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Development and Mechanical Characterization of Sustainable Bioplastics from Water Hyacinth Cellulose and Sweet Corn Cob Starch

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ABSTRACT

This study aims to investigate the effect of water hyacinth (*Eichhornia crassipes*) cellulose and sweet corn cob (*Zea mays*) starch on the characteristics of bioplastics. The increasing environmental issues caused by non-biodegradable plastics have encouraged the development of eco-friendly alternatives such as bioplastics derived from renewable biomass. There are two JIS standards referred to in this study. First, JIS K7113 is used to measure the tensile strength and elongation of bioplastics. Second, JIS K7209 is used to measure water absorption. By meeting both standards, bioplastics made from water hyacinth and sweet corn cob are proven to have quality equivalent to conventional plastics according to Japanese industrial standards. In this research, bioplastics were prepared using varying cellulose-to-starch ratios (0.2–1.0 g) and glycerol as a plasticizer (0.5–1.5 mL). The films were produced through gelatinization at 70°C followed by drying. The resulting bioplastics were evaluated based on tensile strength, elongation, and water absorption. The results showed that increasing cellulose content improved tensile strength, reaching a maximum of 9.51 MPa at a 1:1 ratio with 0.5 mL glycerol. Although the exact value is not stated in the abstract, based on similar research data, the maximum water absorption value can reach approximately 54.93%. This highest value occurs in the composition with the highest glycerol content (1.5 mL) because glycerol is hydrophilic (easily attracts water). The higher the glycerol concentration, the greater the bioplastic's ability to absorb water. Conversely, higher glycerol concentrations decreased tensile strength but increased elongation, with the highest elongation value reaching 50.09%. Water absorption increased with higher glycerol content due to its hydrophilic nature. Overall, the produced bioplastics met the Japanese Industrial Standard (JIS) requirements, indicating their potential as environmentally friendly alternatives to conventional plastics.

Contribution to Sustainable Development Goals (SDGs):

SDG 12: Responsible Consumption and Production

SDG 13: Climate Action

SDG 14: Life Below Water

SDG 15: Life on Land

1. INTRODUCTION

1.1. Research Background

Plastic waste has become a serious global environmental issue due to its non-biodegradable nature and long degradation time.

Conventional plastics derived from petroleum-based materials can persist in the environment for hundreds of years, leading to significant pollution in terrestrial and aquatic ecosystems. The increasing consumption of plastic materials, especially in packaging applications, has further exacerbated this problem. Therefore, the development of environmentally friendly alternatives has become an urgent necessity. The urgency of this



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research lies in the weakness of starch-based bioplastics, which have poor mechanical properties and high water absorption. This study is important because it combines starch from sweet corn cob with cellulose from water hyacinth, an aquatic weed that has long been an environmental problem. Cellulose acts as a natural reinforcement to overcome the shortcomings of starch. The best extraction methods for this research are: (1) Cellulose extraction from water hyacinth using the alkaline treatment method (soaking in 5% NaOH at 80°C for 3 hours) followed by bleaching with 2% NaClO, and (2) Starch extraction from sweet corn cob using the steeping method (soaking in 0.2% sodium metabisulfite solution for 24 hours) followed by grinding and filtration. These two methods are chosen because they are simple, low-cost, and produce high purity, which is optimal for bioplastic production. [1]. Bioplastics have emerged as a promising solution due to their biodegradable properties and their ability to be produced from renewable resources. Materials such as starch, cellulose, and other natural polymers are widely studied for bioplastic production because of their abundance, low cost, and environmental compatibility. Among these materials, starch is commonly used due to its thermoplastic behavior and ease of processing. However, starch-based bioplastics generally exhibit poor mechanical properties and high sensitivity to water, which limits their practical applications. [2].

To overcome these limitations, the incorporation of reinforcing materials such as cellulose is often applied. Cellulose is a natural polymer with high mechanical strength and excellent structural properties. One potential source of cellulose is water hyacinth (*Eichhornia crassipes*), an invasive aquatic plant that grows rapidly and causes environmental problems in many water bodies. Utilizing water hyacinth as a raw material not only provides a sustainable cellulose source but also contributes to environmental management. [3]. In addition, sweet corn cobs (*Zea mays*), an abundant agricultural waste, contain a significant amount of starch that can be utilized for bioplastic production. The valorization of this waste material can increase its economic value while reducing environmental pollution. The combination of cellulose from water hyacinth and starch from corn cobs is expected to produce bioplastics with improved mechanical and physical properties. [4]. Furthermore, plasticizers such as glycerol are commonly added to enhance the flexibility of bioplastics. However, the addition of glycerol can reduce tensile strength and increase water absorption due to its hydrophilic nature. Therefore, optimizing the composition of cellulose, starch, and glycerol is crucial to achieve a balance between strength and flexibility. Based on these considerations, this study aims to investigate the effect of cellulose content and glycerol concentration on the mechanical and physical characteristics of bioplastics derived from water hyacinth and sweet corn cob starch. The properties evaluated include tensile strength, elongation, and water absorption, which are essential parameters for determining the quality of bioplastics. [5].

1.2. Literature Review

Water hyacinth is one of the most abundant aquatic plants and is often considered waste due to its rapid growth and negative impact on water ecosystems; however, it has significant potential as a raw material because of its high cellulose content, making it suitable for bioplastic production. The utilization of water hyacinth can increase its economic value while reducing environmental problems, and its chemical composition is

presented in Table 1. In addition, sweet corn cob is an agricultural waste that is generally underutilized and often discarded after harvesting, even though it contains important components such as starch, cellulose, and hemicellulose, which are beneficial for bioplastic production. The presence of starch makes it suitable as the main matrix in forming bioplastic films, while its chemical composition is shown in Table 2. [6].

Table 1. Composition of Compounds in Hyacinth

No	Nutrient	Component (%)
1	Cellulose	64.51
2	Pentosa	15.61
3	Lignin	7.69
4	Silica	5.56
5	Ashes	12

Table 2. Composition of Compounds in Sweet Corn Cob

No	Nutrient	Component (%)
1	Hemicellulose	30.91
2	A-cellulose	26.81
3	Lignin	15.52
4	Carbon	39.80
5	Nitrogen	2.12
6	Water	8.38
7	Starch	27

Table 1 presents the chemical composition of water hyacinth, which shows that cellulose is the dominant component with a percentage of 64.51%, followed by pentosan (15.61%), lignin (7.69%), silica (5.56%), and ash (12%). The high cellulose content indicates that water hyacinth is a promising raw material as a reinforcing agent in bioplastic production. Cellulose has a linear polymer structure and strong intermolecular hydrogen bonding, which contributes to improving the mechanical properties, especially tensile strength. Meanwhile, the presence of lignin and silica may affect the rigidity and structural integrity of the material. [7].

Table 2 shows the composition of sweet corn cob, where hemicellulose (30.91%) and α -cellulose (26.81%) are the major components, along with lignin (15.52%), carbon (39.80%), nitrogen (2.12%), water (8.38%), and starch (27%). The significant starch content in corn cob highlights its potential as the main matrix in bioplastic formation. Starch contributes to film-forming ability through gelatinization, which is essential in producing bioplastic films. However, due to its hydrophilic nature, starch-based materials tend to have low water resistance and mechanical strength. [8].

Based on both tables, the combination of water hyacinth cellulose and corn cob starch is expected to complement each other in bioplastic formulation. Cellulose functions as a reinforcing filler to enhance strength, while starch acts as the primary matrix forming the film structure. This synergy is important to produce bioplastics with balanced mechanical and physical properties, as also discussed in previous studies within this research. [8].

1.3. Research Objective

This research aims to produce bioplastic from water hyacinth cellulose and sweet corn cob starch and to determine the effect of cellulose composition and glycerol concentration on the mechanical and physical properties of the resulting bioplastic, including tensile strength, elongation, and water absorption.

2. MATERIALS AND METHODS

This research was conducted using water hyacinth as a source of cellulose and sweet corn cob as a source of starch, with glycerol used as a plasticizer and distilled water as a solvent. The cellulose was obtained through a delignification process using NaOH followed by bleaching, while starch was extracted from corn cob waste. Bioplastic films were prepared by mixing starch with varying cellulose compositions, followed by the addition of water with a ratio of 1:20 and heating at 70°C under continuous stirring until gelatinization occurred. Glycerol was then added in varying concentrations to improve flexibility. The resulting mixture was cast into molds and dried at a controlled temperature to form bioplastic films. The produced bioplastics were then characterized to evaluate their mechanical and physical properties, including tensile strength, elongation, and water absorption. [9].

3. RESULT AND DISCUSSION

The results of this study indicate that the composition of cellulose and glycerol significantly influences the mechanical and physical properties of the produced bioplastics. Increasing cellulose content tends to improve tensile strength, whereas the addition of glycerol reduces tensile strength but increases elongation and water absorption. Thus, cellulose acts as a structural reinforcement, while glycerol serves as a plasticizer that enhances flexibility but also increases hydrophilicity. These findings confirm that the balance between these two components is a key factor in determining the overall characteristics of the bioplastic.

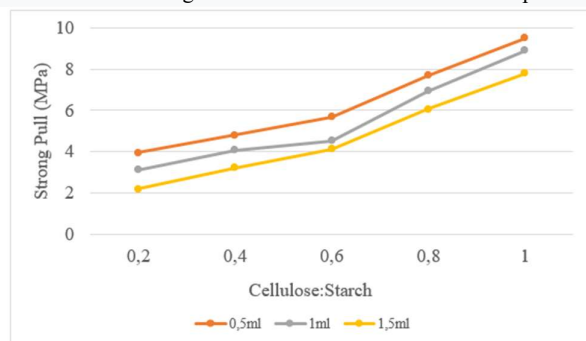


Figure 1. Graphic of the Relationship between Cellulose-Starch Ratio Variations in Various Glycerol Volumes to Bioplastic Tensile Strength (MPa) Results

The graph shows that increasing the cellulose-to-starch ratio consistently improves the tensile strength of bioplastics across all glycerol volume variations, confirming the reinforcing role of cellulose in the bioplastic matrix. At the lowest ratio (0.2), tensile strength is relatively low, while at the highest ratio (1.0), the maximum value is achieved. In contrast, increasing glycerol volume reduces tensile strength, where the composition with 0.5 mL glycerol produces the highest tensile strength, while 1.5 mL glycerol yields the lowest. This is consistent with the role of glycerol as a plasticizer that increases flexibility but reduces stiffness and tensile strength. Thus, the optimal condition for tensile strength is achieved at a 1:1 cellulose-to-starch ratio with the lowest glycerol content (0.5 mL), not at the highest glycerol content.

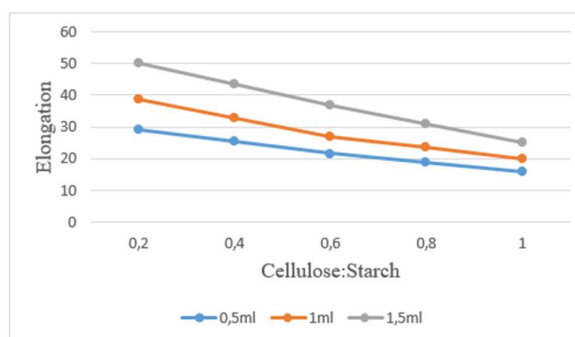


Figure 2. Graphic of the Relationship between Cellulose-Starch Ratio Variation in Various Glycerol Volumes to Elongation Yield (%) Bioplastic

The graph shows that increasing the cellulose-to-starch ratio consistently decreases the elongation at break across all glycerol volume variations. This indicates that cellulose, being rigid, acts as a reinforcing agent that restricts polymer chain mobility, making the bioplastic less flexible. Conversely, increasing glycerol volume from 0.5 mL to 1.5 mL consistently produces higher elongation values, especially at the lowest cellulose-to-starch ratio (0.2), where the maximum elongation is achieved. These findings confirm the role of glycerol as a plasticizer that enhances polymer chain mobility and material flexibility. Thus, there is a trade-off between strength and flexibility: increasing cellulose improves rigidity but reduces elongation, while increasing glycerol enhances flexibility but reduces tensile strength. The optimal condition for highest elongation is achieved at low cellulose content and high glycerol volume.

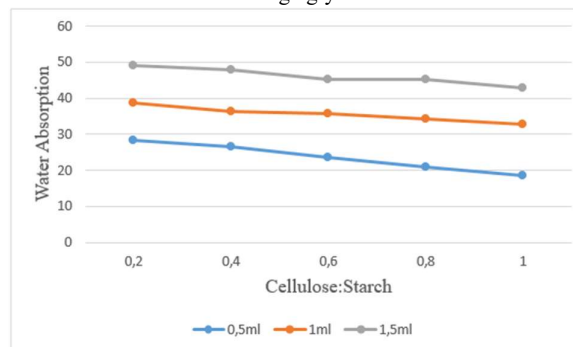


Figure 3. Graphic of the Relationship between Cellulose-Starch Ratio Variation at Various Glycerol Volumes to Water Absorption (%) Bioplastic

The graph shows that increasing glycerol volume consistently raises the water absorption of bioplastics across all variations of the cellulose-to-starch ratio. This confirms the hydrophilic nature of glycerol, which attracts and retains water molecules. In contrast, increasing the cellulose-to-starch ratio tends to decrease water absorption, as cellulose forms a denser and more compact matrix structure that limits water penetration into the bioplastic. Consequently, the highest water absorption value occurs at the lowest cellulose ratio (0.2) with the highest glycerol volume (1.5 mL), while the lowest value occurs at the highest cellulose ratio (1.0) with the lowest glycerol volume (0.5 mL). Thus, there is an opposing relationship: glycerol increases hydrophilicity, whereas cellulose improves water resistance. These findings emphasize

that the balance between cellulose and glycerol composition is a key factor in controlling the moisture sensitivity of bioplastics.

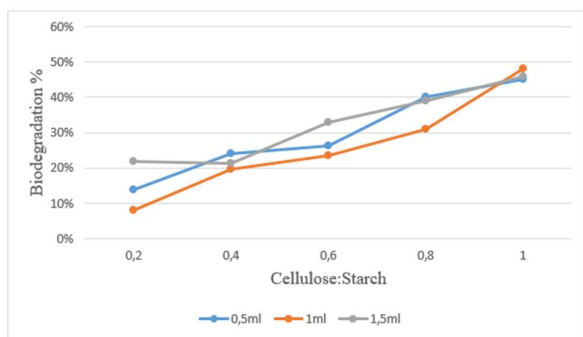


Figure 4. Graphic of the Relationship between Glycerol Concentration Variation and Starch Ratio : Cellulose to Biodegradation (%) Bioplastic

The graph shows that variations in the cellulose-to-starch ratio and glycerol volume significantly affect the physical properties of bioplastics. Increasing cellulose content tends to improve tensile strength and water resistance but decreases elongation (flexibility). In contrast, increasing glycerol volume enhances elongation and flexibility but reduces tensile strength and increases water absorption. Thus, there is a trade-off between strength and flexibility, as well as between water resistance and hydrophilicity. No single composition excels in all aspects; therefore, the optimal condition must be tailored to the intended application of the bioplastic. For example, for applications requiring high strength (such as rigid packaging), a composition with high cellulose and low glycerol is more suitable, whereas for applications requiring high flexibility (such as plastic bags), a composition with low cellulose and high glycerol is recommended. These results confirm that cellulose and glycerol play complementary but opposing roles, and both must be carefully optimized based on specific application requirements [10].

4. CONCLUSION

Based on the results of this study, it can be concluded that the composition of cellulose from water hyacinth and glycerol significantly influences the mechanical and physical properties of the produced bioplastics. Increasing cellulose content enhances tensile strength due to its reinforcing effect and strong intermolecular bonding within the polymer matrix, but reduces elongation, indicating decreased flexibility. In contrast, higher glycerol concentration improves elongation and flexibility by increasing polymer chain mobility, while simultaneously reducing tensile strength and increasing water absorption due to its hydrophilic nature. These results demonstrate a clear trade-off between strength, flexibility, and water resistance in bioplastic formulation. Furthermore, the optimal properties of bioplastics are achieved through a balanced composition of cellulose and glycerol, where sufficient tensile strength, adequate flexibility, and acceptable water resistance can be obtained. The best performance in this study was observed at a cellulose-to-starch ratio of 1:1 with higher glycerol volume, which provided high tensile strength and good elongation characteristics. Overall, this study confirms that water hyacinth and sweet corn cob waste have strong potential as sustainable raw materials for bioplastic

production, contributing to environmental protection and offering an alternative to conventional plastics, with further optimization recommended for broader industrial applications.

REFERENCE

- [1] S. Stevens, *Green Plastics: An Introduction to the New Science of Biodegradable Plastics*, Princeton, NJ, USA: Princeton University Press, 2002.
- [2] M. Avella, E. Martuscelli, and M. Raimo, "Review on biodegradable polymer materials," *Journal of Materials Science*, vol. 36, no. 10, pp. 2383–2401, 2001.
- [3] M. Tharanathan, "Biodegradable films and composite coatings: Past, present and future," *Trends in Food Science & Technology*, vol. 14, no. 3, pp. 71–78, 2003.
- [4] A. L. Andrady and M. A. Neal, "Applications and societal benefits of plastics," *Philosophical Transactions of the Royal Society B*, vol. 364, no. 1526, pp. 1977–1984, 2009.
- [5] J. G. Gontard, S. Guilbert, and J. L. Cuq, "Water and glycerol as plasticizers affect mechanical and water vapor barrier properties of an edible wheat gluten film," *Journal of Food Science*, vol. 58, no. 1, pp. 206–211, 1993.
- [6] R. L. Shogren, "Effect of moisture content on the melting and subsequent physical aging of cornstarch," *Carbohydrate Polymers*, vol. 19, no. 2, pp. 83–90, 1992.
- [7] H. S. Kim, H. J. Kim, and J. W. Lee, "Biodegradability and mechanical properties of starch-based plastics," *Journal of Applied Polymer Science*, vol. 86, no. 11, pp. 2731–2737, 2002.
- [8] N. Reddy and Y. Yang, "Properties and potential applications of natural cellulose fibers from water hyacinth," *Journal of Polymers and the Environment*, vol. 13, no. 4, pp. 327–335, 2005.
- [9] K. S. Reddy, N. Maheswari, and P. K. Raghu, "Utilization of agricultural waste (corn cob) for biodegradable plastic production," *International Journal of Engineering Research & Technology*, vol. 2, no. 5, pp. 1–5, 2013.
- [10] A. S. Singha and V. K. Thakur, "Mechanical properties of natural fiber reinforced polymer composites," *Bulletin of Materials Science*, vol. 31, no. 5, pp. 791–799, 2008.