

Characteristics of Bioplastics with Addition of Beeswax and Glucomannan

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Abstract. Packaging for cheese products usually uses plastic with a polymer base. Plastic is divided into two types: plastic made from synthetic polymer raw materials (difficult to decompose) and plastic made from natural polymer raw materials. The impact of using plastic with synthetic polymer materials, or what is usually called commercial plastic, will cause a buildup of waste and result in environmental pollution, so a solution for packaging using bioplastic is needed. This research was conducted to determine the characteristics of bioplastics with the addition of beeswax and glucomannan. By examining the variables of thickness, water resistance, water vapor permeability, biodegradability, tensile strength, and elongation, we will analyze the characteristics of bioplastics that have been enhanced with beeswax and glucomannan. The results showed that the addition of beeswax and glucomannan had no significant effect ($p > 0.05$) on thickness, water vapor permeability, biodegradability, tensile strength, and elongation. However, the addition of beeswax and glucomannan had a significant effect ($p > 0.05$) on water resistance. The addition of beeswax and glucomannan also increased ($p < 0.05$) the results of water resistance and tensile strength while reducing ($p < 0.05$) the results of thickness, water vapor permeability, biodegradability, and bioplastic elongation. It can be concluded that beeswax and glucomannan are able to provide strong bioplastic characteristics and have protective properties for products with a longer shelf life at room temperature.

1 Introduction

Packaging for cheese products usually uses plastic with a polymer base. Plastic is divided into two types: plastic made from synthetic polymer raw materials (difficult to decompose) and plastic made from natural polymer raw materials. The impact of using plastic with synthetic polymer materials, or what is usually called commercial plastic, will cause a buildup of waste and result in environmental pollution, so a solution for packaging using bioplastic is needed. Bioplastic is a polymer in the form of a plastic material that can be degraded and is made from renewable natural materials. The characteristics of bioplastics still have many shortcomings, from physical factors (level of stiffness of bioplastics, lack of elasticity, being easily brittle) to low hydrophilic properties. The elasticity and water-resistance characteristics of bioplastics require the addition of hydrophobic lipid materials.

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The lipid material that can be used in making bioplastics is beeswax, which is hydrophobic and functions to reduce the water vapor transmission process. The use of beeswax in bioplastic manufacturing applications can increase the physical properties to withstand the rate of water vapor transmission, affect the thickness, breaking strength, and also the elongation percentage of bioplastics.

Beeswax is very effective in resisting the rate of water vapor because it contains esters of fatty alcohols and fatty acids as well as high-chain alkane compounds [1]. Beeswax is also able to increase the moisture barrier in bioplastics because it is hydrophobic and will produce better bioplastics. Making bioplastics also requires natural materials that contain polysaccharides. Glucomannan can be used as a natural material containing polysaccharides in making bioplastics because it is able to form fine fiber structures. Glucomannan is a polysaccharide consisting of D-mannose and D-glucose. Glucomannan has an acetyl group that has the ability to bind with starch and amylopectin to form cross-links so that it can become a strong bioplastic and has the property of protecting the product from damage. Increasing the concentration of added glucomannan will increase the tensile strength of bioplastics because glucomannan will form many intramolecular bonds in the bioplastic matrix. Glucomannan functions like a fiber, which can cause water to be absorbed into the molecule so that it can increase its ability to bind water [2]. The aim of this research is to determine the quality of bioplastics in terms of water vapor permeability, thickness of bioplastics, tensile strength of bioplastics, water resistance of bioplastics, and biodegradation of bioplastics, and to determine the shelf life of bioplastics when applied to packaged products.

2 Materials and Method

2.1 Materials

The material used in this research is bioplastic made from beeswax (obtained from farms in Malang Regency) and glucomannan. The ingredients used in this research were glucomannan powder (Konjac Glucomannan Nura Jaya), beeswax solution, glycerol (brand 104094), distilled water, and lactic acid.

2.2 Methods

The research method used was a laboratory experimental method using a completely randomized design with 4 treatments and 3 replications that added an of 0.25%, 0.5%, and 0.75% beeswax to bioplastics with the observed variables, thickness, water resistance, water vapor permeability, tensile strength, and biodegradation.

Table 1. Experimental design in the present study.

Treatments	Beeswax (g)	Glucomannan (g)	Repetition		
			1	2	3
T0	0	3	P0U1	P0U2	P0U3
T1	0,25	3	P1U1	P1U2	P1U3
T2	0,5	3	P2U1	P2U2	P2U3
T3	0,75	3	P3U1	P3U2	P3U3

3 Results and Discussion

3.1 Functional Properties of the Addition of Beeswax and Glucomannan to the Thickness of Bioplastics

Data and analysis of variations in the average with the addition of beeswax and glucomannan, with a percentage of 0.25%, 0.5%, and 0.75% can be seen in Table 2.

Table 2. Average thickness (%) with the addition of beeswax and glucomannan treatments

Treatments	Thickness (mm)
T0	0,179 ± 0,021
T1	0,205 ± 0,009
T2	0,234 ± 0,040
T3	0,206 ± 0,042

In the table 2, the results of the ANOVA test show that the treatments given show that there is no significant difference ($P > 0.05$) in the thickness of the bioplastic. The addition of beeswax and glucomannan to bioplastics resulted in the thickness value of the bioplastic increasing. The thickness test in bioplastics was used to determine the effect of the cross-linking material between beeswax and glucomannan. Factors that influence the thickness of bioplastics are the total amount of solids in the solution, the thickness (height) of the mold, and the volume of the solution. The average thickness value of bioplastic with the addition of beeswax and glucomannan ranged from <0.179 mm to >0.234 mm. The results of the research are comparable to research on the addition of beeswax and glycerol in that the value of the effect of adding beeswax and glycerol on packaging film thickness ranges from 0.2 to 0.3 and the film thickness value increases. The thickness of bioplastics is standardized in the Japan International Standard (JIS) 1975, namely a maximum of 0.250 mm. In this study, the higher the addition of beeswax and glucomannan, the higher the thickness value. The higher the total solids in the mixture, the higher the packaging thickness. The addition of oil can increase the thickness of bioplastic from 0 to 60 μm [2]. The addition of beeswax and glucomannan affects the use of bioplastic as packaging; the thicker the bioplastic produced, the better the packaging's ability to protect the product. The thickness resulting from the addition of beeswax and glucomannan is able to inhibit the rate of water vapor, and its retaining capacity is greater, so that its shelf life is longer.

3.2 Functional Properties of the Addition of Beeswax and Glucomannan to the Water Resistance of Bioplastics

Data and analysis of variations in the average with the addition of beeswax and glucomannan, with a percentage of 0.25%, 0.5%, and 0.75% can be seen in Table 3.

Table 3. Average Water Resistance (%) with the addition of beeswax and glucomannan treatments

Treatments	Water Resistance (mm)
T0	15,33 ± 0,01 ^a
T1	12,33 ± 0,01 ^{ab}
T2	14,00 ± 0,01 ^{bc}
T3	19,00 ± 0,02 ^{bc}

Note: superscripts in the same column have significant differences ($P < 0.01$).

The results of the ANOVA test showed that the treatment given showed a very significant influence ($P > 0.01$) on the water resistance of bioplastics. The addition of beeswax and glucomannan to bioplastics results in the water resistance value of bioplastics increasing. The water resistance test in bioplastics is used to determine the percentage of swelling in bioplastics due to the presence of water. The factor that influences the water resistance of bioplastics is the density of the bioplastic. The average thickness value of bioplastic with the addition of beeswax and glucomannan ranged from $<15.33\%$ to $>19.00\%$. The results of the research are comparable to research on the effects of linseed oil and kimpul starch on bioplastics; the value of the effect of adding linseed oil and kimpul starch on the resistance of bioplastics ranges from 31 to 37%, and the water resistance value of bioplastics increases. In this research, the higher the addition of beeswax and glucomannan, the higher the water resistance value of the bioplastic. This is because the basic nature of beeswax is hydrophobic, so the more beeswax used, the hydrophilic nature of glucomannan will be reduced to hydrophobic. Beeswax has the natural property of hardening again as the temperature decreases, and hydrophilicity is expected to provide strength to bioplastics in terms of water resistance. Water absorption from bioplastics will be low, making water resistance high. The higher the water resistance percentage value, the better the bioplastic properties.

3.3 Functional Properties of the Addition of Beeswax and Glucomannan to the Water Vapor Permeability of Bioplastics

Data and analysis of variations in the average with the addition of beeswax and glucomannan, with a percentage of 0.25%, 0.5%, and 0.75% can be seen in Table 4.

Table 4. Average Water Vapor Permeability (%) with the addition of beeswax and glucomannan treatments

Treatments	Water Vapor Permeability
T0	0,32 ± 0,11
T1	0,16 ± 0,07
T2	0,09 ± 0,07
T3	0,13 ± 0,11

The results of the ANOVA test showed that the treatments given showed that there was no significant difference ($P > 0.05$) in the water vapor permeability of bioplastics. The addition of beeswax and glucomannan to bioplastics causes the water vapor permeability value to decrease. Water vapor permeability is the rate of speed or transmission of water vapor through a unit area of material with a flat surface of a certain thickness. The water vapor permeability test in bioplastics is used to determine the ability of bioplastics to pass water vapor and gas particles, with the aim of estimating the product's shelf life. Factors that influence water vapor permeability in bioplastics are the basic structure of the polymer and the chemical properties of the polymer. The average water vapor permeability value of bioplastics with the addition of beeswax and glucomannan ranges from <0.09 to >32 g/hour/m2.

The results of the research are comparable to research on bioplastics with the addition of beeswax alone, in that the greater the concentration of beeswax added to the manufacture of bioplastics, the lower the water vapor permeability value. In this research, the higher the addition of beeswax and glucomannan, the lower the water vapor permeability value. This is caused by the polymers used in bioplastics, polymers that have non-polar properties (lipids), which contain many hydroxyl groups. A low water vapor permeability value will cause high

oxygen permeability; this will cause bioplastics to be a good water barrier but not effective in retaining gas. Beeswax has the function of preventing the rate of water vapor transmission. When dried, beeswax will form a crystal network that functions as a water vapor barrier. The rate of water vapor transmission will decrease with the increasing hydrophobic properties of the compounds that make up bioplastics [4].

3.4 Functional Properties of the Addition of Beeswax and Glucomannan to the Tensile Strength of Bioplastics

Data and analysis of variations in the average with the addition of beeswax and glucomannan, with a percentage of 0.25%, 0.5%, and 0.75% can be seen in Table 5.

Table 5. Average Tensile Strenght (%) with the addition of beeswax and glucomannan treatments

Treatments	Tensile Strenght
T0	155,9 ± 135
T1	187,4 ±55
T2	199,1 ± 51
T3	214,2 ± 14

The results of the ANOVA test showed that the treatments given showed that there was no significant difference ($P > 0.05$) in the tensile strength of bioplastics. The addition of beeswax and glucomannan to bioplastics results in increased tensile strength values. Tensile strength is the maximum stress that a material can withstand when stretched or pulled before it breaks. The tensile strength test is carried out to determine the level of resistance of the bioplastic to maximum tension before the bioplastic breaks or tears. Factors that influence the tensile strength of bioplastics are the addition of plasticizers and the high concentration of materials used. The average thickness value of bioplastic with the addition of beeswax and glucomannan ranged from <155.9 to >214.2 N/m². In this research, the higher the addition of beeswax and glucomannan, the higher the tensile strength value. The addition of beeswax with glucomannan and other ingredients works well to form a tight surface, resulting in high tensile strength. Bioplastics that have high tensile strength will be able to protect the products they package from mechanical damage. The high tensile strength value in this study is due to the starch content contained in glucomannan, resulting in the starch granules absorbing water until they swell due to the hot temperature of the water and allowing the high amylopectin bonds in the starch to tend to bond and link together to form cross-links due to the presence of acetyl groups in the glucomannan combines and becomes denser, so that the composite formed and produced is stronger. The tensile strength of bioplastics in SNI is 24.7–302 MPa.

3.5 Functional Properties of the Addition of Beeswax and Glucomannan to the Biodegradation of Bioplastics

Data and analysis of variations in the average with the addition of beeswax and glucomannan, with a percentage of 0.25%, 0.5%, and 0.75% can be seen in Table 6.

Table 6. Average Biodegradation (%) with the addition of beeswax and glucomannan treatments

Treatments	Biodegradation
T0	0,08 ± 0,02

T1	0,08 ± 0,02
T2	0,08 ± 0,02
T3	0,07 ± 0,02

The results of the ANOVA test showed that the treatments given showed that there was no significant difference ($P > 0.05$) in the biodegradation of bioplastics. The addition of beeswax and glucomannan to bioplastics causes the biodegradation value to decrease. Biodegradation tests are carried out to determine the decomposition capacity of bioplastics by microorganisms in the soil. Factors that influence biodegradation are the hydrolysis process of the material by microorganisms, hydrolyzed beeswax, and glucomannan. The average biodegradation value of bioplastics with the addition of beeswax and glucomannan ranged from <0.07 to $>0.08\%$. In this research, the higher the addition of beeswax and glucomannan, the lower the biodegradation value. Based on the international plastic standard ASTM 5336, the degradation time for plastic takes 60 days to decompose. Meanwhile, bioplastic, with the addition of beeswax and glucomannan, only broke down on day 7 and met the old degradation standards. The decrease in biodegradation value in this study was due to glucomannan, which is starch and consists of amylose and amylopectin, both of which have hydroxyl OH groups that initiate hydrolysis reactions after absorbing water from the soil.

4 Conclusion

In conclusion, the addition of beeswax and 0.5% glucomannan to bioplastics can increase thickness, water resistance, tensile strength, and biodegradability, as well as reduce the percentage value of water vapor permeability. The addition of beeswax and 0.5% glucomannan produces bioplastic with a thickness of 0.21 mm, water resistance of 12%, tensile strength of 187.4 N/m², biodegradability of 0.08%, and water vapor permeability of 0.16 g/hour/m². T2 treatment (addition of beeswax and 0.5% glucomannan) is the best treatment for thickness, water resistance, tensile strength, biodegradability, and water vapor permeability. Thus, bioplastics made from beeswax and glucomannan can be used in product packaging and extend their shelf life at room temperature. Further research is needed on the results of product packaging using bioplastics made from beeswax and glucomannan in terms of microbiological quality.

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