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EVALUATION OF BIOPLASTIC FROM BANANA PEELS: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Bioplastics based on natural materials offer an innovative solution to reduce the negative impact of conventional plastics on the environment. This study evaluated bioplastics made from banana peels processed with various plasticizers, such as glycerol, chitosan, sorbitol, polylactic acid polymer, sodium metabisulfite, and tapioca starch. The focus was on mechanical properties, such as biodegradability, tensile strength, and elongation. Banana peels, with a starch content of 59%, proved ideal for bioplastics, with a degradation time of 4–84 days in soil. Bioplastics with 2% glycerol degraded in 4 days, while those with sodium metabisulfite degraded in 84 days. Glycerol increased flexibility but decreased tensile strength. The combination of 1.5% glycerol and tapioca starch produced the highest tensile strength of 66.39 MPa, while the highest elongation was 115.43% with 2% glycerol. This study highlights the potential of banana peel bioplastic as an environmentally friendly alternative, and further research is recommended to optimize the combination of plasticizers to make the bioplastic stronger, more elastic, and antibacterial by combining glycerol, sodium metabisulfite, and tapioca starch. These findings are important for the future development of sustainable and applicable bioplastics.

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Introduction

Plastic is one of the largest contributors to environmental pollution, both on land and at sea. Due to its inherent resistance to natural degradation, plastic waste management requires serious attention. The recycling process not only produces toxic substances but also has carcinogenic potential, and the natural decomposition time can be hundreds of years.[1]. Based on data from the National Waste Management System (SIPSN) released by the Ministry of Environment and Forestry (KLHK) in 2023, as of July 24, 2024, total national waste production from 290 districts/cities was recorded at 31.9 million tons.[2]. Therefore, efforts to overcome plastic waste by using bioplastics.

Bioplastics are plastic materials derived from natural sources and have the ability to decompose naturally through the activity of microorganisms, making them a more environmentally friendly choice compared to traditional plastics.

Biodegradable plastic functions like regular plastic in its use, but has the advantage of being decomposed by microorganisms after disposal. The decomposition process produces water and carbon dioxide as end products. Due to its ability to reintegrate with nature, biodegradable plastic is considered a more environmentally friendly option. Transparent, tasteless, and odorless starch-based bioplastics are of most interest in research due to their product properties. Starch-based bioplastics do have the advantage of being environmentally friendly, but the disadvantages of bioplastic products being easily damaged and having weak elasticity are challenges that must be overcome.[1]In this case, utilizing banana peels as bioplastic offers a potential solution due to their relatively high starch content.

Banana peels are a type of waste that has the potential to be used as a raw material for bioplastics, as they contain approximately 59% starch. However, starch-based bioplastics have several drawbacks, such as brittleness and a lack of elasticity. To address these issues, additional materials, such as reinforcing agents like cellulose and plasticizers, are needed to increase the strength and flexibility of the bioplastic.[3]Therefore, this review of biodegradable plastics will discuss the potential of banana peels as a raw material for bioplastics with the addition of plasticizers, particularly in terms of tensile testing, elongation, and shelf life (biodegradability).

Biodegradability testing is an important test to determine how long it takes for plastic to decompose in the soil. To test the biodegradability of bioplastic film, place it in a pot filled with soil, assuming the soil composition is similar to that of the surrounding environment. Biodegradation itself is a natural process in which organic matter is broken down or destroyed by reactions aided by the activity of microorganisms. One method recommended by the American Society for Testing and Materials (ASTM) to test the biodegradability of bioplastic is to bury it in the soil for a specified period of time, known as the soil burial test.[4].

1. Tensile Strength Test

The purpose of a tensile strength test is to determine the extent to which a bioplastic can withstand tensile loads. In this test, the bioplastic is stretched until it elongates and eventually breaks. This mechanical property testing method follows the ASTM D638 standard, ensuring proper testing.[4]. Both ends of the specimen are clamped in a tensile testing machine, the tensile strength is then measured based on the following equation (1):

$$\sigma = \frac{F_{maks}}{A} \qquad (1)$$

Information:

σ = Tensile strength (N/m2)

$Fmaks$= Maximum tensile force (N)

A = Cross-sectional area (m2)

2. Elongation Test

Elongation, or percent elongation, is the maximum change in length of a tissue sample due to an applied force before the specimen breaks. Testing is performed to determine the breaking span of the specimen. Percent elongation testing can be performed based on ASTM D 638 standards.[5]. The elongation of a material can be calculated according to the following equation (2):

$$\varepsilon = \frac{\Delta L}{L_0} \qquad (2)$$

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Information:
ε = Elongation (%)
ΔL =(L-*Lo*) increase in length (mm)
L_0 = Initial length (mm)

Research Method

This review is based on a search of several international sources covering a similar topic: the production of biodegradable plastic using banana peels as the primary material. Several journal publications have categorized the various combinations of materials, additives, or other combinations that yield the best results, as well as new combinations that researchers might use in the future to produce biodegradable plastics.

Results and Discussion

Biodegradable plastic made from food crop waste is expected to not only reduce environmental pollution but also increase the economic value of these crop residues. Additives, called plasticizers, are added to the plastic or bioplastic manufacturing process to improve the material's flexibility and overall performance.[3]Table 1 will present some of the properties of plasticizers added to make bioplastics.

Table 1. Chemical Structure and Plasticizer Properties of Banana Peel Bioplastic

Polymer Structures & Plasticizers	**Chemical Structure**	**Characteristic**
Starch Including Tapioca Flour and Cornstarch	(C6H10O5)n	Brittle, stiff, high water absorption Increase the tensile strength of bioplastics
Glycerol	C3H8O3	Odorless, hygroscopic, slightly sticky, increases the flexibility of bioplastics
Chitosan	[C6H11NO4]n	Odorless, tasteless. Reduces the rate of water absorption andimprove properties bioplastic mechanics
Sorbitol	C6H14O6	Hygroscopic, odorless, Increases plasticity value, hydrophilic.
Sodium Metabisulfite	Na2S2O5	Preventing the appearance of brown color (anti-browning) Anti-microbial and antioxidant so that bioplastic is durable and not easily damaged

Table 1 shows the chemical structure and properties of various plasticizers used in the production of banana peel-based bioplastics. Starch, as the main polymer, has brittle properties and high water absorption, which can be overcome by the addition of additives such as glycerol and sorbitol to increase flexibility and plasticity. Chitosan plays a role in strengthening mechanical properties and reducing water absorption, while sodium metabisulfite functions as an antioxidant and antimicrobial to extend the life of bioplastics. Polylactic acid polymers offer good strength and durability, making them an environmentally friendly choice in bioplastic development. The combination of various plasticizers with banana peel starch can improve the mechanical properties, flexibility, water resistance, and durability of bioplastics, thus creating more functional and environmentally friendly materials. Several developments of banana peels as a source of starch and cellulose combined with various plasticizers in bioplastic production are shown in Table 2.

Table 2. Mechanical Properties Test Results of Bioplastic from Banana Peels

Material	**Method**	**Test Results**		
		Biodegradation (Day)	**Tensile Strength (MPa)**	**Elongation (%)**
Banana peel 10% 2% glycerol	Extraction Sedimentation Warmup Printing	4	3	115.43 %
Banana Peel 40% Glycerol1.5% Tapioca	Extraction Mixing Printing	56	66.39	-
Banana peel	Extraction Filtering	21	-	-

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(Musa Paradiasica) Glycerol 25%	Mixing Printing			
Banana peel Glycerol 7.5%	Extraction Drying Mixing Drying	-	1.53	18.77
Prata Banana Peel 8 grams Glycerol 15%	Mixing Warmup Filtering	10	-	31
Banana peel Glycerol 25%	Extraction Mixing Printing	10	-	-
Banana peel Glycerol 0.4% Cornstarch	Extraction Sedimentation Mixing Warmup Printing	-	8.22	40.4
Banana peel Glycerol 14%	Extraction Mixing Warmup Drying	10	11.89	-
Banana peel Glycerol 40%	Extraction Mixer Warmup Printing	6	-	44.44
Banana peel Glycerol 7%	Extraction Mixer Printing	13	-	-
Banana skin is always dirty Chitosan 2% Glycerol 3%	Extraction Sedimentation Mixing Warmup Printing	-	4.79	13.32
Kepok Banana Peel Chitosan Sorbitol 2%	Extraction Drying Mixing Warmup Printing	-	10.56	58.33
Banana peel Glycerol Cellulose	Extraction Drying Mixing Printing	-	5.60	-
Banana peel, Glycerol Polylactic Acid Polymer	Extraction Mixing Warmup Mixing	56	39.30	-
Banana peel Sodium Metabisulfite	Mixing Boiling Milling Warmup	84	-	-
Banana peel NaOCl 1% Glycerol 50%	Milling Immersion Bleaching Mixing Printing	8	-	-
Green banana peel Hydrochloric acid (HCl) Sodium hydroxide (NaOH) Sodium metabisulfite	Extraction Mixing Warmup Drying	80	-	-

Mechanical testing of banana peel-based bioplastics, reported in several journals, provides a comprehensive overview of the effects of formulation and plasticizer addition on their mechanical properties. Banana peel-based bioplastics have significant advantages in biodegradation tests compared to conventional plastics. One of the main advantages is their faster biodegradation rate, as seen in banana peel-based bioplastics using glycerol plasticizer.[7],[11]-[19],[22]Based on several sources, it is shown that the addition of glycerol at a concentration of 40% has an effect on biodegradation time, where the greater the glycerol content in the manufacture of bioplastics can speed up the time in the biodegradation process.[18]. The effect of time on biodegradation apart from the addition of glycerol with the addition of sodium metabisulfite which gives an effect of time for 84 days longer but with the help of the addition of hydrochloric acid can provide biodegradation results 4 days faster than just the addition of sodium metabisulfite[24],[26].This is because the

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properties of sodium metabisulfite provide anti-microbial and antioxidant effects so that bioplastics are durable and not easily damaged or degraded.[9]. In addition to the biodegradation test, there are other aspects such as tensile strength (Mpa) and elongation (%) tests.

In terms of tensile strength test aspects, it was found that the addition of 1.5% glycerol combined with tapioca flour produced a tensile strength of 66.39 mPa.[11]. The combination of glycerol plasticizer and tapioca flour has a more optimal tensile strength, compared to using glycerol plasticizer without a combination. In the elongation test aspect, the largest result was 115.43% using 2% glycerol plasticizer.[7]This proves that the addition of glycerol can affect the mechanical properties of bioplastics because glycerol increases the flexibility of bioplastics.[8]. The addition of 50% glycerol and NaOCl in the manufacture of bioplastics has an effect on the biodegradation time of 8 days and another function of the addition of NaOCl as a color bleaching agent in the visual of bioplastic products.[25]Bioplastic with a combination of glycerol and chitosan plasticizers produces a tensile strength of 4.79 MPa and an elongation test result of 13.32%.[20]Meanwhile, the combination of chitosan and 2% sorbitol plasticizers produced a greater tensile strength of 10.56 MPa and elongation test results that increased significantly by 58.33%.[21]. The role of sorbitol plasticizer in bioplastics as a plasticizing agent[5]On the other hand, the use of chitosan can improve the mechanical properties of bioplastics.[8]. In the manufacture of bioplastics with a combination of glycerol and polylactic acid polymers, the mechanical properties of tensile strength are 39.30 MPa, which shows the effect of adding polylactic acid polymers on the results of the tensile strength test which is getting bigger.[23].

The prospects for producing bioplastics from banana peels can be focused on a combination of additives that provides an optimal balance between long biodegradation time and high tensile strength. From the tensile strength test results, the combination of 1.5% glycerol with tapioca showed the highest mechanical strength of 66.39 MPa, reflecting its great potential in applications requiring high durability. On the other hand, to extend the biodegradation time, the use of additives such as sodium metabisulfite, which shows a degradation time of up to 84 days, can be considered. Thus, the combination of 1.5% glycerol with tapioca[11]for tensile strength, supplemented with sodium metabisulfite to slow degradation[24], has the potential to produce durable yet strong bioplastics. This strategy allows for the development of bioplastics that are not only environmentally friendly but also have broader commercial applications in products that require longer shelf life. Slowly biodegradable bioplastics can be used for food packaging applications that require durability over a long shelf life, such as packaging fresh produce or dry goods that are not immediately consumed. Improving the mechanical properties of bioplastics and adding plasticizers is needed to extend the shelf life, which aims to improve the performance of bioplastic packaging for sustainable food production.[28].

Conclusion

Bioplastics developed from banana peels with the addition of additives such as glycerol, chitosan, sorbitol, and sodium metabisulfite have great potential as an environmentally friendly alternative material. The results of the study showed that glycerol increases the flexibility of bioplastics, while chitosan and sorbitol help improve mechanical properties and plasticity. The use of sodium metabisulfite, with antioxidant and anti-microbial properties, extends the biodegradation period of bioplastics, making them more durable. In the biodegradation test, the addition of glycerol accelerated the degradation process, while sodium metabisulfite slowed the biodegradation time to 84 days. The tensile strength test showed that the addition of glycerol and tapioca

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provided the best mechanical strength of 66.39 MPa. Further research is recommended to optimize the combination of additives to achieve a balance between longer biodegradation time and high tensile strength.

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