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Biodegradable Plastic from Klobot Waste with Glycerol as an Educational Alternative to Conventional Plastic Supporting SDGs

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ABSTRACT
Organic waste, including corn husks, presents a significant environmental challenge in Indonesia, particularly in food industry areas such as the roasted corn kiosks at Wergu Wetan Sports Hall, Kudus Regency. Currently, 33.57% of organic waste remains unmanaged, contributing to environmental pollution (National Waste Management Information System, 2024). Similarly, plastic waste is a critical issue, with 5.4 million tons produced annually, causing severe environmental damage. This study explores the development of bioplastics from corn husk waste as an eco-friendly alternative to conventional plastics. Using glycerol as a plasticizer and acetic acid to enhance strength, the research examines various formulations of husk, glycerol, and acetic acid to produce bioplastics with optimal physical properties. The findings indicate that acetic acid improves transparency and strength, while the glycerol ratio influences flexibility and thickness. A formulation ratio of 5:2:1 (husk:glycerol:acetic acid) yielded the best results in physical property tests. Degradation tests further revealed that these bioplastics decompose rapidly through natural biodegradation processes. The study highlights the potential of husk-based bioplastics as a sustainable solution to mitigate the environmental impact of plastic waste. With a suitability rate of 77.1% (Akbar and Sriwiyana, 2011), these bioplastics support efforts to achieve the Sustainable Development Goals (SDGs) in waste management and environmental conservation in Indonesia.

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KEYWORDS
Acetic acid, Bioplastic, Degradation, Environment, Glycerol, Husk waste

Introduction

Corn husks are a type of organic waste derived from corn, which decompose easily through microbial activity. However, organic waste in Indonesia reached 25,927,297.38 tons in 2023, with 66.43% being managed and 33.57% left unmanaged, leading to environmental pollution (National Waste Management Information System, 2024). A significant portion of this waste comes from the food industry, particularly from roasted corn stalls in the Wergu Wetan Sports Hall (GOR), Kudus. If left unaddressed, the accumulation of husk waste from these kiosks could further exacerbate the organic waste problem this year.

Ineffective organic waste management contributes to greenhouse gas emissions, particularly methane (CH_4), which has a greater impact on global warming than carbon dioxide (CO_2) (Puger, 2018). Currently, 65.83% of total waste in Indonesia is still transported and disposed of in landfills, highlighting the urgent need for sustainable and environmentally friendly waste management solutions. At the same time, plastic waste remains one of Indonesia's most pressing environmental challenges. The country faces a serious crisis due to the increasing volume of mismanaged plastic waste, which pollutes the environment and threatens ecosystem sustainability. Indonesia ranks among the largest global producers of plastic waste, driven by high per capita consumption and widespread reliance on single-use plastics. According to the Indonesia Solid Waste Association, plastic waste accounts for 5.4 million tons annually, or 14% of total waste production. In Jakarta alone, plastic bag waste reaches 1,000 tons per day.

The plastic waste crisis in Indonesia has far-reaching consequences, from river and marine pollution that disrupts aquatic ecosystems to public health concerns and significant economic costs (Qodriyatun, 2018). Factors such as the excessive use of disposable plastics, inadequate waste management infrastructure, and low public awareness of sustainable waste management practices exacerbate the situation. Furthermore, accumulated plastic waste does not degrade easily; when burned, it releases harmful substances (Sahwan et al., 2005), and when discarded, it remains in the environment for centuries before fully decomposing (Karuniastuti, 2013).

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Both organic and plastic waste contribute to severe environmental issues, including land, water, and air pollution, as well as increased greenhouse gas emissions. To address these challenges, researchers have developed an innovative approach by processing corn husk waste into bioplastics-a sustainable alternative to conventional plastics. These bioplastics not only help reduce husk waste in residential areas but also offer a biodegradable solution to plastic waste, as they naturally decompose through environmental biodegradation. In Kudus, particularly in the roasted corn culinary area near the GOR, corn husks are abundant. This area alone produces approximately 15 sacks of corn husks per day, which, if not properly managed, contribute to environmental pollution. Given this, researchers have identified corn husk waste as a primary raw material for producing biodegradable plastic.

This study aims to conduct field-based research on transforming organic waste into eco-friendly bioplastics, providing an alternative to conventional plastics in the Society 5.0 era. The goal is to reduce both organic and plastic waste in Indonesia while encouraging students and the wider community to adopt biodegradable plastics made from organic waste. In this research, corn husks are combined with glycerol, which acts as a plasticizer to enhance the flexibility and durability of the bioplastic.

Methods

This study employs an experimental quantitative research approach, focusing on testing and developing innovations to produce biodegradable plastic from corn husk waste and glycerol.

Procedure

The experiment was conducted in the biology laboratory of Kudus State Islamic Institute, utilizing husk samples collected from roasted corn food stalls in Wergu Wetan through a random sampling method. The experimental process involved formulating biodegradable plastic from husk waste and glycerol, followed by an evaluation of its physical properties and degradation potential.

Data Analysis

Experimental data were analyzed quantitatively and descriptively to assess the production process, physical characteristics, and biodegradation capability of the biodegradable plastic. The analysis aimed to determine its feasibility as an alternative to conventional plastics, while also evaluating its contribution to sustainable development goals (SDGs) in Indonesia.

Production Process

The Biodegradable plastic production starts from selecting appropriate materials and production media. The initial step includes the initial design process of raw material composition, mixture formulation with the necessary additional ingredients, as well as a manufacturing process that considers biodegradability criteria and the quality of the resulting product. Before starting the experiment, researchers have developed an FAQ (Frequently Ask Question) BOT called "BIOSTIC AI" as a technological innovation that can make this experiment easier. The BIOSTIC AI display is as follows:

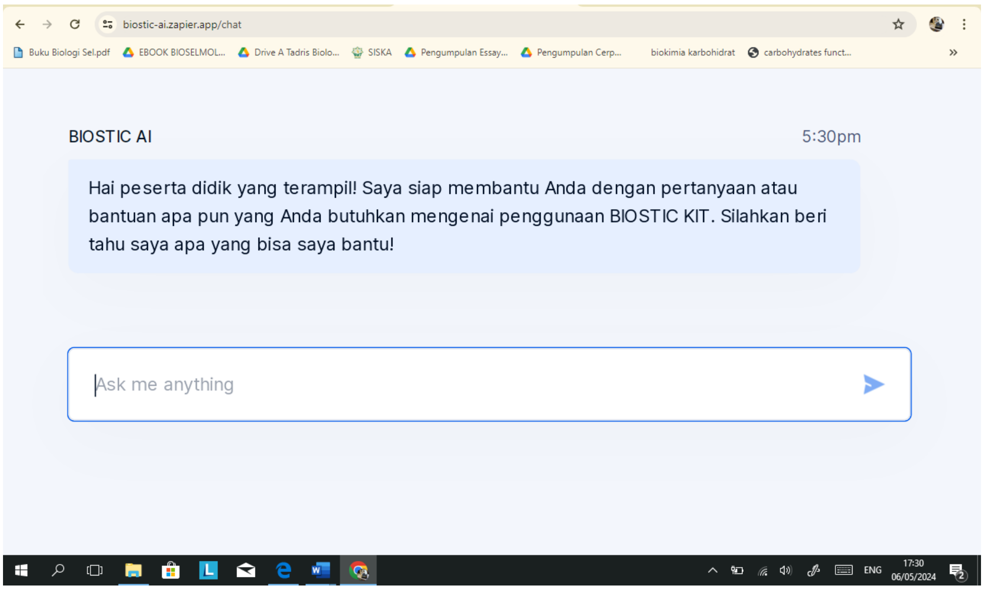

Figure 1. BOT Display FAQ BIOSTIC (Biodegradable Plastic) Experiment

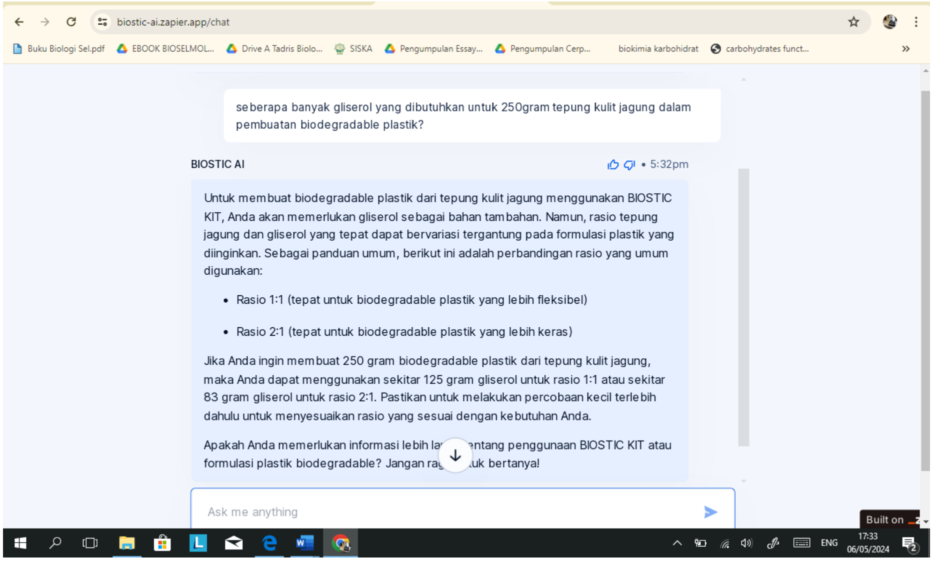

Figure 2. Display of an example of using BIOSTIC AI

Figure 3. BIOSTIC AI service barcode

This experimental research process began by collecting samples of husks (corn husks) from roasted corn traders in Wergu Wetan. In addition to husks, the materials needed include glycerol as an adhesive and acetic acid as a strength enhancer for bioplastics (Harper, 1996). The following are the procedural steps for producing biodegradable plastic from husks:

1. Material Preparation

Corn husks that have been washed and dried are ground into a fine powder using a blender. Glycerol and acetic acid are prepared as adhesive and strengthening agents for bioplastics. In this experiment, four tests were conducted with the following ratios of husks (corn husks), glycerol, and acetic acid: 5:2:1, 5:1:1, 5:1, and 5:2 (without acetic acid).

2. Mixing of Materials

Four mixtures of ground corn husks were prepared by combining corn husk flour with glycerol and acetic acid according to the experimental formulation. This mixing process was carried out in beakers using a hand mixer to ensure even distribution of the ingredients. The beakers were labeled as follows:

AI: Husk (corn husks), glycerol, and acetic acid (5:2:1)

AII: Husk (corn husks), glycerol, and acetic acid (5:1:1)

BI: Husk (corn husks) and glycerol (5:2)

BII: Husk (corn husks), glycerol, and acetic acid (5:1)

Similarly, petri dishes were labeled to match the corresponding beakers.

3. Advanced Heating and Mixing

The four beakers containing the treatment mixtures were heated over a Bunsen burner tripod until the mixture became soft and even. The mixture was stirred continuously using a spatula to ensure thorough mixing of the glycerol and acetic acid with the corn husks. This heating process also helped activate the bioplastic formation.

4. Formation and Compaction

Once the mixtures reached a suitable consistency, each mixture was poured into a different petri dish, corresponding to its respective label. The bioplastic solution was spread evenly using a spatula to ensure proper formation.

5. Cooling and Hardening

The bioplastics in the petri dishes were left to cool and harden at room temperature in the laboratory.

6. Testing and Adjustment

Once fully hardened, the bioplastics were tested for strength, flexibility, residue, and biodegradability.

Results and Discussions

Bioplastic Characteristics

Table 1. Quantitative analysis results to prove the suitability of bioplastic as an alternative to conventional plastic

Characteristic	A_I	A_{II}	B_I	B_{II}	Conventional Plastic
Waterproof	4	3	4	3	4
Thickness	4	2	4	3	2
Transparency	3	4	2	2	4
Elasticity	3	2	2	1	4
Decomposition of organisms	4	4	4	4	0
Burning	3	3	3	3	1
Total	**21**	**18**	**19**	**16**	**15**
Review Percentage Value	**87.5%**	**75%**	**79.2%**	**66.7%**	**62.5%**
Means	**77.1%**				**62.5%**

Score of 0-4 was obtained based on the supervisor's review of the research conducted, with the information (4) very good, (3) good, (2) poor, (1) very poor, and (0) not feasible. The review value is then analyzed into a review percentage value based on the analysis formula for the review results of Akbar and Sriwiyana (2011), the formula is as follows:

$$V = \frac{TSEV}{S-max} \times 100\%$$

Information:
V = Review percentage value
TSEV = Total empirical review score
S-max = Maximum expected score

Table 2. Review percentage value indicator.

Score	Description
0%-25%	Very invalid (forbidden to use)
25.01%-50%	Invalid (unusable)
50.01%-75%	Valid enough (can be used with conditions)
75.01%-100%	Very valid (usable)

Based on Table 1, the quantitative analysis of bioplastic research shows an average review value of 77.1%, indicating that the innovation of producing bioplastics from organic waste, such as corn husks, is highly valid and feasible for use (Akbar and Sriwiyana, 2011). In comparison, conventional plastic has a review percentage of 62.5%, which is classified as **"Valid Enough"** (usable with certain conditions). This suggests that bioplastics are a better alternative, as they can help reduce untreated organic waste and decrease the use of conventional plastic, thereby preventing further plastic waste accumulation in Indonesia. The research results presented in the table above can be described as follows:

Figure 4 shows a control experiment where the addition of acetic acid gives the bioplastic a more transparent appearance compared to the control without acetic acid, which appears white. Acetic acid forms hydrogen bonds between molecules, influencing the order and density of the bioplastic structure. A more ordered and denser structure results in greater transparency, as light can pass more easily through the homogeneous material. The presence of acetic acid aids in forming a more cohesive and uniform structure, enhancing the material's transparency.

Additionally, lower glycerol levels (experiments AII and BII) result in noticeable differences, producing bioplastics that are thinner and stiffer in physical structure, as shown in the image below.

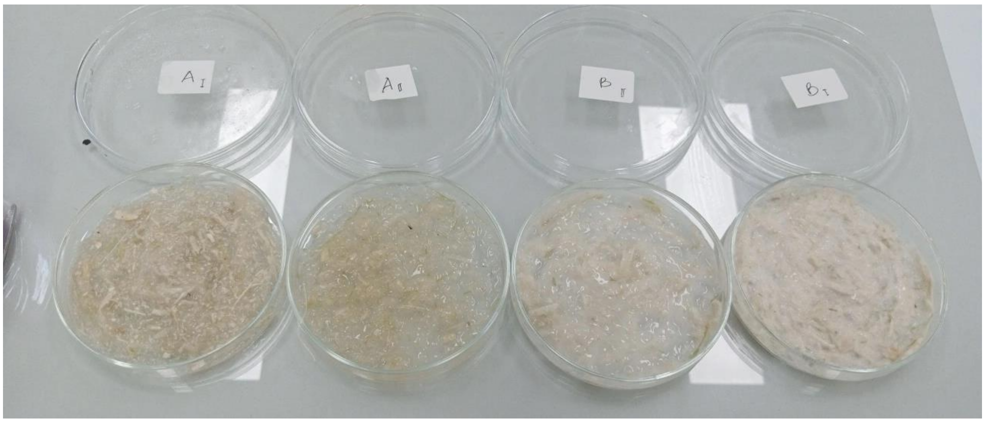

Figure 4. Experimental results of processing husk waste into bioplastic

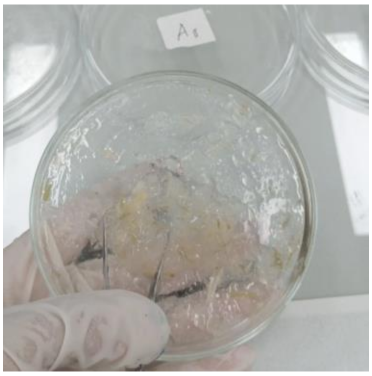

Figure 5. Control experiments (5:1:1 and 5:1) produced thinner bioplastic

Based on the control results with lower glycerol content, it is evident that glycerol, as a plasticizer, plays a crucial role. The lower the glycerol concentration ratio, the thinner and stiffer the resulting bioplastic. In the AII and BII formulations, glycerol was present in low enough amounts to provide only minimal flexibility. Meanwhile, the AI and BI control formulations, which contained higher glycerol levels, produced bioplastics that were stronger and more flexible (pliable) compared to those with lower glycerol content. The presence of glycerol allows corn husk molecules to move more freely and form looser connections between particles, giving the bioplastic elastic properties.

Experiments with a glycerol ratio of 5:1 produced thinner and stiffer bioplastics due to the lower plasticizer content, resulting in reduced flexibility and softness compared to the 5:2 formulations (AI and BI). In contrast, experiments with a glycerol ratio of 5:2 produced stronger and more flexible bioplastics, as the plasticizer composition was sufficient to provide good elasticity.

The role of BIOSTIC AI as a learning media becomes crucial in helping students and researchers analyze these experimental results. By providing real-time guidance and structured educational content, this AI-powered system enhances the understanding of bioplastic properties, making it an effective digital learning tool.

Bioplastic Degradation Capability

Bioplastic formulations using corn husks as the main ingredient have good degradation capabilities due to their natural properties and biodegradability. The use of glycerol in various proportions can affect the physical and mechanical properties of bioplastics, but does not significantly affect its degradation ability. Therefore, all experimental formulations carried out have good potential to produce bioplastics that can decompose naturally under certain environmental conditions. Bioplastic degradation testing in this research is as follows.

Figure 6. Burning test on conventional plastic (A) and bioplastic (B).

Burning tests show that conventional plastic produces black, hazardous residue, as seen in Figure 6(A), and contributes to air pollution by releasing black smoke when burned. According to a literature review, the black smoke generated from burning conventional plastic contains toxic gases such as carbon monoxide (CO), nitrogen oxides (NOx), and light hydrocarbons, which can be dangerous if inhaled in large quantities.

Meanwhile, the bioplastic produced in this study exhibits better degradation properties in combustion tests. The burning process leaves only a small amount of water vapor and white smoke, which, based on literature studies, consists of CO_2 and water vapor, without generating solid particle residue, as shown in Figure 6(B). The superior degradation properties of bioplastics make them a safer alternative, as they decompose without producing harmful residues, unlike conventional plastics.

To further validate the research findings, an additional degradation test was conducted using soil and husk decomposition, yielding the following results.

Figure 7. Comparative test of bioplastic degradation with conventional plastic using the method of decomposing soil organisms (before planting in the ground).

Figure 8. Comparative test results of bioplastic degradation with conventional plastic using the method of decomposing soil organisms after 2 days.

Soil organism degradation tests reveal significant differences in the degradability of conventional plastic and bioplastic. Bioplastics exhibit better biodegradability than conventional plastics because they are made from natural materials that are more easily broken down by soil organisms. After two days, the bioplastic had begun to degrade, although small fragments remained due to the short decomposition period. In contrast, conventional plastic decomposes very slowly in soil. Comparative degradation test results after two days showed that conventional plastic did not undergo any visible physical degradation, and its structure remained intact. These findings demonstrate that bioplastics degrade significantly faster than conventional plastics, which can take years to break down. Additionally, the decomposition of bioplastics can provide nutrients to the soil and microorganisms, contributing to the overall health of the soil ecosystem.

Conclusions

This This study demonstrates that corn husk-based bioplastic is a promising alternative to conventional plastic, offering significant environmental benefits. Moreover, the findings highlight the importance of learning media in enhancing public and student understanding of bioplastics. The integration of BIOSTIC AI as an educational tool supports interactive and technology-driven learning, making the research accessible to a broader audience. By combining experimental research with digital education, this study contributes to sustainability efforts and the achievement of Sustainable Development Goals (SDGs) related to waste management and environmental conservation.

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