Development and Evaluation of Taro (Colocasia Esculenta) Leaves and Banana Pseudo Stem (Musa Acuminata) as an Alternative Hydrophobic Paper Bag

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Development and Evaluation of Taro (*Colocasia Esculenta*) Leaves and Banana Pseudo Stem (*Musa Acuminata*) as an Alternative Hydrophobic Paper Bag

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Abstract: *This study aims to develop an alternative hydrophobic paper bag out of taro leaves and banana pseudo stems using different concentrations of the coating such as 1 coat, 2 coats, and 3 coats of bio-wax from taro leaf and petroleum jelly. The results of bio-wax and petroleum jelly coat significantly affect TS and EAB samples and the paper bag showed quick degradation. In terms of water absorption significant changes (P≤0.05), the amount of water absorbed was accounted at the range of 72.65 % for T1, 71.27 % for T2, and 52.78% for T3 for temperature (25 ºC). Also, the 3 coats of bio-wax and petroleum jelly resulted in more hydrophobic samples. The findings recorded that the overall desirable paper bag is T3. Also, treatments that were treated resulted in hydrophobicity. The taro leaves and banana pseudo-stem fibers can be potential materials for developing hydrophobic paper bags.*

Keywords: Hydrophobic, bio wax, taro leaves, banana pseudo-stem.

1. INTRODUCTION

Plastic pollution has been a topic of rising environmental concern in recent years. Model estimates show that between 0.8 and 30 million metric tonnes of plastic waste enter the aquatic environment annually around the globe [1,2,3]. Most of the plastic pollution is generated on land and transported through rivers and to the marine environment [4,5,6]. Most individuals are converting from using plastic to paper bags primarily for this reason. Paper bags are environmentally good since they are made up of wood fiber, which is a renewable and ever-growing supply [7]. Paper bags have become increasingly popular due to their sustainability; however, they also have some serious environmental disadvantages. Paper bags must first be manufactured, which results in the release of greenhouse gases. Moreover, because of their poor durability, paper bags can only be used four times. Products can avoid deterioration by using waterproof packaging materials and water-resistant paper bags. Waterproof paper bags are also strong and play a significant part in the marketability of the products since they help maintain the appearance of the wrapped product [8].

Meanwhile, taro leaves derived from the taro plant (*Colocasia esculenta*), possess unique properties that make them suitable for various applications, including packaging. Being renewable and biodegradable. Taro leaves provide a sustainable alternative to paper bags. Taro also leaves decay naturally, lessening its environmental impacts and waste development [9]. Taro leaves have been demonstrated to have high tensile strength, tear resistance, and flexibility, all required for long-lasting and functioning bags [10]. Banana pseudo stem is a sustainable and abundant source of packaging materials. It is a byproduct of banana plants, which are widely grown worldwide. Using the pseudo stem for packing decreases waste while increasing resource efficiency [11]. Banana pseudo stem decomposes naturally over time [12], it possesses inherent barrier properties against moisture and gases. These properties help maintain the quality and freshness of packaged products [13], and it exhibits favorable mechanical properties, including tensile strength and durability [14] which make them a viable option for packaging applications, providing protection and support to the packaged goods. The concerns and issues about commercial paper bags prompted the researchers to create an alternative paper bag from taro leaves and banana pseudo stem to address the drastic number of trees cut each year just to make paper bags and the increasing number of plastic bags dumped each year.

2. MATERIALS

The descriptions, functions, and materials used in the development of hydrophobic paper bags made from taro leaves and banana pseudo stem are shown in Table 1.

Table 1. Description and Functions of Materials

Materials	Description and Functions
Taro Leaves	Leaves of the Taro Plant which is used as an ingredient for developing hydrophobic paper bags.
Banana Pseudo stems	The trunk of the banana plant is used as an ingredient for developing hydrophobic paper bags.
Digital Weighing Scale	It is used to measure the mass of a sample.
Molder	It is used to shape and form the blended samples.
Heavy Duty Blender	An electric device used to mix, crush, or emulsify food and other substances.

Oven Dryer	A heated chamber is used to extract water, moisture, and other solvents from matter.
Precision Balance	A device designed to deliver highly exact weighing results.
Beaker	A cylindrical glass or plastic container that holds solutions.
Box Container	Enclosures fabricated from plastic hold the blended samples.
Rotary Evaporator	A device used to efficiently remove solvents and extract bio-wax from taro leaves during the evaporation process.
Universal Testing Machine	A mechanical device used to test the tensile strength and elongation of materials.
Metallic Pot	The material used in containing taro leaves and banana pseudo stems for the boiling process.
Petri Dish	a shallow clear glass or plastic cylindrical dish with a cover, used to hold the sample materials
Vernier Caliper	An instrument for measuring linear dimensions.
Soil Bags	A material used in putting different kinds of soil for the degradation process of developed hydrophobic paper bag.

3. METHODS

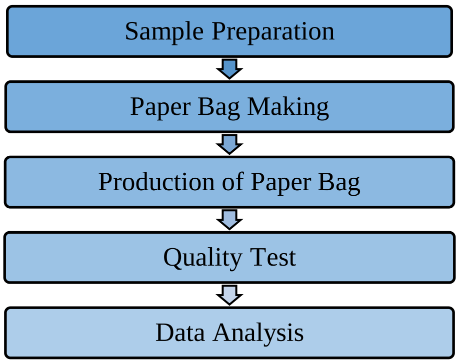

Fig. 1. The general framework of the study

The general representation of the overall structure encompassing various essential stages of the study is shown in Figure 1. It includes sample preparation, paper bag making, production, quality testing, and data analysis.

3.1 Sample Preparation

Sample preparation includes the procurement and collection of materials. Materials were collected and purchased from local producers in Ampayon, Butuan City, Agusan del Norte, Philippines to prevent sample dissimilarity due to seasonal variation. For this study, an unusable banana pseudo stem was utilized while the taro leaf that was neglected has also been utilized. The banana pseudo stem and taro leaf were then pre-cleaned with distilled water to remove foreign materials such as soil, and insects during the cultivation. Lastly, the cleaned and sorted banana pseudo stem and taro leaf were cut into fragments ranging from 1-2 cm. It was temporarily stored and transported to the laboratory of Agricultural and Biosystems Engineering to be subjected to molding and drying of fibers at 105 ºC for 9 hours. For this study, three (3) treatments were applied for the development of a hydrophobic paper bag.

3.2 Paper Bag-Making Process

3.2.1 Extraction of banana pseudo stem fibers

Banana pseudo stem fibers were immersed in distilled water contained in a pot. The developed fibers were heated for 3 hours and mixed with laboratory grade Sodium Hydroxide with varying compositions and were mixed every 10- min intervals. During the extraction process, the alkali-treated banana pseudo stem was filtered using a strainer to remove the liquid. The alkali-treated banana pseudo stem was neutralized by washing it with 8 liters of distilled water for 15 minutes to eliminate the remaining alkali solution. The treated fibers from the bananas were put in a container and blended [15].

3.2.2 Extraction of fibers from taro leaf

The collected taro leaves were immersed in 8 liters of distilled water in a pot. The method by [16] was followed in the extraction of the fibers from the taro leaf. The extracted fibers were heated at 100 °C for 2 hours and were mixed in every 10 min interval. Afterward, the leaves were filtered using a strainer. The taro fibers were then stored in a container for the purpose of blending and mixing with other ingredients.

3.2.3 Isolation of bio-wax from taro leaf

The process of [17] was followed in the isolation of wax from taro leaves. The taro leaves were then cut into fragments ranging from 1-2 cm. The researchers prepared ethanol 800 ml per treatment [18]**.** The taro leaf was extracted using laboratory-grade ethanol and stored for 24 hours in an ultra-low freezer. After the winterization process, the solution was then submitted to the CSU Chemical Laboratory. The winterization process can help to remove waxes from the leaf. A rotary evaporator (DLAB RE100-Pro) was used to remove the ethanol at 48 °C at 46 rpm. The isolated taro wax was then mixed with petroleum jelly to exhibit good-quality wax [19, 20].

3.3 Production of Paper Bag

The manual molding process was performed by using a molder to mold the fibers. Using a laboratory oven (Labtech, LDO-08OF Model, China), the molded fiber was oven dried at 105 °C for 9 hours. Afterward, the paper bags were placed at room temperature (25 °C) to be carefully removed from the mold. Then, the developed paper bag was coated with wax extracted from taro leaves and petroleum jelly. The taro leaf was extracted using ethanol and stored for 24 hours in an ultra-low freezer this method is adapted from the study of [21] with few modifications. The ethanol was evaporated from the mixture using a DLAB RE100-Pro rotary evaporator operating at 48 °C and 46 rpm. Subsequently, the taro wax was combined with petroleum jelly to achieve a high-quality blend. The resulting hydrophobic paper bag was then temporarily stored in a container for further use or examination.

3.4 Quality Test

To assess the quality of the hydrophobic paper bags produced, a series of rigorous quality tests were conducted. These tests aimed to evaluate various key characteristics and performance aspects of the bags. Some of the essential quality tests performed include:

3.4.1 Water Absorption Test

The water absorption test was conducted according to the ASTM D570-98 standard, with certain adjustments to the procedure. The samples were immersed in a 6-liter container at room temperature for a duration of 24 hours. To enhance the reliability of the findings, the experiments were replicated three times, ensuring more accurate and valid results. In this experiment, the methodology described in reference [22] was adapted. The water absorption was determined by measuring the amount of water absorbed by the samples after a 24-hour period. Following each observation, the samples were carefully removed from the water bath, surface-wiped, and weighed using an analytical balance. The percentage of water absorbed was then calculated using Equation 1.

$$Water\ Absorption = \frac{W_{initial} - W_{final}}{W_{initial}}\ x\ 100\ \% \quad (1)$$

$W_{initial}$ – initial quantity of water present before the water absorption test was conducted.
W_{final} - the final amount of water present in the samples after the water absorption test has been completed.

3.4.2 Tensile Strength and Elongation Test

The tensile strength and elongation samples were measured by Universal testing Machine (Micro-computer screen hydraulic universal testing machine, China) in Equiparco, Ambago, Butuan City.

3.4.3 Biodegradability test

The method of [23] was adapted with minor modifications. The biodegradability test was conducted under a controlled environment where there are two (2) soil types were used: organic soil and normal soil. The normal mass (Wo) of the plastic bag was measured and buried under organic soil and normal soil. The amount of sample weight reduction was measured daily for seven days and was continued to monitor until the paper bag degrades. After the soil burial, samples were cleaned properly and dried in an oven for 30 minutes under 60 °C to eliminate the water absorbed and obtain the amount of weight loss [22].

$$\mathrm{WL}\ (\%) = \frac{\mathrm{W_{initial}} - \mathrm{W_{final}}}{\mathrm{W_{initial}}} \times 100\ \% \qquad (2)$$

WL – Biodegradability test
$W_{initial}$ – the initial mass of the sample before the test was conducted.
W_{final} - the final mass of samples after the test has been completed.

3.4.5 Moisture Content

Moisture content is important to verify the quality of the samples. It was determined by weighing the sample before and after drying and determining the difference. The test was conducted inside the CSU campus, particularly in the Agricultural and Biosystems Engineering Laboratory. The method of [22] was used for this test. Before drying, the samples were then weighed using an analytical balance (BSA2202S-CW Precision Balance) and were placed inside the oven dryer for 8 hours at 105ºC until the developed samples were totally dried and weighed. After drying, the developed samples were then separated from the molder and weighed the developed samples using an analytical balance. The initial and final weight data were then recorded. The developed samples were then placed inside the container at room temperature.

$$Moisture\ Content = \frac{W_{initial} - W_{final}}{W_{initial}} \times 100\ \% \quad (3)$$

$W_{initial}$ – initial quantity of water present before the moisture content test was conducted.
W_{final} - the final amount of water present in the samples after the moisture content test has been completed.

3.4.6 Hydrophobicity Test

The hydrophobicity test is an important test to validate the feasibility of the developed samples. The test was conducted using the procedure described in reference [17], wherein water droplets were manually dropped onto the coated paper bags. After dropping the liquid, the samples were observed closely, and the time taken for the coated samples to absorb the liquid was recorded. This test allowed researchers to evaluate the water-repellent properties of the coated paper bags and assess their effectiveness in repelling water.

3.4.7 Physical Property

The evaluation of physical properties is essential to verify the practicality of the product under development. In this regard, the thickness, width, and length of the product were measured using a vernier caliper. This measurement process helped to ascertain the dimensional characteristics of the developed product, ensuring that it meets the required specifications and standards.

3.4.8 Acceptability Test

The acceptability test plays a significant role in validating the practicality of the newly developed product. This test is crucial for assessing the level of consumer approval and determining the extent to which the product meets the desired quality standards. To conduct the acceptability test, the methodology outlined in reference [24], which utilized the Hedonic Scale, was adapted to suit this specific study.

Questionnaires were distributed to a total of 50 individuals, including vendors, students, and paper bag manufacturers in Ampayon, Butuan City. The respondents were asked to evaluate the product and provide their feedback based on the Hedonic Scale. This scale allowed them to express their preferences and satisfaction levels regarding the developed paper bags, ensuring that consumer perspectives and preferences were considered during the product assessment process.

3.11 Data Analysis

This study involved two main statistical analyses conducted on the collected data: descriptive analysis and the Least Significance Difference (LSD) test. To perform these analyses, the researchers utilized the Statistical Tool for Agricultural Research (STAR) Software.

The data was analyzed statistically using a Completely Randomized Design (CRD) with three replications through analysis of variance. The LSD test and Descriptive Analysis test were applied at a significant level of $P \leqslant 0.05$. This allowed the researchers to identify significant variations between the mean values of the different treatments being studied.

4. Results and Discussion

4.1 Effect of Fiber Composition Coated with Bio-wax and Petroleum Jelly to the Biodegradability of Paper Bag

Fig. 2 The developed hydrophobic paper bag

As shown in Figure 2 the actual output of hydrophobic paper bag, created from unsalable banana pseudo stems and neglected taro leaves. These paper bags were similar in size, with an average length of 243.89 mm, a thickness of 2.08 mm, and a width of 167.22 mm. The development of these hydrophobic paper bags involved a manual process, considering the accessibility of the materials and the mixtures used.

According to [25], biodegradability refers to a material's capacity to break down when exposed to biological elements. The crucial factor is how well the paper bag decomposes under regular organic soil conditions. Since the developed paper bag is composed of organic materials, it readily undergoes degradation through the activities of various soil organisms. Several factors, such as bacteria, fungi, and microorganisms, as well as environmental conditions like temperature, humidity, soil moisture content, and acidity, influence the decomposition process. It is highly desirable to have samples with a higher biodegradability rate, as they offer significant potential in reducing the need to cut trees for paper bag production. This study investigated the biodegradability of the paper bags, and the findings are presented in Figures 3 and 4.

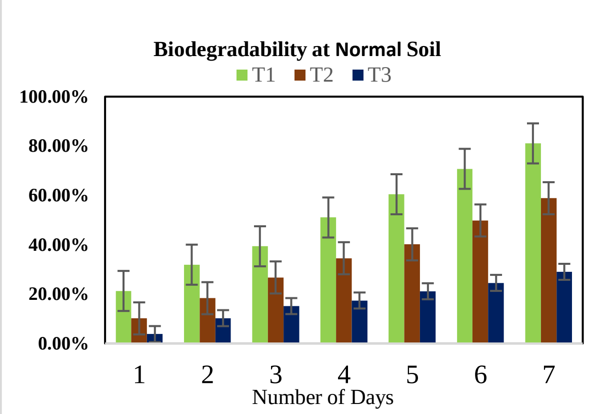

Fig. 3 Biodegradability at Normal Soil

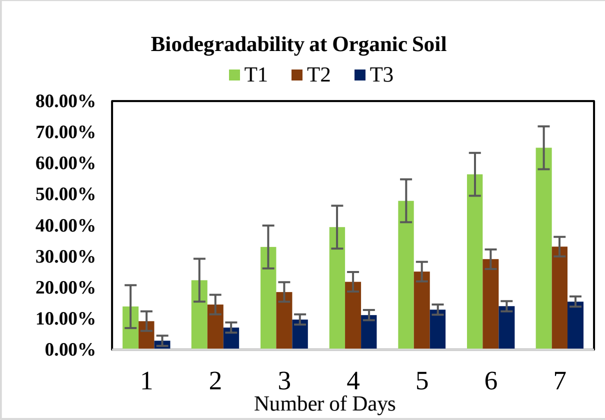

Fig. 4 Biodegradability at Organic Soil

Results revealed that the percentage of weight loss for T1, T2, and T3 from day 1 to day 7 was found to range from 13.84±1.99 - 64.96±5.81, 9.18±2.61 - 33.14±2.08 and 2.85±0. Likewise, the percentage of weight loss for samples under organic soil was found to range from 21.28±6.49, 10.16±2.55, and 3.8±0.87 respectively. As supported by the LSD at $P \leq 0.005$, significant changes were observed in the percentage of weight loss of paper bags in all treatments applied on normal and organic soil. However, among all treatments, T1 showed consistent significant changes at $P \leq 0.05$ of weight loss for the two soil conditions. This implies that the fiber composition coated with bio-wax and petroleum jelly applied have influenced the ability of the paper bag to degrade under normal and organic conditions. Also, animal dung, compost, and plant decomposition all contribute to organic soil. When compared to normal soil, the process generates dirt that is rich in nutrients and microbes that aid in the decomposition of organic materials. The factor affecting the rate of biodegradation is the thickness of the biodegradable material. The thicker the product, the longer its biodegradability.

4.2 Effect of Fiber Composition Coated with Bio-wax and Petroleum Jelly to the Water Absorption of Paper Bag

Based on the results, as shown in Figure 5 the T3 samples demonstrated lower water absorption compared to T2 and T1 at all water temperatures. This indicates that the water uptake varies depending on the treatment applied at room temperature. The LSD test at $P \leqslant 0.05$ supported the significance of the changes observed in all treatments under room temperature for 24 hours. The explanation for these findings lies in the strong bond formed between the cellulose fibers from the banana pseudo stem and the taro leaf fibers, which were coated with bio-wax and petroleum jelly. This bond effectively prevented water molecules from attaching to the fibers, resulting in reduced water uptake. The incorporation of fibers from both the banana pseudo stem and taro leaf had a notable impact on the paper bag's water absorption ability under room temperature.

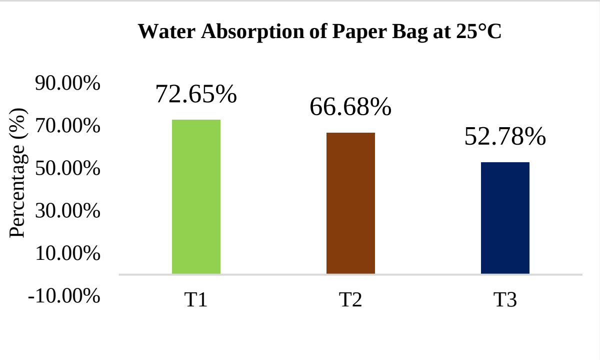

Fig. 5 Results of Water Absorption Test at 25 °C

The findings of this study align with the assertions made by [28] regarding the hydrophobic properties of petroleum jelly and bio-wax from taro leaves, which significantly influence the sensitivity of the samples to water. Regardless of the type of fibers used, water absorption adversely affects the mechanical properties and dimensional stability of natural fiber composites, thereby limiting their applicability in various uses. Additionally, the alkali treatment modifies the shape of the cellulose fibers, leading to a considerable impact on the mechanical properties of the composites [29].

4.3 Effect of Fiber Composition Coated with Bio-wax and Petroleum Jelly to the Moisture Content of Paper Bag

To be able to formulate a good-quality paper bag, the standard moisture content of the paper bag should range from 2% to 12% [32].

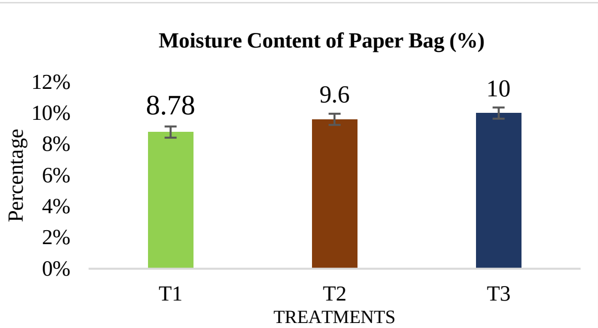

Fig. 6 Results of Moisture content Analysis of Paper Bag

As shown in Figure 6, T3 had the highest moisture content at 10%, followed by T2 at 9.6%, and T1 at 8.78%. The LSD test confirmed a statistically significant difference among T1, T2, and T3. The significant results at $P<0.05$ were influenced by the range of fiber compositions used in the samples. T3, with high moisture content, displayed greater elasticity compared to T2 and T1, which had lower moisture content. As [33] argued, higher moisture content leads to increased swelling stress in materials, increasing the likelihood of microcracking and hydrolysis. However, the findings demonstrate that the coated paper had a reduced risk of microcracking due to the application of bio-wax with petroleum jelly on the samples.

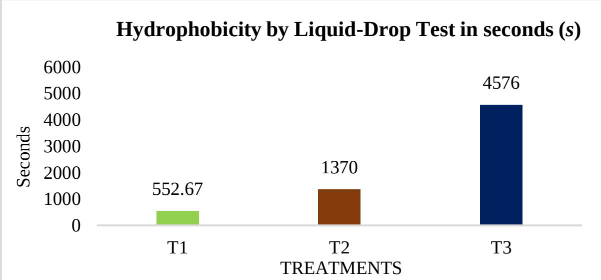

Fig. 7 Results of the Hydrophobicity Analysis of Paper Bag

4.4 Effect of Fiber Composition Coated with Bio-wax and Petroleum Jelly to the Hydrophobicity of Paper Bag

Figure 7 illustrates the hydrophobicity analysis of the paper bags, wherein T3 displayed the highest hydrophobicity with a mean value of 4576 s, followed by T2 and T1 with values of 1370 s and 552.67 s, respectively. This indicates that T3 is the most desirable option as it exhibits excellent quality. The LSD test confirmed a statistically significant difference among T1, T2, and T3, which can be attributed to the range of fiber compositions used in the samples ($P<0.05$). The high fiber composition in T3 led to a well-formulated paper bag with desirable hydrophobic qualities. The study's findings further revealed that the coating of bio-wax and petroleum jelly significantly contributed to the paper bag's hydrophobicity properties, effectively preventing water molecules from interacting with the fibers.

The study's findings revealed that applying three coats of bio-wax and petroleum jelly resulted in the highest level of hydrophobicity in the samples. While one and two coats also exhibited some hydrophobic properties, they were not as effective for long-term use. Therefore, the more coats of bio-wax and petroleum jelly applied to the paper bag, the more effective the hydrophobic coating. Furthermore, the application of this coating significantly enhanced the material's functionality, including improvements in tensile strength, elongation, water absorption, and tear resistance [35].

4.5 Effect of Fiber Composition Coated with Bio-wax and Petroleum Jelly to the Physical Property of Paper Bag

Table 2 displays the length, width, and thickness that are important in the production of paper bags. The LSD test confirmed that T1, T2, and T3 had no statistically significant difference because adding fiber could result in the same effect as other samples. As a result, the variety of fiber compositions used on the samples contributed to these significant results at $P>0.05$. This means that a high composition of paper bag fibers (T3) can represent a suitable formulation because it possesses the desirable length, width, and thickness of paper bags.

Table 2. Effects of Fibers Composition Coated with Bio Wax and Petroleum Jelly to the Physical Property of Paper Bag.

Treatment	n	Thickness(mm)±SD	Length(mm)±SD	Width(mm)±SD
T1	3	1.75±0.12	240.33±5.03	164.00±5.29
T2	3	2.10±0.10	244.33±2.52	165.00±5.29
T3	3	2.39±0.50	247.00±3.61	172.67±3.06

4.6 Acceptability Test Using Sensory Evaluation

According to Figure 8, the appearance of the paper bags received a moderate level of liking from consumers. Treatment 3 (T3) obtained the highest results, followed by T2 and T1. This indicates that T1 and T2 were considered moderately pleasing as their likability was similar. However, T3 was viewed very favorably, signifying that it was particularly attractive to the evaluators. In the context of the study, "like very much" can be interpreted as "really good," while "moderate" is equivalent to "good" if the evaluators had difficulty deciding whether the sample was good or bad [38].
This finding is consistent with [39], which suggests that the appearance of a product significantly influences evaluators' preferences. An evaluator may prefer an "attractive" product over one that is "unattractive." In the case of the paper bags, the positive response to T3's appearance is likely due to its appealing visual qualities.

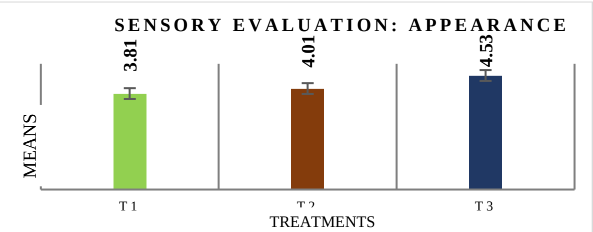

Fig. 8 Appearance Value using Sensory Evaluation

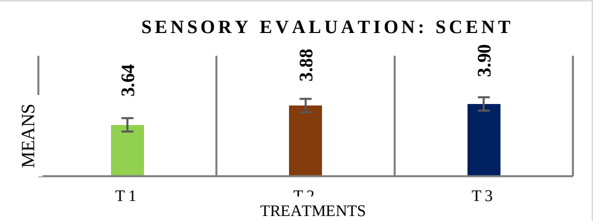

Fig. 9 Scent Value using Sensory Evaluation

As depicted in Figure 9, the ratings for the scent of T1, T2, and T3 were approximately 3.64 ≈ 4, 3.88 ≈ 4, and 3.90 ≈ 4, respectively, which falls in the slightly moderate range. Based on the findings, this suggests that treatments T1, T2, and T3 were perceived to have a good scent. As per [38], "slightly moderate" can be interpreted as "just a little good."
However, the results also indicated that the evaluators believed that the scent could be improved, as they found it too resinous for their liking. Despite being rated as having a good scent, the evaluators felt that it could be enhanced to better suit their preferences.

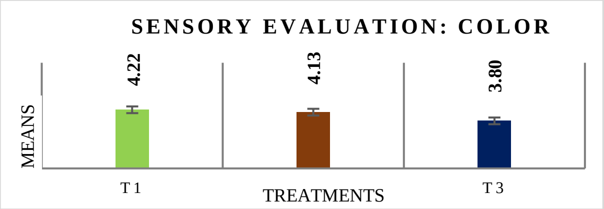

Fig. 10 Color Value using Sensory Evaluation

As depicted in Figure 10, T1 received the highest rating for color, with a value of 4.22, followed by T2 and T3 with corresponding values of 4.13 and 3.8, respectively. This suggests that T3 had a rating of approximately 3.8 ≈ 4. The findings indicate that T1 and T2 were moderately liked in terms of color, while T3 was perceived as slightly moderate. According to [38], "likely moderate" translates to "good," while "slightly moderate" can be understood as "just a little good" concerning color. The evaluators recommended improving the color of the paper bags to make them more aesthetically pleasing to consumers. It appears that consumers value the visual appeal of the product and prefer it to be more attractive and aesthetically pleasing in terms of color. Therefore, enhancing the color may positively influence the consumers' perception and liking of paper bags.

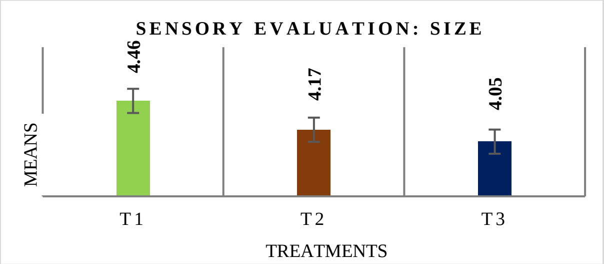

Fig. 11 Size Value using Sensory Evaluation

As displayed in Figure 11, all sample sizes received a moderate level of liking from the evaluators. T1 obtained the highest rating, followed by T2 and T3, with corresponding values of 4.46, 4.17, and 4.05, respectively. According to [38], all samples were perceived as "good" in terms of the size of the paper bag. The evaluators commented that they found the size of all the products to be good and satisfactory, despite the measurements being the same. This suggests that consumers were content with the size of the paper bags, and the slight variations in liking among the samples did not significantly affect their overall positive perception of the product's size.

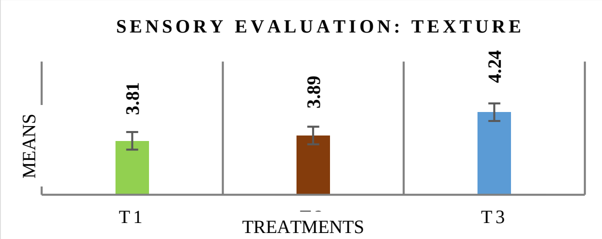

Fig. 12 Texture Value using Sensory Evaluation

Texture values using the hedonic scale using the sensory evaluation test are present in Figure 29. All the samples were likely to moderate. T3 exhibits the highest results followed by T2 and T1 with corresponding values of 4.24, 3.89, and 3.81, respectively. It shows that T2and T1 had a scale of 3.89≈4, and 3.81≈4. All of the samples were moderate which means according to [38] indicates “good” in accordance with the texture of the samples. The evaluators commented that the paper bag is good according to their liking, but it needs improvement as it is a little greasy when touched.

5. CONCLUSION

The present study has demonstrated that using fibers derived from taro leaves and banana pseudo stems, along with a bio-wax coating from taro leaves and petroleum jelly, can serve as a dependable and effective method for developing hydrophobic paper bags. These findings suggest that taro and banana pseudo-stem blended fibers hold significant potential for future applications in this field.

Among the various treatments studied, T3 showed particularly promising results in terms of hydrophobicity, displaying low water absorption, high elongation, excellent tensile strength, and favorable physical properties. This indicates that T3-treated paper bags are likely to withstand moisture and harsh environmental conditions effectively, making them suitable for various practical applications.

On the other hand, T1 treatment displayed encouraging results in terms of biodegradability in both normal and organic soil. This finding suggests that T1-treated paper bags are more environmentally friendly and can break down naturally over time, reducing their impact on the ecosystem.

To enhance the overall performance of hydrophobic paper bags, a combination of these treatments (T3 and T1) could be considered. By integrating the advantageous properties of both treatments, the resulting paper bags may exhibit superior hydrophobicity, low water absorption, high tensile strength, and elongation, while also being biodegradable and having low moisture content. This combination could offer a well-rounded solution that meets both functional and environmental requirements.

Further research and development in this area are warranted to optimize the treatment methods, explore potential variations, and assess the long-term durability and environmental impact of the hydrophobic paper bags. With continuous improvements, these innovative materials could find extensive use in various industries, contributing to a more sustainable and eco-friendly approach to packaging and reducing our reliance on non-biodegradable alternatives.

6. REFERENCES

[1] Borrelle, S. B., Ringma, J., Law, K. L., Monnahan, C. C., Lebreton, L., McGivern, A., "Predicted Growth in Plastic Waste Exceeds Efforts to Mitigate Plastic," *Science 369 (6510)*, p. 1515–1518, (2020).

[2] Lau, W. W. Y., Shiran, Y., Bailey, R. M., Cook, E., Stuchtey, M. R., Koskella, J, "Evaluating Scenarios toward Zero Plastic Pollution," *Science 369 (6510)*, p. 1455–1461, (2020).

[3] Meijer, L. J. J., van Emmerik, T., van der Ent, R., Schmidt, C., and Lebreton, L., "More Than 1000 Rivers Account for 80% of Global Riverine Plastic Emissions into the Ocean," *Sci. Adv*, vol. 7.

[4] Pawar, P. R., Shirgaonkar, S. S., and Patil, R. B., "Plastic marine Debris: Sources, Distribution, and Impacts on Coastal and Ocean Biodiversity," *PENCIL Publ Sci.*, vol. 3, p. 40–54, 2016.

[5] Schmidt, C., Krauth, T., and Wagner, S., "Export of Plastic Debris by Rivers into the Sea," *Environ. Sci. Technol.*, p. 12246–12253, (2017).

[6] Lebreton, L., and Andrady, A., "Future Scenarios of Global Plastic Waste Generation and Disposal.," *Palgrave Commun.*, vol. 5, p. 1–11, 2019.

[7] Brouwer, F., & Vos, H., "Paper versus plastic: environmental disadvantages and," *Journal of Cleaner Production*, vol. 223, pp. 581-598, 2019.

[8] C. &. F. J. Edwards, "Life cycle assessment of supermarket carrier bags: a review of the bags available in 2006.," *Environment Agency.*, no. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/at%09tachment_data/file/291023/scho0711buan-e-e.pdf, 2011.

[9] A. Susilo, E. Aprianti and S. Faisol, "Potential use of taro leaves (Colocasia esculenta) as packaging materials.," in *Earth and Environmental Science*, 2019.

[10] S. Phithakkitnukoon and P. Rachtanapun, "Taro leaf paper: Development and properties of a novel biodegradable material for packaging.," *Journal of Materials Research and Technology*, vol. 6(1), no. 2016.10.03, pp. 16-24, 2017.

[11] A. Nath, S. Mandal and S. Chakraborty, "Banana pseudostem: A novel and sustainable alternative for packaging material.," *Journal of Packaging Technology and Research*, vol. 3, pp. 61-71, 2019.

[12] E. Abraham, B. Deepa, L. A. Pothen and M. Jacob, " Banana pseudostem fibers: Potential and utilization.," in *In Handbook of Natural Fibres*, Woodhead Publishing., 2018, pp. 537-556.

[13] S. Khettry, "Banana fibre and its utilization in packaging: A review.," *International Journal of Environmental Sciences*, vol. 6, 2016.

[14] K. Karthika, S. Ramesh, K. Ramya and A. Ravindran, "Banana pseudostem fibers reinforced bio-based composites: A review.," *Journal of Natural Fibers,* vol. 17, pp. 127-147, 2020.

[15] K. Vardhini, R. Murugan and R. Rathinamoorthy, " Effect of alkali treatment on physical properties in banana fiber.," (2018).

[16] P. N., Feasibility of Taro (Colocasia esculenta) Leaves as an Alternative Paper Bag., 2020.

[17] A. &. T. N. Kalita, "Colocasia esculenta (l.) Leaf bio-wax as a hydrophobic surface coating substance for paper for preparing hydrophobic paper bags.," *International Journal of Pharmacy and Biological Sciences.,* no. Retrieved from: https://www.ijpbs.com/ijpbsadmin/upload/ijpbs_5b29a72987027.pdf on, 2018.

[18] ColeParmer, "Solvent Extraction Methods of plants using ethanol," *An Antylia Scientific Company.,* 2020.

[19] G. &. D. M. Savage, The effect of soaking and cooking on the oxalate content of taro leaves, National Library of Medicine, 2006.

[20] FUCHS LUBRICANTS SWEDEN AB., "Petroleum jelly - Product information.," 2020. [Online]. Available: https://www.fuchs.com/se/sv/produktinformation/industriella-smorjmedel/petroleumjelly/.

[21] A. Driscolli, "Ethanol Removal in Cannabis Applications.," Rotavaps.net, 2019.

[22] N. E. Wahyuningtiyas and H. Suryanto, "Analysis of Biodegradation of Bioplastics Made of Cassava Starch.," *Journal of Mechanical Engineering Science and Technology,* vol. 1, no. 1, pp. 24-31, 2017.

[23] Bezirhan Arıkan, and H. Bilgen, "Production of bioplastic from potato peel waste and investigation of its biodegradability," *International Advanced Researches and Engineering Journal,* pp. 93-97, 2019.

[24] Guingguing, EGG SHELL POWDER AS AN ALTERNATIVE FOR SYNTHETIC, 2022.

[25] R. O. a. P. Goswami, "Sustainable Design: Eco-labeling Biodegradability, and Beyond," *In: Handbook of Sustainable Engineering,* vol. 2, pp. 129-146 , 2016.

[26] Glaskova-Kuzmina and A. Aniskevich, ""Effect of moisture on elastic and viscoelastic properties of fiber reinforced plastics: Retrospective and current trends.," *Creep and Fatigue in Polymer Matrix Composites (Second Edition),* pp. 83-120., 2019.

[27] C. Siva, M. Thirumal and R. Gobinath, ". Study on Mechanical Properties and Water Absorption Behaviour of Alumina and Banana/Glass Fiber Reinforced Hybrid Polymer Composites," *Journal of Materials Engineering and Performance,* vol. 30, no. 3, pp. 1919-1929., 2021.

[28] J. H. Oh and C. H. Park, "The Effect of Fiber Type and Yarn Diameter on Superhydrophobicity, Self-Cleaning Property, and Water Spray Resistance. Polymers," vol. 13, 2021.

[29] A. ,. &. S. Ramamoorthy, "Effect of water absorption on mechanical properties of soybean oil thermosets reinforced with natural fibers," *Journal of Reinforced Plastics and Composites,* vol. 31, no. 18, p. 1191–1200, (2012.

[30] S., Sanjeevi, V.,Shanmugam, Kumar, S., Ganesan, V., Sas, G., Johnson,, "Effects of water absorption on the mechanical properties of hybrid natural fibre/phenol formaldehyde composites.," *Scientific Reports,* vol. 11, no. 1, 2021.

[31] M. J. John and S. Thomas, "Biofibres and biocomposites," *Carbohydr. Polym.,* vol. 3, no. 71, pp. 343-364, 2008.

[32] Avenys, "Moisture in paper," IM SERIES, 2020. [Online]. Available: https://avensys.com/wp-content/uploads/2020/10/av-chino-imseries-paperconverting-moisture-in-paper.pdf.

[33] M. Li, TEMPERATURE AND MOISTURE EFFECTS ON COMPOSITE MATERIALS FOR WIND TURBINE BLADES, Bozeman, Montana, 2000.

[34] Z. Shi , Z. Liu , H. Song and X. Zhang, "Prediction of contact angle for hydrophobic surface fabricated with micro-machining based on minimum Gibbsfree energy," 2015. [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0169433215032043?via%3Dihub.

[35] M. Lewandowski and R. Kozłowski, "Petroleum-based polymeric materials as effective water-proofing agents for roofing membranes.," *ournal of Applied Polymer Science,* vol. 13, no. 44894, pp. 134-138, 2017.

[36] D. &. M. R. Singh-Ackbarali, "Sensory evaluation as a tool in determining the acceptability of innovative products developed by undergraduate students in food science and technology at the University of Trinidad and Tobago," *Journal of Culinary Science & Technology,* vol. 12, pp. 43-58, 2014.

[37] A. N. Silva, R. Silva, M. M. Ferreira, V. R. Minim, . T. Costa and R. Perez, "Performance of hedonic scales in sensory acceptability of strawberry yogurt.," *Food Quality and Preference,* vol. 30, no. 1, p. 9–21, 2013.

[38] R. Popper and J. J. Kroll, "Consumer testing of food products using children.," *Developing Children's Food Products,* p. 163–187, 2011.

[39] H. Kayina and G. Sushma , "Product Appearance: Impact on Product Selection.," *International Journal of Trends in Marketing Management,* vol. 3, p. 297–307, 2014.