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Development and Assessment of Cassava (*Manihot esculenta*) Peel Starch and Sugarcane (*Saccharum officinarum*) Bagasse Cellulose as Food Packaging Bioplastics

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Abstract: *The expeditious development and widespread utilization of disposable plastics have caused the current rise in plastic pollution. This study explored the development of bioplastics for food packaging using cassava (Manihot esculenta) peel starch and sugarcane (Saccharum officinarum) bagasse cellulose to address the issue of plastic pollution. Three different formulations for bioplastic were tested: 50:50, 70:30, and 30:70 starch-to-cellulose ratios, focusing on elongation at break, tensile strength, and peak force. A quantitative analysis utilizing one-way ANOVA showed significant differences in the mechanical properties. The 50:50 ratio performed the best, achieving the highest peak force (17.27 N), tensile strength (1.4 MPa), and elongation at break (22.69 %). On the contrary, the 70:30 ratio showed the lowest results, suggesting that too much starch or insufficient cellulose might affect the results. The findings indicate that agricultural waste materials can be effectively used for bioplastic production. Furthermore, future research should investigate water vapor permeability (WVP), biodegradability, advanced analytical methods, and formulations with additives to improve the mechanical performance and quality of the food packaging bioplastic.*

Keywords: *Bioplastic, Cassava Peel, Elongation at Break, Sugarcane Bagasse, Tensile Strength*

1. INTRODUCTION

The expeditious development and omnipresent utilization of traditional plastics have significantly contributed to plastic pollution, specifically in food, cosmetics, and pharmaceutical packaging, which can take over 400 years to decompose (Lomartire et al., 2022). In the company of most global waste management systems are unable to handle the immense amounts of plastic produced therefore, finding alternatives is progressively critical (Palardy, 2020). Among potential solutions, bioplastics are developed as an alternative to synthetic plastic as they are considered more environmentally friendly (Casiňo et al., 2023). Additionally, biodegradable plastics derived from renewable and waste products, such as cassava (*Manihot esculenta*) peel and sugarcane (*Saccharum officinarum*) bagasse, offer a propitious alternative. These agricultural by-products are often discarded, causing environmental harm (Oghenejoboh et al., 2021; Ajala et al., 2021). In contrast with conventional plastics, bioplastics derived from such waste materials can biodegrade under various environmental conditions, making them more manageable and sustainable.

A variety of studies have indicated that bioplastics have the potential to be an alternative to petroleum-based plastics in food packaging and other applications. Moreover, starches like corn, wheat, potato, and cassava are key components in developing these biodegradable films (Thuppahige, 2022). However, despite their known potential in bioplastic production, limited studies are focused on utilizing sugarcane (*S. officinarum*) bagasse and cassava (*M. esculenta*) peel starch in regions such as Malaybalay City Bukidnon, Philippines. While studies have explored various formulations of bioplastics derived from cassava (*M. esculenta*) peel, further research is essential to enhance the material properties of food packaging bioplastics derived from these agricultural by-products.

The primary objective of this study was to develop a bioplastic for food packaging utilizing sugarcane (*S. officinarum*) bagasse and cassava (*M. esculenta*) peel, which will aid in lessening waste and promote sustainability. Additionally, the study aimed to evaluate the quality of the produced bioplastics to ensure their suitability for utilization as food packaging. By attaining these objectives, the study has contributed to ameliorating bioplastic production and practical use, addressing environmental waste management challenges and the demand for renewable food packaging solutions.

2. MATERIALS AND METHODS

2.1. Research Design

The study utilized an experimental quantitative research approach to evaluate the physical properties of food packaging bioplastic derived from three different starch-to-cellulose ratios, 50:50, 70:30, and 30:70. Additionally, the experimental research involved testing a theory through various experiments, utilizing a quantitative research design to gather and analyze data on the physical properties of the food packaging bioplastics. Moreover, the researchers focused on an independent variable and evaluated its impact on the dependent variable, using naturally occurring groupings rather than random assignment. Most importantly, manual testing was conducted using acknowledged methods to compare the physical qualities of the bioplastics in line with the study's objectives.

2.2. Study Site

The food packaging bioplastics derived from cassava (*M. esculenta*) peel and sugarcane (*S. officinarum*) bagasse were washed, ground and prepared at a residence in Indalasa Malaybalay City, Bukidnon, Philippines and were sent to Central Mindanao University (CMU), specifically to the Museum for specie identification and to the Mindanao Engineering Integrated Center (MinEC) Engineering Integrated Laboratory for various tests, including tensile strength, peak force, and elongation at break.

2.3. Species Confirmation

The raw samples of collected cassava (*M. esculenta*) peel and sugarcane (*S. officinarum*) bagasse were identified at a Museum in Central Mindanao University (CMU) to confirm the type of plant species from which the bioplastic was produced. Another point is that this test ensured the raw agricultural by-products utilized were all of the same plant species and guaranteed consistency in the production of food packaging bioplastic.

2.4. Preparation of Samples

The cassava (*M. esculenta*) peel and sugarcane (*S. officinarum*) bagasse, totaling three hundred (300) grams each, were gathered from the local farmers in Malaybalay City, Bukidnon. Additionally, Glycerol and Sodium Hydroxide (NaOH) were purchased from a chemical market in Cagayan de Oro, and the research laboratory at San Isidro College supplied additional materials and equipment needed for the study.

2.5. Extraction of Starch in Cassava (*M. esculenta*) Peel

The cellulose extraction from sugarcane (*S. officinarum*) bagasse follows a slightly modified method based on Thakur et al., 2021. To extract starch from three hundred (300) grams of fresh cassava (*M. esculenta*) peels, they were washed and cleaned thoroughly using tap water, then crushed and sieved for uniformity. Subsequently, 700 mL of distilled water was poured into the ground cassava (*M. esculenta*) peels that were placed in a large bowl, it was stirred and squeezed through cheesecloth to recover the starch from the mixture. Meanwhile, the mixture was left undisturbed to settle for 6 hours, and then the water was drained slowly, leaving the wet starch behind. The extracted starch was spread thinly on an aluminum tray to air dry for 24-72 hours. Once the starch was thoroughly dried, it was ready for food packaging bioplastic production.

2.6. Extraction of Cellulose in Sugarcane (*S. officinarum*) Bagasse

The cellulose extraction from sugarcane (*S. officinarum*) bagasse follows a slightly modified method based on Mzimela et al. (2018). First, three hundred (300) grams of sugarcane (*S. officinarum*) bagasse was dried and ground into small pieces. The ground sugarcane (*S. officinarum*) bagasse was boiled in a 4% sodium hydroxide (NaOH) solution at 100°C for two hours to remove lignin and hemicellulose. Most importantly, the mixture was stirred continuously for even treatment. After boiling, the solid cellulose-rich residue was filtered and rinsed with distilled water to neutralize the sodium hydroxide and achieve a neutral pH. The cellulose was then spread thinly in an aluminum tray, and left to be air-dried at room temperature for 24-72 hours. Once the cellulose was thoroughly dried, it was ready for food packaging bioplastic production.

2.7. Production of Bioplastic

The procedure for developing bioplastic from cassava (*M. esculenta*), peel starch, and sugarcane (*S. officinarum*) bagasse cellulose was adapted from Bhausaheb (2023) with slight modifications. The process began with cassava (*M. esculenta*) peel starch gelatinization by mixing cassava starch with 120 mL of distilled water and heating it to 60-80°C while stirring continuously until an even paste was formed. This process ensures proper distribution of starch in the bioplastic.

Once the extracted cassava (*M. esculenta*) peel starch was gelatinized, sugarcane (*S. officinarum*) bagasse cellulose and 2 grams of glycerol (plasticizer) were added to improve flexibility. Three different formulations were produced and tested using ratios of 50:50, 70:30, and 30:70 for starch and cellulose. The mixture was stirred for 10-15 minutes to ensure thorough homogenization.

Subsequently, the solution was poured into an aluminum tray (8.27 x 11.69 inches) lined with foil and lightly oiled for smoother peeling after drying. The bioplastic mixture was dried in an oven at 60-70°C for 30 minutes, followed by air drying for approximately four days. Careful monitoring of the drying process ensured uniformity and prevented cracks. Once dried, the bioplastic was gently removed from the aluminum tray and was ready to be used for testing its physical properties.

Table1. *Composition of Different Bioplastic Samples*

Treatment	Starch (g)	Cellulose (g)	Glycerol (g)	5% Acetic Acid (tsp)	Distilled Water (mL)
T1	10	10	2	1	120
T2	7	3	2	1	120
T3	3	7	2	1	120

2.8. Statistical Treatment of Data

The findings of each investigational group, including the mean and standard deviation for each variation of bioplastic derived from cassava (*M. esculenta*) peel and sugarcane (*S. officinarum*) bagasse, were evaluated. One-way Analysis of Variance (ANOVA) evaluated all data, with the p-value compared to a significance level of 0.05, to determine the rejection of the null hypothesis.

2.9. Ethical Consideration

The study followed research ethics by ensuring unbiased, honest, and transparent data collection and accurate reporting of results. Following the Data Privacy Act of 2012, the study prioritized protecting privacy rights while fostering the free flow of information for innovation. Consent was obtained from the school principal and parents to secure approval. Furthermore, strict safety measures were applied during study site visits to minimize health risks and lessen the potential for injury.

3. RESULTS AND DISCUSSION

3.1. Properties of the Developed Food Packaging Bioplastic from Three Various Ratios

Peak Force

Peak force is the maximum detachment force a material can withstand before breaking (Ali & Bakalis, 2011). The starch extracted from cassava (*M. esculenta*) peels played an important role in the production of food packaging bioplastics, as these peels can be produced into bioplastics, showing their potential in bioplastic development (Nee & Othman, 2022). Additionally, starch remains one of the most propitious biodegradable materials because of its abundance, affordability, and biodegradability (Yu et al., 2021).

Among the three different ratios of bioplastic, the highest peak force of 17.27 N was evaluated in the 50:50 ratio of cassava (*M. esculenta*) starch to sugarcane (*S. officinarum*) bagasse cellulose, followed by 10.17 N for the 30:70 ratio and 7.93 N for the 70:30 ratio. The balance between starch and cellulose potentially affected the bioplastic's ability to absorb and divide out pressure, highlighting the importance of formulation in ensuring strength and flexibility (Saiful et al., 2019).

Tensile Strength

Tensile strength calculates a material's capacity to resist breaking under tension, which is essential for bioplastics in packaging applications. Bioplastics integrated from only starch possess a lesser degree of mechanical strength and warm sturdiness and can be enhanced by the incorporation of fillers, as stated by Abera et al. (2023). Additionally, Siddiqui et al. (2024) further emphasized that adding fillers enhances bioplastics' physical, mechanical, and active properties, making the bioplastic more congruous for food packaging utilization.

Among the three different ratios of bioplastic, the highest average tensile strength, 1.4 MPa, was evaluated in the 50:50 ratio of starch to cellulose, with the 30:70 and 70:30 ratios recording 0.833 MPa and 0.633 MPa, respectively. While the tensile strength in this study does not reach the Indonesian National Standard for food packaging bioplastics (24.7-100 MPa), it exceeds the Japanese Industrial Standard (0.39 MPa), indicating that these bioplastics are suitable for certain international standards (Gabriel et al., 2021; Kanagesan et al., 2022).

Figure 4. 50:50 Ratio

Figure 5. 70:30 Ratio

Figure 6. 30:70 Ratio

Table2. *Physical Properties of the Developed Food Packaging Bioplastic Peak Force*

Variants	Peak Force (N)	Tensile Strength (Mpa)	Elongation at Break (mm)
T1 (50:50)	17.27 ± 3.10	1.4 ± 0.216	22.69 ± 7.03
T2 (70:30)	7.93 ± 1.15	0.633 ± 0.125	16.42 ± 3.20
T3 (30:70)	10.17 ± 1.79	0.833 ± 0.189	20.41 ± 3.86

Percent Elongation at Break

A study by Tan et al. (2022) evaluated the mechanical enhancement of decomposable chitosan-reinforced starch-based bioplastics. They observed a notable reduction in tensile strength, from 3.22 MPa to 0.78 MPa ($p < 0.05$), following the incorporation of fillers. This finding highlights the significant influence that filler materials' type and concentration can have on bioplastics' mechanical properties. Similarly, Ramadhan et al. (2024) reported that variations in filler concentrations in bioplastic mixtures resulted in differences in material properties, such as flexibility and tensile strength, even when identical amounts of glycerol were utilized. Additionally, studies have shown that plasticizers like glycerol can improve elongation by increasing molecular mobility and enhancing flexibility (Amni et al., 2020).

The percentage elongation data showed a significant difference among the three tested samples. The results showed that the 50:50 ratio exhibited the highest elongation at 22.69%, followed by 20.41% for the 30:70 ratio and 16.42% for the 70:30 ratio. The decreased elongation with higher starch content suggests that too much starch leads to increased brittleness (Tan et al., 2022). This corresponds with balancing the starch-cellulose ratio to achieve optimal flexibility in bioplastics.

3.2. Significant Differences in the Properties of the Developed Food Packaging Bioplastic from Various Ratios

Table3. *One-way ANOVA summary of the peak force, tensile strength, and elongation at break properties of the developed food packaging bioplastic from three different ratios*

	Peak Force (N)	Tensile Strength (Mpa)	Elongation at Break (Mpa)
One-way ANOVA Summary (p)	p = 0.012	p = 0.013	P = 0.49

The analysis of the three different ratios of the food packaging bioplastic showed significant differences in mechanical properties, as the results did not meet the significance level of 0.05. The peak force (N) yielded a p-value of 0.012, tensile strength a p-value of 0.013, and elongation at break a p-value of 0.049, all below the 0.05 significance level. These results indicate that the three different ratios of food packaging bioplastic formulations exhibit statistically distinct mechanical properties.

This variability aligns with findings by Azmin et al. (2020), who emphasized that bioplastics generally have lower tensile properties than traditional plastics. Additionally, Safitri et al. (2022) and Siddiqui et al. (2024) emphasized that adding fillers to the bioplastic formulation can enhance bioplastics' mechanical, barrier, and active properties, enhancing their renewability for food packaging applications (Amni et al., 2020). Moreover, the ASTM D638 standard is recommended for preparing bioplastic samples to ensure reliable tensile testing.

4. CONCLUSIONS

This study demonstrates the potential of agricultural waste materials, specifically cassava peel starch and sugarcane bagasse cellulose, in developing bioplastics with propitious mechanical properties. The results emphasize the importance of the starch-to-cellulose ratio in determining bioplastic quality. The 50:50 ratio exhibited the best mechanical performance, achieving the highest results in peak force, tensile strength, and elongation at break, indicating that a balanced formulation enhances the bioplastics' consistency and flexibility. In contrast, uneven ratios negatively impacted the bioplastics' properties, highlighting the importance of accurate formulation. Factors such as variations in bioplastic thickness, drying methods, and the manual production process also affected the mechanical properties. These findings highlight the potential for using agricultural by-products to develop sustainable bioplastics, offering an eco-friendly alternative to traditional plastics at the same time addressing agricultural waste management problems.

Based on the results of the study, the following are recommended:

Expand the scope of testing parameters to include water vapor permeability (WVP) and biodegradability tests, along with advanced analytical techniques such as SEM, FTIR, and DSC. These tests would allow for a deeper evaluation of the characteristics of the bioplastics, aiding in developing the suited formulation and improving the mechanical properties of the food packaging bioplastic. Further experiments exploring additional ratios beyond those tested in this study are recommended to process the optimal balance for enhanced mechanical performance. Additionally, adding additives, such as natural fibers or plasticizers, should be explored to improve tensile strength, flexibility, and durability.

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REFERENCES

[1] Abera, W. G., Kasirajan, R., & Majamo, S. L. (2023). Synthesis and characterization of bioplastic film from banana (Musa Cavendish species) peel starch blending with banana pseudo-stem cellulosic fiber. Biomass Conversion and Biorefinery, 14(17), 20419–20440. https://doi.org/10.1007/s13399-023-04207-8

[2] Ajala, E. O., Ighalo, J. O., Ajala, M. A., Adeniyi, A. G., & Ayanshola, A. M. (2021). Sugarcane bagasse: biomass sufficiently applied for improving global energy, environment, and economic sustainability. Bioresources and Bioprocessing, 8(1). https://doi.org/10.1186/s40643-021-00440-z

[3] Amni, C., Ismet, N., Aprilia, S., Mariana, N., & Akbar, S. A. (2020). MECHANICAL PROPERTIES OF BIOPLASTICS JANENG STARCH (Dioscorea hispida) FILM WITH GLYCEROL AND ZINC OXIDE AS REINFORCEMENT. RASAYAN Journal of Chemistry, 13(01), 275–281. https://doi.org/10.31788/rjc.2020.1315492

[4] Azmin, S. N. H. M., Hayat, N. a. B. M., & Nor, M. S. M. (2020). Development and characterization of food packaging bioplastic film from cocoa pod husk cellulose incorporated with sugarcane bagasse fibre. Journal of Bioresources and Bioproducts, 5(4), 248–255. https://doi.org/10.1016/j.jobab.2020.10.003

[5] Bhausaheb, G. S. (2023). Production of Biodegradable Plastic from Potato Starch. International Journal of Science and Research (IJSR), 12(2), 226–230. https://doi.org/10.21275/mr23131183605

[6] Casiño, V. J. A., Reyes, N. Q. D., Jr, Casas, R. Y., Saldo, I. J. P., & Peñafiel-Dandoy, M. J. (2023). Characterization of Cornstarch-Based Bioplastic Reinforced with Three Different Species of Bamboo Shoots. *American Journal of Environmental Protection*, *11*(1), 25–33. https://doi.org/10.12691/env-11-1-4

[7] Gabriel, A. A., Solikhah, A. F., & Rahmawati, A. Y. (2021). Tensile Strength and Elongation Testing for Starch-Based Bioplastics using Melt Intercalation Method: A Review. Journal of Physics Conference Series, 1858(1), 012028. https://doi.org/10.1088/1742-6596/1858/1/012028

[8] Kanagesan, K., Abdulla, R., Derman, E., Sabullah, M. K., Govindan, N., & Gansau, J. A. (2022). A sustainable approach to green algal bioplastics production from brown seaweeds of Sabah, Malaysia. Journal of King Saud University - Science, 34(7), 102268. https://doi.org/10.1016/j.jksus.2022.102268

[9] Lomartire, S., Marques, J. C., & Gonçalves, A. M. M. (2022). An overview of the alternative use of seaweeds to produce safe and sustainable Bio-Packaging. Applied Sciences, 12(6), 3123. https://doi.org/10.3390/app12063123

[10] Mahmud, M. A., & Anannya, F. R. (2021). Sugarcane bagasse - A source of cellulosic fiber for diverse applications. Heliyon, 7(e07771. https://doi.org/10.1016/j.heliyon.2021.e07771De

[11] Mzimela, Z. N. T., Linganiso, L. Z., Revaprasadu, N., & Motaung, T. E. (2018). Comparison of Cellulose Extraction from Sugarcane Bagasse Through Alkali. Materials Research, 21(6). https://doi.org/10.1590/1980-5373-mr-2017-0750

[12] Nee, F. C., & Othman, S. A. (2022). Preparation and Characterization of Irradiated Bioplastic from Cassava Peel – A Review. Journal of Physics Conference Series, 2169(1), 012041. https://doi.org/10.1088/1742-6596/2169/1/012041

[13] Oghenejoboh, K. M., Orugba, H. O., Oghenejoboh, U. M., & Agarry, S. E. (2021). Value added cassava waste management and environmental sustainability in Nigeria: A review. Environmental Challenges, 4, 100127. https://doi.org/10.1016/j.envc.2021.100127

[14] Palardy, J. (2020, July 23). Science study shows that nearly 80% of the annual plastic flow into the environment can be stopped using existing technology. The Pew Charitable Trusts. https://www.pewtrusts.org/en/research-and-analysis/articles/2020/07/23/science-study-shows-that-nearly-80-percent-of-the-annual-plastic-flow-into-the-environment

[15] Ramadhan, M. H., Nurrahman, A., Steven, S., & Mardiyati, Y. (2024). Enhancing mechanical properties, degradation rate, and water resistance of bioplastic Lignin/Polyvinyl Alcohol (PVA) by fractionation of lignin. Emergent Materials. https://doi.org/10.1007/s42247-024-00805-y

[16] Safitri, A., Sinaga, P. S. D., Nasution, H., Harahap, H., Masyithah, Z., Iriany, N., & Hasibuan, R. (2022). The role of various plasticizers and fillers additions in improving the tensile strength of starch-based bioplastics: A mini review. IOP Conference Series Earth and Environmental Science, 1115(1), 012076. https://doi.org/10.1088/1755-1315/1115/1/012076

[17] Saiful, N., Helwati, H., Saleha, S., & Iqbalsyah, T. M. (2019). Development of bioplastic from wheat Janeng starch for food packaging. IOP Conference Series Materials Science and Engineering, 523(1), 012015. https://doi.org/10.1088/1757-899x/523/1/012015

[18] Siddiqui, S. A., Yang, X., Deshmukh, R. K., Gaikwad, K. K., Bahmid, N. A., & Castro-Muñoz, R. (2024). Recent advances in reinforced bioplastics for food packaging – A critical review. International Journal of Biological Macromolecules, 130399. https://doi.org/10.1016/j.ijbiomac.2024.130399

[19] Tan, S. X., Ong, H. C., Andriyana, A., Lim, S., Pang, Y. L., Kusumo, F., & Ngoh, G. C. (2022). Characterization and parametric study on mechanical properties enhancement in biodegradable Chitosan-Reinforced Starch-Based bioplastic film. Polymers, 14(2), 278. https://doi.org/10.3390/polym14020278

[20] Thakur, V. K., Thakur, M. K., & Gupta, R. K. (2014). Review: Raw Natural Fiber–Based Polymer Composites. International Journal of Polymer Analysis and Characterization, 19(3), 256–271. https://doi.org/10.1080/1023666x.2014.880016

[21] Thuppahige, V. T. W. (2022). Characterization and performance analysis of cassava peel and bagasse as alternative, non-edible starch sources for biodegradable food packaging. https://doi.org/10.5204/thesis.eprints.233701

[22] Yu, X., Chen, L., Jin, Z., & Jiao, A. (2021). Research progress of starch-based biodegradable materials: a review. Journal of Materials Science, 56(19), 11187–11208. https://doi.org/10.1007/s10853-021-06063-1

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