photograph shows the surface of the film that is homogeneous and without any fractures.

Keywords: edible film, belitung taro starch, chitosan

INTRODUCTION

Plastic packaging is one of the most used kind of packaging in food and beverage industries. Unfortunately, it is often used for a one-time purpose only and is a non-biodegradable material that contributes as one of the biggest waste in the environment. The biodegradable and environment-friendly edible film is regarded as one of the alternatives to food packaging.

In the past few years, researches about the production of edible film are starting to develop. Researches lead to the development of the usage of new materials, development of film producing methods and the improvement of characteristics of the film and its usage. Many farm-produced materials such as cassava [1], rice [2,3], corn [4-6], belitung taro [7-9], mung bean [10], potatoes [11,12], bananas [13], wheat [14], and sea produces such as seaweed [15], carrageenan [16] has been tested in the production of edible film to achieve better quality of the film. But, according to properties of the film that is produced, such as the tensile strength, is still unsatisfactory. Thus, another alternative for the raw material of the edible film still needs to be found.

Edible film made from starch is less elastic and is hydrophilic, and to cope with this, another additional material needs to be added to improve its mechanical characteristic. The addition of glycerol as the plasticizer, is intended to improve its elasticity and to weaken the stiffness of the polymer, and to improve the flexibility of the polymers. Glycerol has the ability to decrease the internal hydrogen bond in the intermolecular bond [2].

Belitung taro starch can be used as the material of edible film production. Belitung taro (*Xanthosomasagitifolium*) is chosen as the source of starch because of its cheap price, its renewability, its biodegradability, and it is edible. Belitung taro contains 34.2% carbohydrate [17]. What makes taro better than other materials is its starch is easy to digest. This is caused by the small size of the starch granules and it also contains quite a lot of amylose (20-25%) [18].

Chitosan is one of the co-polymers of D-glucosamine and N-acetyl-D-glucosamine [6]. Chitosan is obtained from N-deacetylation of chitin [19, 20]. Unlike the insoluble characteristic of chitin in most solvents, chitosan is soluble in some organic and an organic acids and also forms cationic polymer [12]. Currently, there are many applications of the usage of chitin and chitosan and their derivatives in food industries, food processing, biotechnology, agriculture, pharmacy, health, and environment [12, 19, 21, 22].

The usage of starch and chitosan in the production of edible film has been studied many times before. But, the usage of starch from belitung taro and chitosan has never been studied before. This paper illustrates the production and characterization of edible film made from belitung taro starch and chitosan with glycerol as its plasticizer for food packaging purpose.

EXPERIMENTAL SECTION

2. 1 Materials

Belitung taro tuber is bought in a traditional market in Padang, Indonesian. Food grade of glycerol and acetic acid (Merck) is obtained from Novalindo Company (Padang, Indonesian). Chitosan is obtained from Chemix Company (Yogyakarta, Indonesian). Belitung taro starch is made from Belitung taro tuber using modified RF Sinaga's method [23].

2.2 Film preparation

Belitung taro starch 5% (w/v) and glycerol 2% (w/v) are gelatinized in 120 mL diluted water. Chitosan with variations as follows: 0.5%, 0.75%, 1.0%, 1.25%, and 1.5% (w/v) is dissolved in 30 mL acetic acid 1% (w/v) which is heated for 10 minutes on the temperature of 65 ^{o}C. Both solutions are mixed so the total volume of the mixture become 150 mL. The mixture is then heated at the temperature of 65 ^{o}C for 30 minutes. The mixture is poured to a 30 cm x 18 cm x 1 cm glass plate, and is dried at the temperature of 70 ^{o}C for seven hours. Later, the mixture is cooled at room temperature and film layers is removed from the cast.

2.3 Characterization of ediblefilm

2.3.1 Thickness of belitungtarofilm

Thickness of edible film is obtained from measurement in five different locations using screw micrometer with 0.01 mm accuracy. The mean values are used to calculate mechanical properties. Measurement of thickness is conducted at the temperature of 25 ^{o}C.

2.3.2 Mechanical properties

Mechanical properties that are measured are tensile strength and maximum strain with using a Universal Testing Machine *COM-TEN testing machine 95T series* model. The tests are carried out according to the ASTM D638 2005 [24].

2.3.3 Scanning Electron Microscopy (SEM) characterization

The morphology of edible film's surface is analyzed using Scanning Electron Microscopy (SEM) Hitachi S3400N. The accelerating voltage is 8.00 kV with the working distance of 5.7 mm and 6.0 mm.

2.3.4 Fourier Transform Infra-Red (FT-IR) Spectroscopy

The functional cluster inside edible film is analyzed using FT-IR Thermo Nicolet iS10. Spectra is recorded at a spectral wave with obtained wave number between 500 cm^{-1} and 4000 cm^{-1}.

RESULTS AND DISCUSSION

Edible film made from starch and chitosan (PK1, PK2, PK3, PK4, and PK5) that is produced has soft surface, clear, transparent, homogenous and flexible. The color of chitosan is yellow, so, addition of more chitosan causes the film's color to be more yellow (Figure 1.a – 1.e). Formation of film is based on gelatinization process when starch's granules expanded in size and exploded which will spread to all parts and forms colloid dispersion in water when flour is heated. Gelatinization process is marked with the color change in flour mixture that is plasticized by the glycerol and mixture will become thicker. Drying process will result to shrinking due to released water, so gel will form a stable bioplastic. Starch with high amylose level will form harder gel [2].

Figure 1. Edible film PK1 (a), PK2 (b), PK3 (c), PK4 (d), PK5 (e)

3.1 Thickness of ediblefilm

Edible film thickness that is produced during research is around 100 – 200 µm (Table 1). Film thickness tends to raise as more chitosan is added.During gelatinization process, starch clotting takes place when denaturization happened. That clotting forms water-absorbant gel. Film mixture viscocity is affected by water absorbing capacity on materials that will affect film thickness. Usage of polysacaride as the main material to this edible film causes a high viscosity that will produce greater thickness [2]. Usage of film as packaging must be adapted to products it will pack and is affected to film thickness. Film mechanical characteristic is also affected by film thickness.

Table 1. Thickness of belitung taro starch edible film and chitosan

Film name	Starch concentration (%)	Chitosan concentration (%)	Thickness (µm)
PK1	5	0,50	100
PK2	5	0,75	100
PK3	5	1,00	100
PK4	5	1,25	180
PK5	5	1,50	200

3.2 Edible film mechanical characteristics

The components of belitung taro starch edible film are belitung taro starch, chitosan, and glycerol, which affect the produced edible film's mechanical characteristics. From previous researches, edible film from belitung taro starch has tensile strenght of 25.72 MPa [8]. Addition of chitosan gives higher strain tensile strenght (Fig. 2). The highest tensile strenght is recorded when 0.5% chitosan (PK1) is added, which is 84.34 MPa, and it decreases as more chitosan is added. On the other hand, a different result is reported that by adding thermoplastic chitosan, it gives a significant effect to the decrease of tensile strenght of the mixture based on corn starch and thermoplastic chitosan [4].

The more hydrogen bonds found in edible film, the stronger its chemical bond will be. Stronger chemical bond needs big amount of energy to break the bond, thus, to reach maximum strain needs bigger force. Hydrogen bonds formed also cause the increase of matrix amount inside the edible film. During drying process, glatinicized starch will bond each other forming a compact and strong film matrix [25].

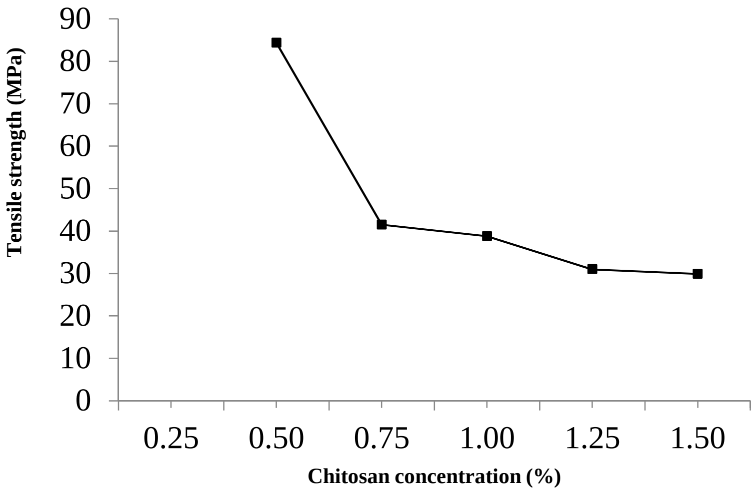


Figure 2.Tensile strength of edible filmbelitung taro starch-chitosan

From previous researches, edible film made from belitung taro starch has maximum strain of 14.4% [8]. Belitung taro starch edible film with variations of chitosan addition give higher maximum strain (Fig. 3). The higest maximum strain is obtained when adding 1.5% chitosan (PK5) which is 49.1%.

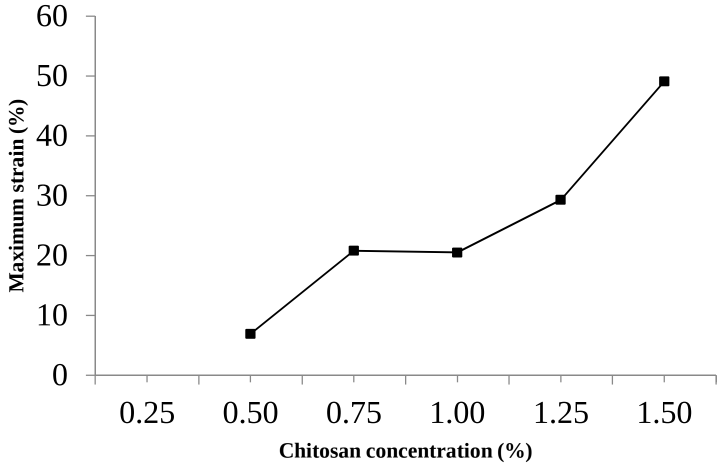


Figure 3.Maximum strainof edible film belitung taro starch-chitosan

Maximum strain is affected by the decrease of bioplastic uniformity due to the increase of amorf parts. During the production process of edible film, adamage to crystal structure of the starch takes place due to high temperature in gelatinization mechanism and mixing. Plasticizer is pushed into starch matrixes by the change of starch micro-structure. Effectivity of glycerol as plasticizer in biodegradable plastic is caused by the small size of glycerol molecules compared to starch molecules, thus it is relatively easy to penetrate between the polymer chains in starch. Next, plasticizer will decrease starch inter-molecular interactions (cohesion) by forming hydrogen bonds between hydroxyl chain in starch molecules and plasticizer. Macro-molecular chains inside starch will again form that results to the increase of film flexibility [26].

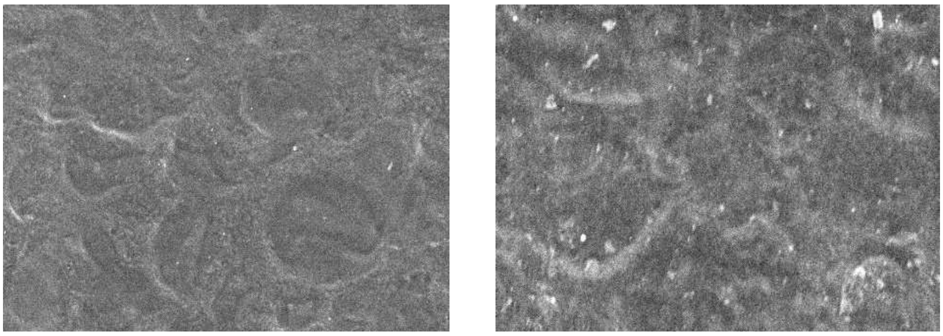
From the edible film, tensile strength of around 29.89 – 84.34 MPa is obtained with maximum strain of around 6.9 – 49.1%. According to Table 2, if mechanical characteristic of belitung taro starch and chitosan edible film is compared to edible films from previous researches, belitung taro starch and chitosan edible film has better mechanical characteristics.

Table 2. Comparison of the mechanical characteristics of edible filmbelitung taro starch-chitosanand edible film some previous studies

Research	Tensile strength (MPa)	Maximum strain (%)	Elongation of break (%)
Belitung taro starch-chitosan	84.34	49.1	-
Corn starch-chitosan [4]	1.5	-	108
Corn starch-chitosan [6]	20	9.09	-
Mung bean starch-gliserol-chitosan [10]	38	-	0.75
Potato starch-chitosan [11]	10.61	-	-
Cassava starch-chitosan [11]	9.27	-	-
Chitosan-potato starch [12]	13	-	3
Wheat starch-chitosan [14]	48	-	4.6
Breadfruit starch-chitosan [22]	16.34	6.0	-

3.3 Morphology analysis with Scanning Electron Microscopy (SEM)

Visual observation of edible film shows that edible film has soft surface. Surface morphology of edible film is decided using SEM with 1000x magnification. The micrograph shows that PK1 film that is produced doesnot have any fractures and is homogenous (Fig.4a). A different result is obtained from PK3 film that is less homogenous (Fig.4b). The presence of white peaks shows dispersed chitosan particles inside starch matrixes, which means not all chitosan is dissolved in acetic acid solution. The more chitosan added, the less the solubility will be, that causes a decrease of the mechanical characteristic values (tensile strength and maximum strain). The same result is also reported which is film layer that contains starch nanoparticles become uneven and rough, and with addition of 15% nanoparticles will cause aggregation of the nanoparticles and micro phase separation between nanoparticles and matrixes [5].

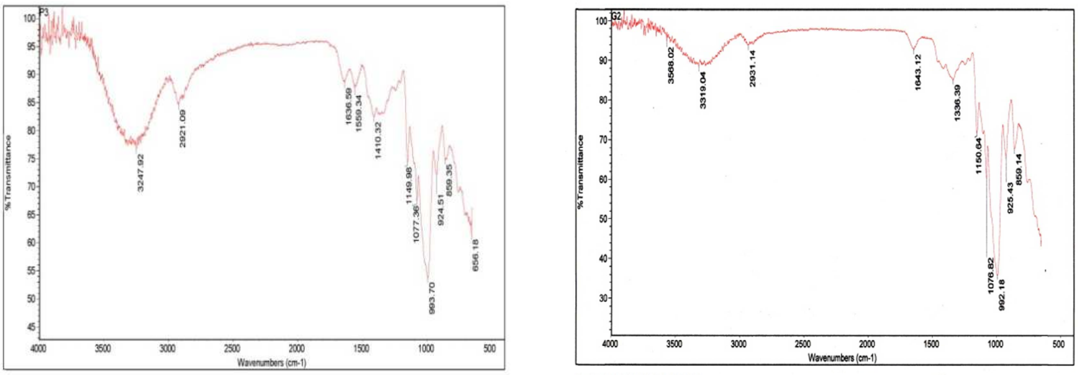


(a) (b)

Figure 4. SEM micrograph (x 1000) of edible film PK1 (a), PK3 (b)

3.4 Analysis with Fourier Transform Infra-Red (FTIR)

Analysis of functional chains in PK3 edible film is conducted using FTIR. Figure 5a shows that the main FTIR spectra of PK3 edible film which is alkene groups at absorption of 924.51 and 993 cm^{-1}, C-O-C stretching of 1077.36 and 1149.98 cm^{-1} C-O stretching di-alkyl ether; C-H alkene bending is substituted at 1410.32 cm^{-1}; carboxyl anion stretching at 1559.34cm^{-1}; C=C non-conjugated alkene amides at 1636.59 cm^{-1}; C-H alkene stretching at 2921.09 cm^{-1}; and O-H vibration polymeric association stretching groups at absorption of 2931.13 cm^{-1}.



(a) (b)

Figure 5. FTIR spectra of edible film PK3 (a), FTIR spectra of edible filmbelitung taro starch (b)

PK3 film FTIR spectra has a similarity with belitung taro starch film spectra (Fig.5b). This similarity means that both has similar functional clusters even they experience a little turbulence at the wave number. The biggest difference between both spectra is on OH groups of PK3 film has a high and wide intensity due to addition of OH groups from chitosan. Greater interaction and water absorbency on edible film can cause a widening in the absorption of OH groups [27]. This result has a similarity with previous research [4], which was a high peak at 3300 cm^{-1}, 3280 cm^{-1}, and 3286 cm^{-1} that identifies the presence of OH groups.

CONCLUSION

The addition of chitosan 0.5% (PK1) is the best edible film if viewed from its tensile strength of 84.34 MPa and chitosan 1.5% (PK5) if viewed from its maximum strain of 49.1%. SEM morphological photos show that the surface of edible film PK1 structure doesnot have any fractures and is homogenous. Functional cluster test result from FT-IR shows a significant absorption on OH groups.

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