Mechanical and Physical Properties of Edible Film from Pectin, Corn Starch, and Chitosan

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**Abstract.** The pervasive use of synthetic plastics in food packaging has led to significant environmental concerns. An alternative to reduce the utilization of synthetic packaging materials is edible film. The aim of this study was to identify the optimal composition and analyze the effect of adding pectin from orange waste and chitosan on the characteristics of the edible film produced. The methods employed in this study included the extraction of pectin from orange peel waste, the production of edible film, and the characterization of edible film*.* The materials used were corn starch 3 g, sorbitol 2 ml, CMC 0,1 g, pectin (0.6 g; 0.9 g) and chitosan (1 mL; 1,5 mL; 2 mL). The addition of pectin and chitosan concentrations significantly affected the biodegradation and tensile strength of edible film. The results showed that the optimal concentration was obtained in the treatment of 0.9 g pectin and 1 ml chitosan, which resulted in 0.211 mm of thickness, 47.14% of degradation, 1.624 Mpa of tensile strength of, 13.7% of elongation, and 0.096 MPa of elasticity.

Keywords: edible film, pectin, chitosan, corn starch

# 1. Introduction

The food packaging has made extensive use of synthetic plastics due to their benefits, including a lower price, flexibility, lightweights, transparency, ease of shaping, and ability to protect packaged products effectively. Nevertheless, plastic is typically non-biodegradable, which has led to serious environmental issues. This problem has prompted researchers to develop packaging from renewable materials that can maintain food quality, naturally biodegrade, and be environmentally friendly. In recent years, there has been a rise in the use of food waste and by-products such peels. Waste and byproducts from the food processing industries include a large number of useful chemicals, including starch, and bioactive elements, which results in chances for the food packaging sector. This potential includes the active and intelligent packaging materials, functional chemicals, and biodegradable plastics. But further research is needed to fully assess the viability, flexibility, and applicability of expanding this lab-based study to an industrial scale (1). In order to preserve the quality of the product or extend its shelf life, active packaging uses active ingredients like antimicrobials and antioxidants that interact with the product. By gradually distributing active compounds from the packaging to the food product, active packaging prevents food from spoiling and requires less active compounds than direct absorption into food. (2) Active packaging is typically applied as a film (a thin layer of solid laminate), or coatingg.

Edible film can be an alternative to synthetic plastic packaging by offering advantages such as preventing loss of moisture and aroma, preserving product quality during storage, and reducing the amount of chemical and environmental hazards. In the past few years, various studies on biopolymers have continued to explore new materials for film production, including polysaccharide-based materials such as cellulose, starch, pectin and alginate (3). Starch, such as corn starch, is a material that can be used in the production of edible film (4). Starch-based edible film offers several advantages including plastic-like physical characteristics, colorlessness, odor lessness, tastelessness and smooth surface. (5) However, it exhibits low water resistance and barrier properties due to the hydrophilic nature of starch, impacting its stability and mechanical properties. (6) The low stability of the film will result in a shorter shelf life of the product as water vapor can penetrate, causing faster deterioration of the packaged product (7).

Therefore, the addition of other additives such as plasticizers and fillers are essential to enhance the physical and mechanical characteristics of starch film. The addition of pectin in the production of edible film is capable of improving tensile strength and elongation of the film. (8) The relatively high content of pectin has the potential to be utilized as a material for polysaccharide-based edible film production.

Chitosan has been used in the production of edible film in order to improve its physical and mechanical properties and to provide high water resistance due to its hydrophobic nature and poor solubility in water. (9) It functions as an antimicrobial agent in edible film and also capable of improving the mechanical properties and barrier properties of corn starch edible film (4).

Chitosan facilitates the formation of hydrogen bonds, thereby strengthening the chemical bonds within the film. (10) In this study, the biofilm was made from corn starch, orange pectin, chitosan, sorbitol and CMC. The aim of this study was to analyze the mechanical and physical characteristics of the film made from pectin, corn starch and chitosan.

# 2. Method

## Materials

The materials utilized in this study include corn starch, orange peel, chitosan, sorbitol, HCl 37% (Merck), ethanol 96% (Merck), distilled water. The instruments utilized in this study include hot plate with magnetic stirrer, glass apparatus, thermometer, analytical balance (Ohaus), oven (Memmert), blender, thickness gauge (Mitotuyo), and Universal Testing Machines (Hounsfield).

The study involves three stages as follows: the extraction of pectin from orange peel, the production of a biofilm, and the testing characterization of biofilm.

## The Extraction of Pectin from Orange Peel

One and half kilograms of oranges was peeled to separate the peel from the flesh. Then, each peel was cut into small pieces and dried in an oven at 55oC for approximately 3 hours. The dried peels were then ground using blender to obtain the powder. The peel powder was cooked in 1% HCl solution with a ratio of 1:30 (w/v) for 60 minutes at a temperature of 75ºC until acidic slurry was produced. The pectin slurry was then cooled to room temperature and filtered to separate the filtrate from the precipitate. The filtrate was soaked in ethanol (96%) in a dark bottle for 24 hours and then filtered to obtain the precipitate which was wet pectin. Next, the wet pectin was washed with ethanol 96% and then placed in an oven until dried. Finally, the dried pectin was blended and sieved to obtain pectin powder.

## The Production of Edible Film

Three grams of corn starch was dissolved in 50 mL of distilled water and then stirred using hotplate stirrer for 18 minutes until it reached the corn starch gelatinization temperature of 80°C. Next, the pectin solution in distilled water, the chitosan at a concentration of 0.5% for each treatment (1 mL; 1.5 mL; and 2 mL), 2 mL of sorbitol and CMC solution were added and stirred until homogeneous mixture was obtained. The compound was poured into the petri dish and allowed to stand for approximately 30 minutes to remove air bubbles in the solution. The edible film solution was then dried in an oven at temperature of 60oC for 12 hours. The dried edible film was stored at room temperature for 24 hours before being taken out of the mold. The composition of the materials used in the production of edible film is shown in Table 1.

**TABLE 1.** The composition of the materials

|  |  |  |  |
| --- | --- | --- | --- |
| **No** | **Name** | **Pectin (g)** | **Chitosan(g)** |
| 1 | P1CI | 0.6 | 1 |
| 2 | P1C2 | 0.6 | 1.5 |
| 3 | P1C3 | 0.6 | 2 |
| 4 | P2C1 | 0.9 | 1 |
| 5 | P2C2 | 0.9 | 1.5 |
| 6 | P2C3 | 0.9 | 2 |
|  |  |  |  |

## The Characterization Testing of Edible Film

### Tensile Strength Testing

The tensile strength test was carried out according to the ASTM-D882 method using the Hounsfield Universal Testing Machine. The sample was cut into a size of 15 x 100 mm, and then both ends of the sample were clamped onto the tensile testing machine. The test was carried out three times (in triplicate). The tensile strength was calculated by using equation 1.

|  |  |
| --- | --- |
|  | (1) |

Where:

Fmaks = maximum force (N)

A = cross sectional area of sample (mm2)

### Elongation Testing

Elongation is defined as the rate of change in the length of the bioplastic film when it is stretched until it breaks or the ability of the bioplastic film to elongate before breaking. The elongation test was carried out using the Universal Testing Machine according to the ASTM D-882 method, by cutting the sample into a size of 100 mm x 15 mm. Then both ends of the sample were clamped and pulled by Universal Testing Machine until the sample breaks. The elongation was calculated by using equation 2.

|  |  |
| --- | --- |
|  | (2) |

Where:

L1 = Final length (Length at Fracture)

L0 = Initial length

### Elasticity Testing

The elasticity test is a measurement carried out on the resulting film to determine its stiffness value. The elasticity value is derived from a comparison (ratio) of tensile strength to elongation. The equation used is equation 3.

|  |  |
| --- | --- |
|  | (3) |

### Thickness

The film thickness was measured using a micrometer with a precision of 0.01 mm. The film was determined by taking measurements at five different points, which were at each end and the center. The thickness value was obtained from the average of the thickness measurements. The test was carried out three times (in triplicate).

### Degradation Test

The degradation test was carried out using the soil burial method. The sample was cut into a size of 20 x 20 mm, then dried in a desiccator for 30 minutes and weighed before burial (Wo). Each sample was buried in 100 g of soil at a burial depth of approximately 5 cm for 44 days to determine the mass reduction of the film. The degradation rate was expressed as weight loss percentage and calculated using the following equation:

|  |  |
| --- | --- |
|  | (4) |

Where:

W = Sample weight after burial (g)

Wo = Initial sample weight (g)

# 3. Results and Discussion

## Tensile Strength Testing

The tensile strength test results are shown in Fig. 1. The resulting edible film had tensile strength ranging from 1.292 to 1.624 MPa. The results indicated that the highest value of edible film tensile strength was 1.624 MPa and obtained in the treatment with a composition of 0.6 g pectin and 2 ml chitosan (P1C3), while the lowest value of edible film tensile strength was 1.292MPa and obtained in the treatment with a composition of 0.9 g and 1 ml chitosan (P2C1). The tensile strength value of the edible film increased with the increasing chitosan concentration but decreased with the increasing pectin concentration. The increase in the tensile strength value of the edible film with increasing chitosan concentration is consistent with the findings of previous study. (11) The higher the concentration of added chitosan, the more hydrogen bonds are formed, resulting in stronger chemical bonds of the film that are difficult to break because it requires a significant amount of energy to do so. The increase in tensile strength is due to the formation of a polysaccharide network during the drying process of the film. Meanwhile, the tensile strength value of the edible film decreased with increasing pectin concentration.

**FIGURE 1.** Tensile strength of edible film

This result is inconsistent with the previous study (12) which stated that the tensile strength of the film increases with the increasing pectin concentration. The formation of numerous hydrogen bonds within the edible film solution resulted in a denser and less flexible film. The decrease in tensile strength since during the production of edible film, the mixture with 0.6 g pectin concentration reached the gelatinization point faster, resulting in a higher tensile strength value. The retrogradation results in the formation of strong bonds within the film, leading to an increase in the tensile strength value. (13) The analysis results showed that the treatment with the addition of pectin and chitosan had a significant effect on the tensile strength of edible film, as indicated by the significance value obtained (p value = 0.010), which was less than 0.05 (p < 0.05).

## Elongation Testing

The elongation test results are shown in Fig. 2. The resulting edible film had elongation ranging from 13.7% to 19.44%. The results indicated that the highest rate of edible film elongation was 19.44% and obtained in the treatment with a composition of 0.6 g pectin and 2 ml chitosan (P1C3), while the lowest rate of edible film elongation was 13.70% and obtained in the treatment with a composition of 0.9 g and 1 ml chitosan (P2C1). The elongation rate of the edible film increased with the increasing chitosan concentration but decreased with the increasing pectin concentration. The interaction between the plasticizer and polymer chains may have increased the overall flexibility of the film and the chain mobility as it facilitated the sliding of chain at higher chitosan concentration (14).

**FIGURE 2.** The elongation of edible film

The higher the concentration of chitosan, the more compact and robust the film structure, resulting in higher tensile strength and elongation. (15) The elongation was affected by the addition of plasticizers, such as sorbitol and CMC. This was indicated by a relatively high rate of elongation. However, in this study, the concentration of chitosan also affected the increase in elongation rate. This might occur because the higher the concentration of added chitosan, the more hydrogen bonds are formed, resulting in stronger chemical bonds of the film that are difficult to break. The analysis results showed that the treatment with the addition of pectin and chitosan had no significant effect on elongation of edible film, as indicated by the significance value obtained (p value = 0.073), which was greater than 0.05 (p > 0.05).

## Elasticity (Modulus Young) Testing

The elasticity test results are shown in Fig. 3. The resulting edible film had elasticity ranging from 0.079 to 0.096 MPa. The results indicated that the highest value of edible film elasticity was 0.096 MPa and obtained in the treatment with a composition of 0.9 g pectin and 1 ml chitosan (P2C1), while the lowest value of edible film elasticity was 0.079 and obtained in the treatment with a composition of 0.6 g and 1 ml chitosan (P1C1). The elasticity value decreased from 0.086 MPa to 0.084 MPa when the amount of chitosan in the treatment increased from 1.5 ml to 2 ml, with a composition of 0.6 g pectin. Meanwhile, the elasticity value increased from 0.086 MPa to 0.087 MPa when the amount of chitosan in the treatment increased from 1.5 ml to 2 ml, with a composition of 0.9 g pectin. The elasticity is directly proportional to the tensile strength. The higher the elasticity value, the more brittle and less elastic the bioplastic. The lower the elasticity value, the more elastic the bioplastic.

**FIGURE 3.** The elasticity of edible film

The analysis results showed that the treatment with the addition of pectin and chitosan had no significant effect on elasticity of edible film, as indicated by the significance value obtained (p value = 0.717), which was greater than 0.05 (p > 0.05).

## Thickness Testing

The thickness test results are shown in Fig.4. The resulting edible film had thickness ranging from 0.198 mm to 0.213 mm. The results indicated that the highest value of edible film thickness was 0.213 mm and obtained in the treatment with a composition of 0.9 g pectin and 2 ml chitosan (P2C3), while the lowest value of edible film thickness was 0.198 mm and obtained in the treatment with a composition of 0.6 g pectin and 1 ml chitosan (P1C1).

**FIGURE 4.** The thickness of edible film

The thickness value of the edible film increased with the increasing pectin and chitosan concentrations. The thickness value of the edible film increased in accordance with the increasing pectin concentration. This is due to the increased viscosity of the formed solution, resulting in the formation of a thicker edible film. The analysis results showed that the treatment with the addition of pectin and chitosan had no significant effect on thickness of edible film, as indicated by the significance value obtained (p value = 0.928), which was greater than 0.05 (p > 0.05).

## Biodegradability

The biodegradability test results are shown in Fig.5. The resulting edible film had degradation ranging from 41.54% to 48.38%. The results indicated that the highest rate of edible film degradation was 48.38% and obtained in the treatment with a composition of 0.9 g pectin and 1.5 ml chitosan (P2C2), while the lowest rate of edible film degradation was 41.54% and obtained in the treatment with a composition of 0.6 g and 1.5 ml chitosan (P1C2). The degradation rate of the edible film increased with the increasing pectin concentration but fluctuated with the increasing chitosan concentration.

**FIGURE 5.** The biodegradability of edible film

The increase in the degradation rate of the edible film with increasing pectin concentration is due to the hydrophilic properties of pectin. (16) This property allows the film to easily absorb water. The degradation rate of the film fluctuated with the increasing chitosan concentration. The higher the chitosan concentration added, the lower the percentage of mass loss due to the hydrophobic property of chitosan. The degradation of the film is affected not only by the properties of its constituent materials, but also by external factors such as environmental conditions (temperature, light intensity, and humidity) (17) This result indicated that the film using pectin, and chitosan was easy to decompose in a short time. The analysis results showed that the treatment with the addition of pectin and chitosan had a significant effect on the degradation of edible film, as indicated by the significance value obtained (p value = 0.012), which was less than 0.05 (p < 0.05).

# 4. Conclusions

The addition of pectin and chitosan into the synthesized edible film had significant effect on the biodegradation and tensile strength. However, it had no significant effect on the physical (thickness), and mechanical such as elongation, and elasticity properties. The optimal concentration for the production of edible film from pectin, corn starch and chitosan were obtained in the treatment of 0.9 g pectin and 1 ml chitosan (P2C1).

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