Sustainable Biodegradable Plastics: A Comparative Study of Taro (*Colocasia esculenta*) and Cassava (*Manihot esculenta*) Starches for Eco-Friendly Packaging Solutions

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ABSTRACT

This study examines the possible use of Taro (Colocasia esculenta) and Cassava (Manihot esculenta) starch as a sustainable alternative bioplastic for eco-friendly packaging. The use of plastics, however, has increased concerns regarding plastic pollution and environmental sustainability and hence the search for biodegradable plastics from natural resources. The research was focused on creating biodegradable plastic films using Taro and Cassava starches and their comparative assessment in terms of some mechanical properties, biodegradation and environmental safety. The performed methods included starch isolation from plants, film making and testing the stripped films for select parameters such usability, tensile stress and degradation. The results show that although both starches can in some measure be used for biodegradable packing, Taro starch's accompanying tensile strength allows it to be perceived as the more durable of the two. Cassava starch however had a higher valve of biodegradation potential, indicating lower potential for environmental persistence. The study concludes that plastics made from Taro and Cassava starches are also bioplastics and can satisfactorily replace synthetic plastics according to use requirements such as strength or biodegradability. The findings make positive step towards the realization of sustainable packaging solutions to plastic waste management and environmental protection.

Keywords*: Taro (Colocasia esculenta), Cassava (Manihot esculenta), Bioplastic, Sustainable packaging.*

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1. INTRODUCTION

In recent years, the human population in the Philippines has grown significantly (Lim, R. J. M., 2022). As a result, the production and use of plastics in the country have also increased to meet the demands of individual consumers. The Philippines currently ranks as the third-largest contributor to global plastic waste, following China in first place and Indonesia in second (Jambeck, J. R., 2015). Most produced plastics are not biodegradable (Cavaliere, A., 2020; & Walker, T., 2020). According to a report by the World Wildlife Fund (WWF), only 9% of plastic is recycled, resulting in 91% of plastic waste accumulating in land and water or being incinerated, which harms living organisms (Anyango-van Zwieten et al., 2019). Conventional plastics resist degradation, leading to waste accumulation, pollution, and environmental harm, which drives the development of biodegradable plastics (Kolybaba, M., 2023). Plastics cannot naturally decompose by microorganisms, and since they are derived from limited, non-renewable petroleum, research is shifting toward packaging materials made from organic matter that can decompose naturally and are more easily sourced (Marsh, K., & Bugusu, B., 2007).

Biodegradable plastic packaging technology offers a solution to the problem of conventional plastic packaging, which cannot degrade (Raheem, D., 2012). Bioplastics made from starch-based are more environmentally friendly and degrade faster than traditional plastics (Briones, M. F. et al., 2020). Taro (Colocasia esculenta (L.) Schott) is a tropical tuber crop cultivated in many countries, including the Philippines. It is commonly used in various food products such as baby food, taro chips, taro bread, and taro sorbet (Briones et al., 2020). Starch extracted from Taro, a tropical tuber, has granule sizes ranging from 1 to 5 mm (Shanmathy, M., 2021). Its crystalline structure allows the starch to withstand high heat and shear conditions (McGlashan & Halley, 2003). On the other hand, Cassava is rich in starch, making it an ideal candidate for bioplastic production. This potential presents a significant opportunity to enhance the value of cassava as a raw material for eco-friendly plastics (Firdaus & Chairil, 2004). In fact, cassava possesses substantial promise for bioplastic manufacturing (Suharyo, 2011).

Despite increasing awareness of plastic waste issues, there is limited research comparing the effectiveness of Taro (Colocasia esculenta) and Cassava (Manihot esculenta) starches in producing sustainable biodegradable plastics. Existing studies often focus on one material, lacking a comprehensive comparison of their properties and applications in eco-friendly packaging. Furthermore, the specific context of Hinatuan National Comprehensive High School has not been explored regarding biodegradable alternatives. This presents an opportunity to investigate the feasibility and performance of Taro and Cassava starches for effective waste management and pollution reduction in educational settings.

Biodegradable plastics, particularly starch-based ones, have shown significant potential for reducing plastic waste. Studies by Zhao et al. (2019) emphasize that cassava starch provides high biodegradability and flexibility, while Shanmathy et al. (2021) highlight taro starch’s crystalline structure and resistance to heat. Research also indicates that the combination of glycerin, vinegar, and starch influences tensile strength and durability in bioplastics (Ghazali et al., 2019). These insights guide the current investigation into evaluating the mechanical properties and environmental sustainability of taro and cassava-based bioplastics for practical applications in packaging.

Industries are increasingly seeking sustainable packaging solutions that align with global efforts to reduce plastic pollution and promote environmental responsibility. This research compares the use of Taro and Cassava starches in biodegradable plastics to identify which material offers superior mechanical, thermal, and biodegradability properties. By determining which starch performs better, this study could lead to advancements in eco-friendly packaging, supporting industries in transitioning away from harmful, non-biodegradable plastics. Besides this, finding a superior starch source can assist in boosting and promoting agricultural productivity of these crops in areas where they are abundantly available and promote economic growth and sustainability. These findings can set out the very base for minimizing ecological effects of one-use plastics and promote biodegradable alternatives in different industries, supporting reduced plastic waste in the world and moving closer to a more circular economic model.

2. RESEARCH QUESTIONS

1. What are the differences in physical and chemical properties between Taro and Cassava-based biodegradable plastics in terms of:
   - 1.1 Water absorption;
   - 1.2 Tensile strength; and
   - 1.3 Degradability;
2. What is the level of acceptability of Taro and Cassava starch as a biodegradable packaging material among stakeholders (students, teachers, and parents), terms of:
   - 2.1 Strength improvement;
   - 2.2 Durability;
   - 2.3 Suitability for use in school-related packaging needs; and
   - 2.4 Cost Effectiveness
3. What recommendations can be formulated based on the comparative analysis of Taro and Cassava starches to enhance the development and implementation of sustainable biodegradable plastic solutions within the school community?

2.1 Hypothesis

Null Hypothesis (Ho)

There are no significant differences in the physical and chemical properties between Taro and Cassava-based biodegradable plastics in terms of water absorption, tensile strength and degradability.

3. RESEARCH METHODOLOGY

3.1 RESEARCH DESGIN

The study was using a comparative experimental method of research. This study will test the applicability of taro (*Colocasia esculenta*), and cassava (*Manihot esculenta*) starches in making biodegradable packaging films to be used as a potential alternative for single-use plastic. The researchers prepared plastic films using both these starches and evaluate them for strength, water uptake, and biodegradability in the soil. Like making sure each of them is in the same temp, like what is their thick when we made plastic form it etc. then analyze which one of these starches could make a better plastic. The idea is to determine which one lasts longer, breaks down quicker and costs less to manufacture.

3.1 RESEARCH LOCALE

This study was conducted at Hinatuan National Comprehensive High School, situated in Barangay Sto. Niño, Hinatuan, Surigao del Sur. The school serves as an ideal location for the research due to its accessibility and its role as a hub for educational and environmental initiatives within the community.

3.2 RESEARCH PARTICIPANTS

The participants of this study include students, teachers, parents, DENR representatives, and LGU officials. Their feedback assessed the project's feasibility, environmental benefits, and potential for reforestation and ecological restoration.

3.3 RESEARCH INSTRUMENT

The researchers developed a research questionnaire and validated by experts in school. Also, researchers made sure that every participant would participate voluntarily in the study and would give their full consent before releasing the questionnaire. The techniques and overall design of the study were thoroughly explained to the participants by the researchers. Every time a responder has a question during the study process, they can ask, explain, or decline. It was emphasized that participation in the study was voluntary and that participants might cancel their consent at any moment. Additionally, participants are free to suspend themselves.

3.4 DATA GATHERING PROCDEURE

The data collection process involved several steps. Taro (Colocasia esculenta) and Cassava (Manihot esculenta) roots from Barangay Sto. Niño, Hinatuan, Surigao del Sur. The roots were peeled, sliced, and blended to extract starch, which was strained and left to settle for two hours. After removing excess water, the dried starch was powdered and mixed with water, glycerin, and vinegar. The mixture was stirred manually, heated on a stove, poured into a drying pan, and dried for 48 hours to produce biodegradable plastic.

3.5 ETHICAL CONSIDERATIONS

The researchers made sure that every participant would participate voluntarily in the study and would give their full consent before releasing the questionnaire. The techniques and overall design of the study were thoroughly explained to the participants by the researchers. Every time a responder has a question during the study process, they can ask, explain, or decline. It was emphasized that participation in the study was voluntary and that participants might cancel their consent at any moment. Additionally, participants are free to suspend themselves.

3.6 SCOPE AND LIMITATION

This study focuses on comparing the effectiveness of Taro and Cassava starches in creating biodegradable plastics for eco-friendly packaging. Conducted at Hinatuan National Comprehensive High School, Sto. Niño, Hinatuan, Surigao del Sur, it examines the physical and chemical properties of the plastics, such as water absorption, tensile strength, degradability, and thermal stability. Stakeholder feedback from students, teachers, and administrators will be gathered to assess environmental impact, economic viability, and suitability for school use. The study is limited to these properties and assessments, excluding large-scale production or commercial applications.

4. RESULTS AND DISCUSSIONS

Table 3. Comparison of Taro and Cassava Based Bioplastics.

Characteristics	Taro-Based Bioplastic	Cassava-Based Bioplastic
Starch Yield	75g per 100g taro	85g per 100g Cassava
Tensile Strength	Moderate	High
Flexibility	High	Moderate
Texture	Smooth	Slightly Rigid
Biodegradability (2 Weeks)	93.3%	71%
Cost	Moderate	Low
Ease of Starch Extraction	Time-Consuming	Efficient

The data presents a comparison of different properties between bioplastics made from taro and cassava starches. Bioplastics made from taro starch had relatively higher starch content, higher tensile strengths, and better biodegradability, showing around 93.3% degradation in two weeks, while cassava-based bioplastics degraded by 71%. Furthermore, taro-based materials were found to be more pliant, which is advantageous for packaging applications requiring greater flexibility (McGlashan & Halley, 2003). Although smooth in texture, taro-based bioplastics differed in toughness, indicating potential trade-offs between pliability and durability (Briones et al., 2020).

Table 4. Physical Properties of Taro and Cassava-Based Bioplastics.

Characteristics	Taro-Based Bioplastic	Cassava-Based Bioplastic
Viscosity	Less Viscosity	High Viscosity
Absorption	93.3%	85.7%
Elasticity	High	High
Pigmentation	Pale White	Light Yellow
Odor	Organic	Organic

The data compares various properties of bioplastics produced from taro and cassava starches. Economically and in terms of availability, Taro was more cost-effective since it had higher returns and was less difficult to extract (Shanmathy, 2021). Cassava would require some more effort in the extraction of starch, but the production of a bioplastic that is more flexible can make it beneficial for some specific functions (Zhao et al., 2019).

It was observed that both bioplastics were completely adhered to the surfaces they were applied. The viscosity of the bioplastic made from taro was not as thick as that of cassava starch bioplastic, which had a thicker viscosity, making it ideal for applications where thicker or stiffer materials are needed (McGlashan & Halley, 2003). Also, the taro bioplastic had more elasticity, adding to the flexibility of the material (Briones et al., 2020). Regarding color, both had light colors; the taro bioplastic was more of a pale white color, while the cassava appeared to be a yellowish color (Firdaus & Chairil, 2004).

Table 6. Water Absorption Testing

Type of Bioplastic	Water Composition Rate (2 weeks)
Taro Based Bioplastic	93.3%
Cassava Based Bioplastic	85.7%

The water absorption testing results in Table 6 show that taro-based bioplastic has a higher water composition rate (93.3%) compared to cassava-based bioplastic (85.7%) over a 2-week. This indicates that taro-based bioplastic absorbs more water than cassava-based bioplastic, suggesting it may be more hydrophilic or have a more porous structure (Zhao et al., 2019). The higher absorption rate could influence the bioplastic's suitability for applications where moisture resistance is essential, as greater water uptake may impact its durability and integrity in humid or wet environments (McGlashan & Halley, 2003).

The water absorption rates of the taro-based and the cassava-based bioplastics were tested under controlled environmental conditions. Taro-based bioplastic exhibited the highest water retention capacity at 93.3%, while cassava-based bioplastic showed 85.7%. These results suggest that taro bioplastics are more water-saturated and porous, whereas cassava-based bioplastics, with lower moisture absorption, may perform better in ecological settings requiring moisture resistance (Raheem, 2012).

The tensile strength experiment compared the durability of bioplastics made from taro and cassava starches by applying successive weights to 10x10 cm samples until they fractured. Results showed that taro bioplastics were significantly stronger, with a breaking point at 712.5 grams, whereas cassava bioplastics failed at weights under 300 grams (Ghazali et al., 2019). This highlights taro bioplastics' superior resistance to stretching, making them more suitable for durable applications. The difference in tensile strength is attributed to variations in the starch and glycerol content of each bioplastic, which directly affect their mechanical properties (Firdaus & Chairil, 2004).

Although taro bioplastics are stronger, cassava bioplastics have their own advantages, particularly in creating biodegradable products (Zhao et al., 2019). By refining the formulations of both types, it is possible to enhance their unique properties, expanding their potential uses in eco-friendly packaging (Marsh & Bugusu, 2007). These findings suggest that combining their strengths could lead to versatile and sustainable packaging solutions that benefit the environment.

Table 5. Biodegradability Testing

Type of Bioplastic	Decomposition Rate (2 weeks)
Taro Based Bioplastic	93.3%
Cassava Based Bioplastic	71%

Biodegradability tests conducted over two weeks in natural conditions showed that taro bioplastics degraded by 93.3%, while cassava bioplastics broke down faster at 70%, highlighting cassava's better environmental impact in decomposition (Ghazali et al., 2019; Briones et al., 2020). During experiments, adjustments were made to improve the bioplastics' quality. The first trial resulted in a watery mixture due to excessive water and glycerol, leading to weak structures and longer drying times (Shanmathy, 2021). However, reducing these components in the next trial improved the bioplastics' texture, consistency, and drying time, ensuring better results (Raheem, 2012).

The responses from students, teachers, and parents indicate a high level of acceptance regarding the strength and durability of taro and cassava-based bioplastics for packaging applications. With weighted means of 4.81, 4.70, and 4.75, respectively, all three groups rated the bioplastics as "Highly Acceptable" across criteria such as tensile strength, structural integrity, and resistance to minor impacts. This consensus suggests confidence in the bioplastics' performance, particularly in applications that require strength and durability during handling and transport. The positive feedback across all groups underscores the bioplastics' potential viability as sustainable alternatives in packaging.

As part of durability, bioplastics were investigated with tensile strength, resistance to moisture and physical stability. Student (4.80), teacher (4.69) and parent grades were all "Highly Acceptable" for the bioplastics The material impressed most when it came to moisture resistance and the highest score was achieved, proving these materials will fit well in diverse packaging traits. This indicates that Taro and Cassava-based bioplastics are a versatile substitute for traditional packaging, leaving sustainable longevity just like plastics-but without the petroleum liquids.

Strong community support for the suitability of taro and cassava-based bioplastics in school-related packaging across students, teachers, and parents. With average weighted means of 4.80 (students), 4.75 (teachers), and 4.80 (parents), each group rated these bioplastics as “Highly Acceptable” for criteria including positive perception, willingness to adopt, environmental impact reduction, and contribution to ecological sustainability (Briones et al., 2020; Shanmathy, 2021). These high ratings reflect a strong consensus on the value of incorporating these bioplastics into school projects, highlighting their potential as environmentally friendly alternatives to conventional plastics (Ghazali et al., 2019; Raheem, 2012).

On the other hand, strong community approval of taro and cassava-based bioplastics in terms of cost-effectiveness, with all groups-students, teachers, and parents—rating them as “Highly Acceptable.” Weighted averages of 4.73 (students), 4.68 (teachers), and 4.76 (parents) indicate that respondents positively perceive these bioplastics as affordable packaging alternatives with lower maintenance costs compared to traditional plastics (Briones et al., 2020; Raheem, 2012). Additionally, there is a favorable view of the environmental benefits, underscoring the community's willingness to support these bioplastics due to their sustainable qualities (Ghazali et al., 2019; Shanmathy, 2021).

Based on the assessment of students, teachers, and some parents towards acceptability by taro and cassava-based bioplastics in four different categories: Strength Improvement, Community Acceptance, and Cost-Effectiveness. The weighted average means of each criterion across other grades responded to have a degree of high acceptability, suggesting that these bioplastics are potentially sustainable alternatives for packaging applications while being comparable with neat counterparts (Marsh & Bugusu, 2007; Zhao et al., 2019).

In general, the results demonstrate high acceptability of Taro and Cassava-based bioplastics in different demographical conditions to satisfy basic requirements such as being robust, sustainable and cost-effective for appropriate packaging. This high level of community acceptance implies considerable future adoption potential. The outcomes of this research support the promising aspects that Taro and Cassava as bioplastics can serve in packaging materials to maintain a sustainable future for environmental conservation, which also helps cost reductions from waste management fees.

In terms of significant difference between Taro and Cassava-based biodegradable plastics. Taro-based bioplastics have a mean water absorption rate of 93.3%, outperforming Cassava's 85.7%, which is supported by a t-statistics of 2.62 and a p-value of 0.018, indicating better water absorption. In terms of tensile strength, Taro bioplastics has a mean tensile strength of 712.5 grams, while Cassava only reaches 300 grams, demonstrated by a t-statistic of 4.20 and a p-value of 0.0006, highlighting Taro's superior durability. Furthermore, Taro-based bioplastics decompose at a rate of 93.3%, significantly higher than Cassava's 71%, with a t-statistic of 2.75 and a p-value of 0.012. Overall, Taro-based bioplastics excel in water absorption, tensile strength, and biodegradability compared to their Cassava counterparts, hence there is a significant difference between Taro and Cassava-based biodegradable plastics.

5. CONCLUSION

Both taro and cassava starches are viable sources for bioplastics, with cassava-based bioplastics performing better overall in terms of yield, tensile strength, and biodegradability, while taro-based bioplastics excel in flexibility, making them suitable for elastic structures. Both materials have good absorption properties, and the printed texture on both was smooth, though cassava-based bioplastic was less rigid. While taro-based bioplastics are effective for their intended use, cassava-based bioplastics show greater potential as a sustainable packaging solution that significantly reduces plastic waste.

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