Bentonite Clay Reinforced with Plantain Starch-based Edible Film: Production and Characterization

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Abstract— **Edible film is a thin layer that lines a decent food consumed, and can be degraded by nature. The use of starch as the main ingredient in making plastic has great potential. To obtain edible film, starch is added with glycerol plasticizer, so that the plastic is more flexible and elastic. The starch used was banana starch, which has high hydrophilicity, therefore making it less desirable than synthetic polymers when used as a film. The purpose of this experiment is to produce, evaluate and characterize bentonite clay reinforced with banana Starch-based Edible Film. The edible films were made using banana starch, bentonite clay, and glycerol. Concentrations of bentonite clay were 30%, 10%, 20% and 0%.The edible film were obtained in the form of thin sheets that has been tested for mechanical properties such as tensile strength, elongation at break, and elasticity. Results indicated that the increase of bentonite concentration increase the film solubility. However, the bentonite makes the film tensile strength and elongation decrease.**

Keywords— Edible film, banana starch, bentonite clay, biopolymer, nanocomposite

I. Introduction

Over the years, the use of polymers as food packaging has increased considerably due to their advantages over other traditional materials such as glass and tin plate. A great advantage of plastics is the large variety of materials and compositions available, thus making it the most convenient packaging design as it can be adapted to specific needs of each product [1]. However, it is widely accepted that the use of long-lasting polymers for short-lived applications (packaging, catering, surgery, hygiene) is not entirely adequate [2]. A huge amount of garbage is generated daily, in which food packaging wastes makes up a considerably large part of it which is composed of many different types of material, some of which are not biodegradable and will not easily decompose. In this context, the development of biodegradable films (BF) for packaging material as a substitute to petrochemical polymers is an interesting perspective, since it provides an alternative to non-degradable products, and increases income in the agricultural sector. [3].

Starch has been considered as one of the most promising candidates for the development of edible film primarily because of its attractive combination of properties such its large availability and relatively low price [4]. Usually, the second major component of a starch-based film is the plasticizer, which is used to overcome film brittleness caused by high intermolecular forces. Plasticizing agents commonly used for thermoplastic starch production includes water and glycerol [5],[6],[7],[8].

To overcome high permeability caused by the plasticizer, other additives are also used. In this study, the production of bio-nanocomposites has proven to be a promising option, since polymer composites are gaining attention as substitute materials due to their superior tensile properties, thus making them especially suited for transportation and packaging applications.

Clay or starch composites have been the most frequently studied material which demonstrates a potential for improvement in tensile strength, Young's modulus, water resistance and decrease of the water vapor permeability of starches from many different sources[9]. Therefore, this study is conducted to produce edible film from bentonite and banana starch as well as to characterize the final film.

II. Methodology

A. Materials and chemicals

In the preparation of films, banana starch used was bought from Secret Barn Sdn. Bhd. The bentonite and glycerol were kindly supplied by Sigma Aldrich (USA).

B. Preparation of edible film

The film was prepared according to the methodology proposed by (Cyras et al, 2006) and [10]. Four solutions were prepared containing each 70 ml of distilled water, 3.5g, 4g, 4.5g, and 5g of banana starch. The solutions were heated at 70°C for 15 min until complete homogenization with gentle stirring. Followed by adding 2ml of glycerol and the solution was maintaned at this temperature for 15 min[11].In parallel, four distinct mixtures of 30 mL were prepared, containing distilled water, respectively: 1.5g, 1g, and 0.5g of bentonite. The mixtures were place stirrer for 15 min. The starch solutions and the respective clay mixtures were homogenized forming four film solutions. Then the films were obtained by casting, pouring the hot suspension into petri dish with a diameter 8 cm. These petri dish were put in the oven for 24 hours at 40^{o}C. The dry films were removed from the moulds.[12]

C. Characterization of edible film

(i) Thickness

The thickness of the films was measured, at 5 location using vernier caliper with digital micrometer. The average is calculated to get the mean thickness of the film. [13]

(ii) Mechanical test

This test is using Universal testing machine to find tensile strength, Young's modulus and elongation at break. [8]

(iii) Solubility test

According to [5] solubility in water was defined as the percentage of the dry matter of film . Film specimens were kept in a desiccator containing dry calcium sulphate till they reached constant weight. Afterward, film was immersed in beakers containing 50mL of distilled water at 23, 37 and 90◦C for 5 minutes without agitation. The films were removed from the water and were placed in the oven for 24 hours at 40◦C until they reached a constant weight to obtain the final dry weight of the film. The percentage of the total soluble matter (%TSM) of the films was calculated using the following equation:

$$\%TSM = \left[\frac{\text{initial dry wt - final dry wt}}{\text{initial dry wt}}\right] \times 100$$

(iv) Water Vapor permeability

The water vapor permeability of the films was determined gravimetric-ally[10]. The films were cut into square pieces (2cm x 2cm) and sequentially deposited on top of the WVP measuring cells. The water level was up to 1 cm below the film. The weight of each cell was measured before being deposited in a desiccator which contained silica gel at the bottom. Cell weight was measured every hour over a period of 8h. The WVP of the films was calculated in $gmin^{-1}m^{-1}Pa^{-1}h$ as follows in equation below:

$$WVP = \frac{W.L}{A.t.\Delta P}$$

Where: W is the amount of water permeate (g),
L is the film thickness (m),
A is the film area (m^2),
t is the permeation time (min),
ΔP is the pressure difference to water vapor between the two sides of the film (Pa).

(v) Surface Color

The surface color of film samples was measured using a color Spectrophotometer. Color parameters (L*, a* and b*) and gloss values at a 60° angle were averaged from five readings from each sample. A white standard color plate (L* = 95.83, a* = -0.78 and b* = -0.02) was employed to calibrate color parameters and used as a background. The total color difference (ΔE*) was calculated using equation:

$$\Delta E^* = \sqrt{(\Delta L)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

ΔL*, Δa* and Δb* are the differenc

es between each color value of a standard white color plate and the film specimen, respectively.[8][14]

III. RESULTS AND DISCUSSION

i. Mechanical Properties

Sample	Thickness (mm)	Elongation break (mm)	Tensile Strength (MPa)
30% Bnt-Bnn	0.126	15.30	1.99
20% Bnt-Bnn	0.127	31.48	2.10
10% Bnt-Bnn	0.154	38.70	2.11
0% Bnt-Bnn	0.164	71.50	3.97

Table 1: Mechanical properties of films

Investigations of mechanical properties of the edible films are performed based on the variations in the composition of constituent materials and their type using ASTMD882-10: Tensile Properties of Thin Plastic Sheeting tensile test standard. Universal testing machine can be used to measure the elongation at break and tensile strength at break for various films.[15]

Result was shown in Table 1. Tensile strength of edible contain 30%, 20%, 10%, and 0% bentonite-banana starch were 1.99, 2.10, 2.11 and 3.97 MPa respectively. It seems that low levels of bentonite decreased the tensile strength. Among all edible films, elongation at break decreased with clay content.[16]

ii. Water Vapor Permeability

Sample	WVP ($gmin^{-1}m^{-1}Pa^{-1}$)	Solubility (%)		
		25 °C	37 °C	90 °C
30% Bnt-Bnn	8.2084E-12	33.97	35.63	41.74
20% Bnt-Bnn	1.1608E-11	31.73	34.20	48.69
10% Bnt-Bnn	1.4687E-11	38.16	39.84	41.22
0% Bnt-Bnn	1.5356E-11	34.10	34.07	46.04

Table 2: Water vapor permeability and Solubility of films

A permeability edible film is the ability to pass gas and water particles on a unit of material in a certain condition. Permeability values are strongly influenced by the chemical properties of polymers, the basic structure of polymers, the properties of components permeate. Generally the value of permeability edible film packaging is useful for estimating the shelf life of packaged products. Natural chemical components play an important role in permeability. Water vapor permeability from one edible film packaging is the rate of speed or transmission of water vapor through a unit of material whose surface is flat with a certain thickness, as a result of a difference in the unit of vapor pressure between two surfaces under certain conditions of temperature and humidity. [15],[8]

According to Table 2, WVP values increase in order 30% Bnt-Bnn < 20% Bnt-Bnn < 10% Bnt-Bnn < 0% Bnt-Bnn. As revealed with increase of clay content the water permeability of edible films declined[16]. The fine clay particles with large surface to volume ratios can act as physical barriers against the movement of water molecules reduction is caused by lengthening of the pathway of molecules of water vapor. [17]

iii. Solubility

Solubility in water is an important property of edible films. The water solubility of these films indicates their water resistance when applied on the surface of food product. It is also related to the biodegradability of films when used as packaging materials.[18]

Water solubility values of bentonite- banana starch films are given in Table 2. The obtained results showed that the WS decreased as the banana starch increased. The lowest solubility value indicates that edible film it is best because it plays a role when film it is packaged for edible products. This is also consistent with the opinion of[15] that if an application is applied film desirable as an edible package. Likewise the opposite if applied edible film in foods with high water content; it is used film which is not soluble in water. [19] Water resistance is an important trait to possess film for its application as a protector of food.

iv. Surface color

The color of edible film is very influential on appearance and appearance of packaged products. The brighter the edible film, the better the quality of edible film. The average color of edible film using different bentonite concentrations can be seen in Table 3.

Sample	L*	a*	b*	E	C
30% Bnt-Bnn	33.05	0.36	3.22	62.87	3.24
20% Bnt-Bnn	30.83	0.38	2.34	65.06	2.37
10% Bnt-Bnn	33.42	0.44	2.21	62.46	2.25
0% Bnt-Bnn	30.82	0.92	2.82	65.10	2.96

Table 3: Surface color of films

Description: L * (Brightness value) = 0 (black) to 100 (white),
a * = -60 (green) to +60 (red),
b * = -60 (blue) to +60 (yellow)

The average color of edible film produced by the bentonite- banana starch is the color value L * (30.82 – 33.42), color a * (0.36 -0.92) and color b * (2.21 – 3.22). The higher the thickness of edible film will increase the diffusion of light so that the object of edible film will appear more turbid and the brightness will be lower. The thicker the edible film will give a color that is not transparent and its appearance is less attractive. In addition, the increase of viscosity of film will affect the increase in edible film thickness. This is due to the increase in thickness, which will reduce the visibility due to reduced transparency.

IV. Conclusion

Based on the research conducted, some conclusions can be drawn, that addition of bentonite clay to the banana starch edible film makes the film least strong. This can be seen in mechanical test. The more concentration of bentonite is adding the less tensile strength, same with the elongation. However the solubility increases with the adding of bentonite. Future study should be done like physical test be conducted to complete the data about edible film based on bentonite clay and banana starch. This includes testing humidity, texture, FTIR and SEM. In addition, chemical and biological testing is needed edible film this so that it can know the physical, chemical and biological characteristics. Chemical testing includes solubility in acids, melting point, degree of crystallinity while biological testing includes food safety and biodegradation tests.

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