Development of Edible Films from Modified Oil Palm Trunk Starch by Acetate Buffer for Instant Seasoning Packaging

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ARTICLE INFO

Article history
Received August 6, 2025
Revised September 28, 2025
Accepted September 29, 25

Keywords
Acetate buffer hydrolysis
Edible film
Oil palm trunk starch
Primary packaging

ABSTRACT

This research aims to produce edible film from non-productive Oil Palm Trunk (OPT) starch. Starch from OPT contains high amylose, so it is easier to modify. In this study, OPT starch was altered through hydrolysis with an acetate buffer solution at pH 7, followed by a bleaching stage. Meanwhile, the edible film-making process involved mixing OPT starch with various types of plasticizers, including gelatine, glycerol, CMC, and chitosan, before the molding and drying process. The best edible film was obtained from starch modified with an acetate buffer solution (20 mL) and Carboxymethyl Cellulose (CMC) plasticizer, processed at 80 °C with a mixing time of 30 minutes. Edible films with these variations had the highest tensile strength, elongation, and Young's modulus values, respectively, of 29.6342 MPa, 1.1333%, and 4.3092 MPa. The results of the solubility test indicate that the primary packaging product, when applied as an edible film for instant noodle seasoning packaging, can help mitigate environmental pollution problems. It dissolves completely in cold water and immediately dissolves when poured over hot water, along with instant noodles. However, there needs to be improvement in the elongation value so that edible film products can protect the contents of their packaging from external influences, including environmental conditions, perfectly when used. The result of this research is the first finding on the application of acetate buffer-modified OPT starch as a primary packaging material, similar to edible films currently on the market.

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1. Introduction

The increase in production and consumption of fast food products in Indonesia is in line with technological development in the global food industry. These products give convenience to customers in their servings, so it isn't surprising that many people like to consume fast food, one example of which is instant noodles. However, behind the convenience, a significant problem arises, namely, the accumulation of plastic waste from food packaging. The packaging is primary and secondary. Primary packaging is the type of packaging that comes into direct contact with the food it contains, while secondary packaging is the opposite. If associated with instant noodle packaging, an example of primary packaging is the plastic wrapper for instant noodle seasoning. According to the *World Instant Noodles Association* (WINA), Indonesian people's consumption of instant noodles was 12.64 billion packs in 2020 [1].

Based on the data, it can be seen that instant noodle seasoning packaging waste reaches two to three times the amount of instant noodle packaging produced. Considering that one package

typically contains two or three packets of seasoning and its complements, such as oil, chili powder, and dried vegetables. Therefore, innovations are needed to reduce plastic use in Indonesia. Efforts to reduce plastic waste can be done in various ways, one of which is making edible film. Edible film is a thin plastic layer used as primary packaging [2] and can be consumed because it's made from organic materials, such as amylum (starch), lipids, and proteins. So, it's safer for health. Edible film is an innovative packaging material that also functions to preserve food in the long term, as it prevents the entry of unwanted components, both biotic and abiotic, into the food [3]. The principle of edible film application is to seal food on its surface, and the type of application depends on the food being packaged and its storage conditions [4], [5].

By using edible film, the level of pollution in plastic waste from instant noodle seasoning packaging can be reduced, as the edible film dissolves with the seasoning without altering the taste and aroma before human consumption. Likewise, over long periods, biochemical and physicochemical changes in the packaged noodle seasoning are likely to occur. Edible films must ensure food safety and enhance the properties of the food they package [6], [7]. Additionally, edible film is more easily degraded than plastic packaging, which can take decades to decompose. The ease of degradation is supported by the structure of edible films, which are based on biopolymer hydrocolloids. Hydrocolloids that make up edible films can be polysaccharides (amylum, cellulose, chitosan, alginate, and so on) [8], protein (collagen, gluten, gelatine, vegetable protein, casein) [9], lipids (wax, paraffin, jojoba oil, fatty acids) [10], and a combination of the three, or from various biomass [11], [12].

One of the polysaccharides is found in oil palm trunks. Oil Palms that are 20-25 years old are ready for replanting. In general, oil palm trunks that have been replanted are only chopped and mixed with the soil of the oil palm replanting land. In the pit of the oil palm trunk, there is a high amylum content of 96%, indicating potential use as a raw material in edible film production. Amylum, including palm starch, is very promising for making edible films because it is obtained from plants that are generally resistant to climate change and are available in abundant and sustainable quantities, making it easy to get [13], [14]. Moreover, Indonesia is one of the countries with the largest area of oil palm plantations in the world. This is an excellent opportunity in efforts to reduce plastic waste in Indonesia. However, previous attempts to obtain amylum from oil palm trunks have not yielded optimal results. Several researchers have extracted amylum from oil palm trunks [15], [16] and [17]. They extracted palm amylum using sodium metabisulfite, both with and without a catalyst. The resulting yield was still very low, with a maximum value of only 2.02%. Furthermore, amylum cannot be directly used as a raw material for bioplastics or edible films, as edible films made directly from unmodified amylum have poor mechanical properties, limiting their use. Amylum is not as plastic as synthetic plastics; it tends to be brittle and has low elasticity [18], [19]. Its high hydrophilic properties also pose a challenge in its application. Edible film can be made directly from sago starch without modification, and produces a dense and stiff edible film [20]. Sago starch is almost similar to palm starch, which has a high amylose content in its starch components. The characteristics of starch originating from plant trunks are generally the same in terms of amylose content compared to amylopectin. The ratio of amylose and amylopectin depends on the botanical origin of the plant [21]. Amylose can form hydrogen bonds between glucose when heated, so that starch can retrograde due to high water retention in its network, thus harming its elasticity and easily breaking when folded [22].

There are ways to improve amylum properties through structural modification. Modification can be achieved through hydrolysis, acetylation, crosslinking, or a combination of these methods. The most widely used method is acetylation, but this method is not time-efficient, and the solvent used is relatively expensive. The acetylation method tends to be lengthy because the amylum molecular bonds are powerful, making them difficult for reagents (solvents) to penetrate. If the reaction is carried out for a short time, structural modification will only occur on the amylum surface (the acetylation reaction is less successful) [23]. The crosslinking method is preferable, but it risks high ash content because it typically employs large amounts of inorganic compounds. The most economical method is hydrolysis. The hydrolysis method can cause a change in amylopectin to amylose by breaking the amylopectin branches, allowing the reaction to occur more quickly. However, if the pH used is too low, damage to the amylose and amylopectin structures can occur [24]. The reaction that combines acetylation and hydrolysis methods can be modified by using a buffer compound with a pH close to neutral, such as an acetate buffer. This method was previously

carried out, but these researchers only discussed amylum modification and had not yet reached the application stage [25].

Besides that, there are several studies on the manufacture of *edible film*s from plant amylum, including the manufacture of *edible film*s from cassava [26]. Other studies include the manufacture of *edible film*s from taro amylum and glycerol plasticizer [27]. There is also research from Tafa et al. [28] which also used glycerol as a plasticizer to make edible films from tef amylum. Edible films produced with good tensile strength, specifically ranging from 17.97 to 24.25 MPa; however, the elongation was still very low, ranging from 1.21% to 2.03%. In contrast to the research, which used additional chitosan, *edible film* from kepok banana amylum experienced an increase in tensile strength, but also decreased elongation [29]. The results of both studies still show weakness in the physical and mechanical properties of the *edible film* products produced. Both properties can be improved by using the right plasticizer. Plasticizer is an organic compound that generally has a lower molecular weight than the primary raw material of edible film, which can increase the mechanical properties [30]. There are various food-grade plasticizers suitable for edible films. These plasticizers have varying effects on the properties of edible films. Some of them are from the type of polyol, glycol, sugar, and lipid [31], [32] The right plasticizer can increase the strength, durability, and flexibility of edible film [33], [34]. This research differs from previous research. Efforts to improve the characteristics of edible films were carried out by modifying OPT starch with an acetate buffer. Additionally, the direct application of modified starch combined with various plasticizers to edible film products for instant noodle seasoning packaging was also carried out. The results of this research have not been previously reported.

2. Research Methodology

2.1. Materials

The raw materials used were oil palm trunks obtained from the experimental garden owned by LPP Polytechnic in Rangkas Bitung, West Java, which were 25 years old and no longer productive. The chemicals used in this study were aquadest purchased from CV Progo Mulyo; gelatine, glycerol, chitosan, Carboxymethyl Cellulose (CMC) purchased from Toko Beli Kimia Jogja (food grade); Acetate buffer (CH_3COOH and CH_3COONa) (pa, Merck); H_2O_2 35%; and NaOH (pa, Merck).

The tools used in making *edible film*s are knives, planer machine (Modern M-2900), analytical balance (Kern ABJ 220-4NM), thermometer, hot plate (Cimarec), oven (Memmert UN30), filter cloth, basin, 120 mesh sieve, 60x40x3 cm pan, beaker glass, measuring flask, thermometer, stirring rod, volume pipette, plastic warp, hand sealer (H&L Impulse sealer), magnetic stirrer, waterbath (Memmert WNB 22), moisture analyzer (Ohaus), and aluminium foil.

2.2. Procedures

1) Preparation of Raw Materials

The oil palm trunk is cut into 1-meter lengths starting from the top. The hard skin and pith are separated. The pith is grated into wood powder, and the obtained wood powder is placed in a container. Clean water is then added in a 1:1 ratio, and the mixture is filtered and squeezed. The dregs are discarded, while the water containing starch is allowed to precipitate for 12 hours, producing a wet amylum. The wet amylum is washed with aquadest, then precipitated again for 12 hours [35]. The wet amylum obtained is then oven-dried at a temperature of 600°C for about 13 hours until the dry amylum is obtained. Dry starch was taken to characterize its functional groups using FTIR.

2) Amylum Modification of Oil Palm Trunk

Amylum was modified via hydrolysis in an acetate buffer solution at pH 7. This buffer was prepared by titrating acetic acid into a 10.85 M sodium acetate solution to achieve the target pH. For the modification, 10 grams of starch were dissolved in varying volumes (18, 20, 22, 24 mL) of the pH 7 buffer. The mixture was then stirred and heated at 40°C on a hotplate until it thickened, followed by drying at room temperature. After drying, the modified amylum was sieved in two stages: the first stage using an 80 mesh sieve, then the second stage using a 120 mesh sieve [25].

3) Bleaching Modified Amylum

After drying, the amylum is bleached using 5% hydrogen peroxide (H_2O_2). The bleaching process begins with 50% H_2O_2 diluted to 5% H_2O_2 so as not to damage the amylum. Then, the

modified dry amylum is prepared with a ratio of amylum to H_2O_2 of 1:4. Afterward, H_2O_2 is added to the NaOH solution until the pH reaches 11. The modified amylum is placed in a beaker containing H_2O_2 at pH 11 and then immersed in a water bath at a temperature of 50-60°C for 30 minutes. Bleaching is done 2 times in the same way. FTIR characterized the modified starch with acetate buffer at various volumes and after bleaching.

4) Making Edible film

Edible film production follows the previous research procedure, by weighing 2 grams of modified amylum (18, 20, 22, 24 mL), then adding 1 gram of plasticizer (chitosan, glycerol, gelatine, and CMC) into a 100 mL beaker, and then adding distilled water up to 40 mL [36]. The amylum is heated with a hot plate stirrer to form a gel when the temperature reaches 80°C and is maintained at this temperature for 30 minutes. The gel is then cooled to 50°C. After that, it is printed on a 9x9 cm sheet and put in the oven at a temperature of 60°C until dry. The dried *edible film* is removed from the mold. Then, the edges of the edible film are glued with a hand sealer. One side is left to insert instant noodle seasoning, and then it is glued again [7]. A dried edible film sheet (approximately 2 cm x 2 cm) was used to characterize the changes in its chemical structure using FTIR.

5) FTIR Test

FTIR (Fourier Transform InfraRed) test using Nicolet Avatar 360 RI to determine the functional groups in compounds formed from the hydrolysis and synthesis of *edible film*. The identified wavelengths are around 3600-3300, 1750-1630, 1400-1300, 1100-900 cm^{-1}. The wavelengths belong to amylum compounds and bioplastics (including *edible film*s).

6) Solubility Test

The solubility test is performed by cutting the edible film into 3 cm x 3 cm pieces. The edible film is oven-dried at 100°C for 30 minutes. Then, the edible film is weighed as the initial dry weight (w0) and soaked for 15 minutes. The undissolved edible film is removed and dried in an oven at 100°C for 2 hours. The edible film was taken and stored in a desiccator for 10 minutes. Then it was weighed to obtain the dry weight of the edible film after soaking (w1). The percentage of edible film solubility in water is calculated using the equation:

$$\text{Solubility (S)} = \frac{w0-w1}{w0} \text{ x } 100\% \quad (1)$$

Additionally, during the soaking process, observations and recordings are made of the dissolution time of the edible film until it has completely dissolved.

7) Tensile Strength and Elongation Test

The tensile test sample in the form of a dumbbell follows the ASTM D638 standard. Tensile strength and elongation test on edible film using Universal Testing Machine (UTM). The tensile strength value is calculated using the formula:

$$\text{Tensile strength } (\sigma, \text{ in MPa}) = \frac{\text{maximum force (N)}}{\text{initial cross-sectional area } (mm^2)} \quad (2)$$

$$\% \text{ Elongation} = \frac{\text{Final length} - \text{Intial Length}}{\text{Initial Length}} \text{x } 100\% \quad (3)$$

Based on Japanese Industrial Standard (JIS) Z1707, the tensile strength, elongation, and Young's Modulus values for edible film products are at least 0.39 MPa, 50% and 0.35 MPa, respectively.

8) Moisture Content Test

Moisture content tests are conducted to predict the quality of edible films used for storing and packaging food. The moisture content test is performed using a moisture analyzer, allowing for the measurement of the moisture content in the edible film. According to SNI 06-3735-1995, the maximum moisture content requirement for edible film is 16%.

3. Results and Discussion

3.1. Fourier Transform InfraRed (FTIR) Analysis of Oil Palm Trunk Amylum

In terms of quantity, the amount of dry amylum obtained from 7.6 kg of oil palm trunk shavings was 57.5 grams. However, to ensure that the results of the shavings and squeezing were amylum, an FTIR test was carried out.

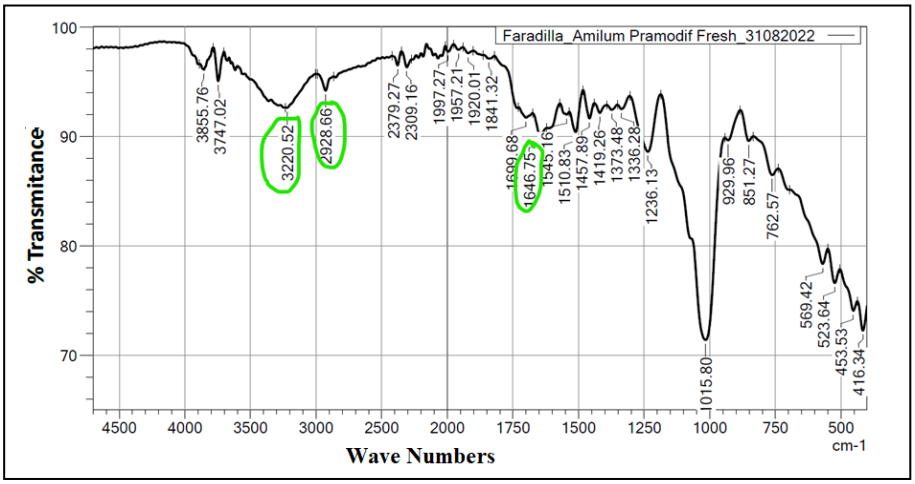

Fig. 1. FTIR spectra of OPT amylum

The FTIR spectrum of the OPT sample can be seen in Fig. 1. The spectrum shows strong absorption at wave numbers 3220.52 cm^{-1}, 2928.66 cm^{-1}, and 1646.75 cm^{-1}, which are respectively the stretching vibrations of the O-H group, C-H from CH_3, and C=O, which make up amylum. This spectrum is not much different from the FTIR spectrum of Banggai sweet potato starch from the previous research results [37], which has stretching vibrations at wave numbers 3520 cm^{-1}, 2927.94 cm^{-1}, and 1645.28 cm^{-1}. This proves that OPT contains high amounts of amylum (starch).

3.2. Modification of Oil Palm Trunk Amylum

Amylum modification was carried out using a pH 7 acetate buffer solution with volume variations of 18 mL, 20 mL, 22 mL, and 24 mL. From the modification results, it was found that the more the acetate buffer solution, the higher the amylum content produced. However, the color of the starch became darker. The high starch content is evident in the results of the amylum component bond index, particularly at the O-H wave number, which increases when using a buffer with a volume of 24 mL (Fig. 2).

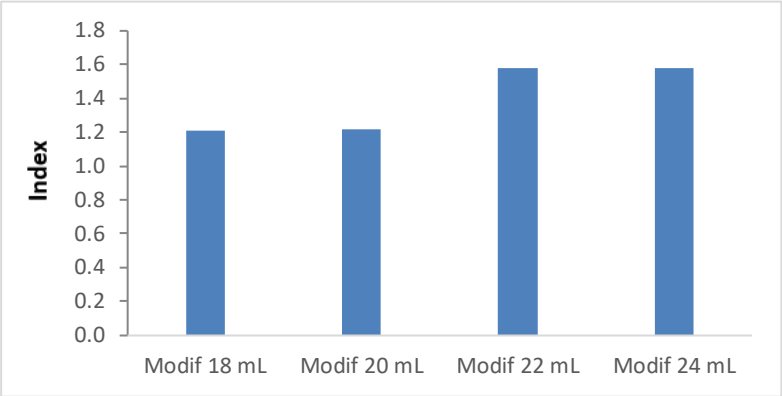

Fig. 2. O-H group index of modified starch with varying acetate buffer volume

The reaction of amylum modification with the acetate buffer is shown in Fig. 3. The hydroxyl group in amylum attacks the C atom that binds the carbonyl group in the acetate buffer, thus obtaining the intermediate structure of amylum (starch) acetate [38]. Because the acetate buffer is a mixture of sodium acetate and acetic acid, the carbonyl groups of both compounds have the same potential to react with starch (competition for reaction occurs) with the same type of hydroxyl group, namely the primary hydroxyl group in starch. However, the sodium ions in the acetate buffer are more likely to act as catalysts compared to the hydrogen ions (protons) of acetic acid. Then, the intermediate releases protons (H^+ ions), sodium ions, and water molecules, thus forming starch acetate.

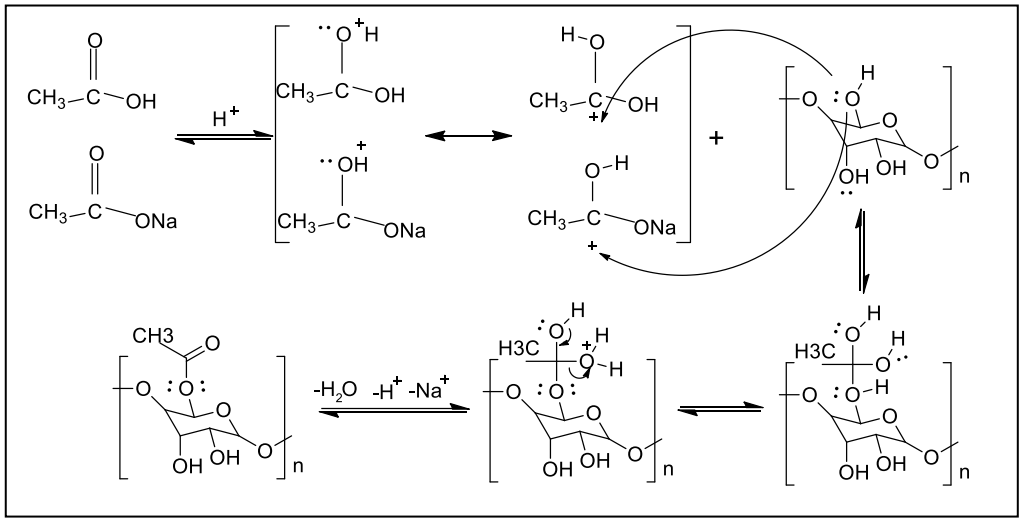

Fig. 3. Reaction between the modified starch and the acetate buffer

The starch acetate formed is unstable because the acetyl group is easily released during the reaction. Furthermore, the reaction is reversible. The increase in the C=O group, representing the carbonyl group in the acetyl group, increased the index from 1.74 to 2.82. The spectra showed a stronger absorption peak than when the starch had not been modified. This instability indicates the presence of varying acetyl groups, with a tendency to easily detach from the main chain structure of starch (as evidenced by the C=O index, which varies or shows no tendency, even with the addition of an acetate buffer). This is what causes hydrolysis-modified starch to lack the perfect characteristics necessary to possess the same properties as those of acetate-based edible films in general. However, some test results show values that meet JIS standards. The use of an acetate buffer can only maintain the pH of the starch, preventing it from deteriorating quickly, while also increasing the short-chain amylose content, without focusing on the inclusion of acetyl groups in the starch chain.

3.3. The Synthesis of Edible Film

Of the plasticizers tested for OPT starch, glycerol performed poorly. Across all acetate buffer volumes, glycerol-produced films were difficult to release from molds, remained wet after 24 hours of heating, and lacked cohesion, resulting in a crumbly, soil-like texture. In contrast, films with a gelatine plasticizer demonstrated superior properties. Although still somewhat brittle, they released from molds successfully and exhibited a smooth, shiny surface on the mold-facing side.

Edible film with CMC plasticizer has the highest tensile strength value of all types of plasticizers. However, the visual appearance of edible film with chitosan plasticizer is better than that of CMC, because CMC produces an edible film with a less smooth surface when viewed under sunlight. The optimal formulation for producing edible film from OPT starch involves using 2 grams of modified starch and 1 gram of plasticizer (50%). Because the resulting edible is black, a bleaching process is carried out on OPT starch using H_2O_2, where H_2O_2 is adjusted to a pH of 11.

Fig. 4. Edible film replaces instant noodle seasoning

The bleaching process on polysaccharides using H_2O_2 can only be maximized if the H_2O_2 solution has a basic pH, specifically pH 11 [39]. At pH 11, H_2O_2 decomposes into H_2O and free O_2. Free oxygen reacts with the pigments in the starch, so that the color-carrying pigment compounds are lost along with the oxygen gas released during the bleaching process [40]. The bleaching process using H_2O_2 is more popular and safer, because the reaction results are not harmful to human health and are more environmentally friendly (there are no side effects that are harmful to the environment).

In the FTIR results of edible films, combined peaks were found between OPT starch and its respective plasticizers. According to the results, the highest C-O bond index was observed in the edible film with CMC plasticizer. An increase in this index indicates that a chemical reaction has occurred, also marked by a decrease in the O-H index and a shift in several peaks.

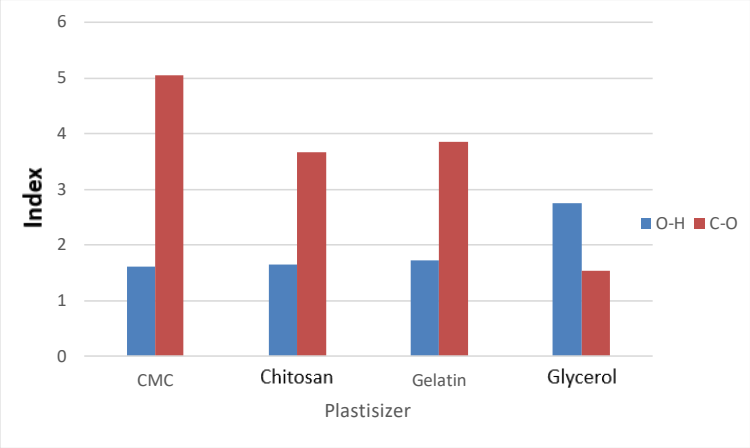

Fig. 5. Edible film index with various plasticizers

3.4. Mechanical Properties of Edible Film: Result

For edible films with gelatine plasticizer using acetate buffer volumes of 22 mL and 24 mL, tensile strength and elongation tests can't be carried out because the sample is very brittle. For edible films with glycerol plasticizer, using any variation of acetate buffer volume, tensile strength tests can't be carried out because the texture resembles that of soil, being damp and sticky on the plastic mold. So that when it is tried to be removed from the mold, it is destroyed. The difference in the results is due to differences in plasticizer properties [41]. Glycerol can soften the structure of some materials, making them softer and slower to dry. That is what prevents edibles that use glycerol plasticizers from being tested for their mechanical properties. Gelatine plasticizers tend to be non-polar and can hinder the reaction of starch with water, making it difficult for starch to gelatinize and resulting in more fragile edible films. Chitosan plasticizer is difficult to dissolve in water, but not as tricky as gelatine. This property is due to its hydrogen bonds, which can form a rigid crystal structure [42]. Therefore, if chitosan is used as a plasticizer in excess, it will reduce the tensile strength of edible films. This differs from CMC, which can form a more stable structure through hydrogen bonds. The use of CMC as a plasticizer can increase the tensile strength value; however, further study is needed on its effect on the elongation at break value. The Japanese Industrial Standard (JIS) specifies a minimum standard value for the Young's modulus of 0.35 MPa, indicating that all edible films tested have met this standard [43].

Table 1. Tensile Strength and Elongation at Break of Edible Films with Various Plasticizers

Acetate Buffer Volume (mL)	Tensile strength (MPa)			Elongation at break (%)		
	Chitosan	***Gelatine***	***CMC***	***Chitosan***	***Gelatine***	***CMC***
18	5.58 ± 0.80	16.67 ± 1.09	13.45 ± 0.94	1.07 ± 0.28	0.8 ± 0.11	1.07 ± 0.08
20	12.76 ± 0.03	1.07 ± 0.30	29.63 ± 1.09	0.87 ± 0.06	0.27 ± 0.01	1.13 ± 0.39
22	4.91 ± 0.24	-	6.79 ± 0.93	0.87 ± 0.07	-	0.93 ± 0.07
24	7.75 ± 0.60	-	16.63 ± 0.62	0.93 ± 0.07	-	1.04 ± 0.05

These values are the average ± SD with n = 3.

Table 2. Young's Modulus Value of *Edible Film* Based on Variations in Acetate Buffer Volume

Acetate Buffer Volume (mL)	Young's modulus (MPa)		
	Chitosan	***Gelatine***	***CMC***
18	0.57 ± 0.08	2.08 ± 0.07	1.33 ± 0.28
20	1.49 ± 0.26	0.37 ± 0.09	4.31 ± 0.09
22	0.67 ± 0.18	-	0.72 ± 0.03
24	1.10 ± 0.04	-	0.96 ± 0.12

These values are the average ± SD with n = 3.

The table above shows that the tensile strength and Young's modulus values for edible films meet the standards, regardless of whether chitosan, gelatine, or CMC is used as a plasticizer. The JIS standard for tensile strength is a minimum of 0.39 MPa. However, all of them have elongation values below 70%. These results indicate that the edible film is highly plastic, requiring a suitable plasticizer if using starch hydrolyzed with an acetate buffer. Another possible reason for the elongation values falling below the standard is that the starch used needs to be modified using a method other than hydrolysis. Hydrolysis is only capable of breaking down long amylose chains into shorter ones. Furthermore, hydrolysis also causes damage to amylopectin, especially in the branched regions, resulting in the amylopectin being converted into short-chain amylose [44]. Although some amylose can bind to acetyl groups from the acetate buffer to form bioplastics or edible films, the acetyl groups formed are unstable, unlike those formed through starch acetylation. This is likely what causes the edible film in this research to exhibit low plasticity properties, unlike most edible films.

3.5. Solubility Test Result

Solubility testing was used to assess the water stability of the films. The film, prepared with 18 mL of acetate buffer and a chitosan plasticizer, dissolved fastest, in just 10 minutes at room temperature. However, analysis across all acetate buffer volumes revealed that films with CMC plasticizer generally achieved superior solubility. This solubility value more accurately indicates how readily the film disintegrates into microscopic particles in water, a key characteristic for its intended application. From the tests conducted, the following data were obtained:

Table 3. The Results of The Solubility Test of Edible Films Made From Modified Starch are Based On The Type of Plasticizer and The Volume of Acetate Buffer as Modifying Solvents as Variables.

Acetate Buffer Volume (mL)	Solubility test results (%)			
	Chitosan	**Gelatine**	**CMC**	**Glycerol**
18	100 (Dissolved after 10 minutes)	36.64 ± 0.08	96.34 ± 0.01	can't be tested
20	100	61.77 ± 0.18	100 (dissolved after 3 hours)	47.5 ± 0.21
22	94.75 ± 0.02	29.82 ± 0.38	88.2 ± 0.12	can't be tested
24	83.01 ± 0.08	50.00 ± 0.58	8,4 ± 0.01	can't be tested

These values are the average ± SD with n = 3.

Table 4. Results of The Solubility Test Based on The Mixing Time Variable of *Edible Film*

Mixing time (minutes)	Disintegration times
10	1 hour 51 minutes.
20	1 hour 51 minutes
30	40 minutes
40	1 hour 51 minutes

In addition to the solubility percentage, the disintegration time of the edible films produced at various mixing times (production times) was also measured. The modified acetate starch used for the test is the best acetate starch, with a 20 mL volume of acetate buffer. The results showed that the best disintegration time was achieved with edible films synthesized using a processing time of 30 minutes.

Edible film for instant noodle seasoning packaging applications must have high solubility, especially in hot water. The results shown in Tables 3 and 4 represent the solubility values of edible

films in cold water. The best edible film, which utilizes CMC plasticizer, has been tested for instant noodle seasoning packaging. The results show that it dissolves completely in hot water within less than 1 minute, which is significantly faster than the typical cooking time of instant noodles, which is 3-5 minutes. The solubility value of edible films is adjusted to the application. Judging from the results obtained, the best edible film produced with CMC plasticizer is easily soluble in hot water, but has a longer dissolution time in cold water. Low solubility in cold water (before the edible film is brewed with hot water) indicates that the edible film exhibits good water resistance at room temperature, which will significantly enhance its stability and shelf life. The solubility value is related to the stability and shelf life of an edible film [45]. The edible film with CMC plasticizer in this research has a shelf life of 2 weeks at room temperature. Therefore, preservatives are needed to extend the shelf life of edible film, for example, by using natural preservatives.

3.6. Moisture Content Result

From Tables 5 and 6, it can be seen that the addition of glycerol plasticizer increases the water content. This is because glycerol can bind water or is more hydrophilic than CMC and chitosan so that it can increase the percentage of edible film solubility [46], [47]. However, when viewed from the mixing time variable, the best results are obtained at a mixing time of 30 minutes for a solubility temperature of 80°C. Therefore, it can be stated that the optimal time for edible film production is 30 minutes at a mixing temperature of 80°C, which corresponds to the general melting point of starch acetate.

Table 5. Water Content Based on The Acetate Buffer Volume Variable and Plasticizer Type

Acetate buffer volume (mL)	Water content (%)			
	Chitosan	***Gelatine***	***CMC***	***Glycerol***
18	11.65 ± 0.02	10.58 ± 0.01	11.54 ± 0.08	17.48 ± 0.13
20	12.00 ± 0.32	9.91 ± 0.14	11.32 ± 0.05	18.92 ± 0.28
22	13.00 ± 0.02	0.67 ± 0.08	13.73 ± 0.09	21.70 ± 0.08
24	11.88 ± 0.28	16.98 ± 0.10	15.38 ± 0.01	17.92 ± 0.18

These values are the average ± SD with n = 3.

Table 6. Water Content Based on Time Variable

Mixing time (minutes)	Water content (%)
10	12.87 ± 0.03
20	12.26 ± 0.01
30	11.43 ± 0.02
40	11.93 ± 0.03

These values are the average ± SD with n = 3.

4. Conclusion

The optimal edible film formulation utilized modified starch, 20 mL of acetate buffer, and 50% CMC plasticizer, processed at 80°C for 30 minutes. This produced a film with a tensile strength of 29.63 MPa, a Young's modulus of 4.31 MPa, 100% solubility, and a water content of 11.32%. However, improvements are needed in starch yield from acetate buffer hydrolysis, elongation at break, and shelf life. As the first application of starch from oil palm trunks for edible films, this research holds significant potential for primary packaging that requires good stiffness, such as for instant noodle seasonings. Future work should optimize the starch extraction yield and conduct additional tests for oxygen/water vapor permeability, component migration, and sensory evaluation to ensure the suitability of the material as food packaging.

Acknowledgment

We want to thank the Directorate of Learning Student Affairs, Ministry of Education, Culture, Research, and Technology, for supporting this research activity through the Student Creativity Program (PKM), and LPP Polytechnic for facilitating its implementation.

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