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Production of Vegan Leather Material Using Java Cotton (*Ceiba pentandra*) as a Raw Material

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Abstract— *This study explores the production of vegan leather using java cotton blended with sodium alginate, calcium chloride, glycerin, coconut oil, and water. Three formulations were tested to evaluate their biodegradability, mechanical properties (water resistance, thickness, tensile strength, elongation), and physical properties (tear resistance, flammability, hardness, and texture) to determine the most effective and sustainable composition. The results showed that while other samples exceed genuine durability, others demonstrated weakness in some tests. The study concludes that java cotton-based vegan leather is promising eco-friendly alternative to traditional leather, though improvements in texture and appearance are recommended by manually separating the fibers to improve the surface smoothness, appearance and durability. Furthermore, limit the composite materials used to promote natural biodegradability over time.*

Keywords— *Java cotton, sustainable,vegan leather.*

I. Introduction

In In this present time, it is truly evident that the planet's natural reserves are already not enough to sustain and meet human demands as the population increases. With the presence of global warming and climate change, humans and other living organisms are at risk to starvation, draught and other natural calamities and death. However, there are also indications which shows increasing enough handiness of vital materials which are not as well-known and that are instead viewed as economic outlook.

The increasing need for sustainable, environmentally friendly options to conventional leather has driven extensive research into the possibility of plant-based materials as substitutes. Conventional leather manufacturing from animal hides comes with great environmental and ethical issues, such as deforestation, carbon footprint, and animal abuse (Pereira et al., 2021). Consequently, alternatives have turned to plant-based, synthetic, and fungal materials, with vegan leather being a likely candidate (Choi, 2020). The problem is that high-quality, long-lasting, and affordable alternatives need to be developed to match the haptic and aesthetic properties of traditional leather (Tisserat & Chia et al., 2021).

Java cotton, a little-used by-product of cotton cultivation, is one such raw material that can be used to create such sustainable alternatives. Java cotton, with its high cellulose content, presents a thrilling prospect for creating vegan leather with a lower environmental impact (Almeida et al., 2019). Usually left to be thrown away as agricultural residue, Java cotton's cellulose has been studied for different purposes, such as biodegradable films and textiles (Bourbon et al., 2022). Due to its vast availability and biodegradability, it is a suitable candidate for the production of eco-friendly leather-like material.

Vegan leather, as a product category, has already demonstrated potential to substitute animal leather across industries, particularly fashion and furniture, with various alternatives already produced from plant sources such as pineapple, apple, and cork (Pramanik & Mitraet al., 2020). To produce a high-performance substitute, however, it is important to treat the cellulose fibers in a way that improves their mechanical properties and simulates the texture, flexibility, and durability of animal leather. Some studies have also examined cellulose modification for improved properties, such as crosslinking, plasticization, and blending with natural fibers (Huang et al., 2019).

Utilizing java cotton fibers as the raw material to produce vegan leathers is this study's endeavor to identify what potential properties the material possesses to be considered as an alternative to other chemical or plastic-based synthetic leathers. this study also is committed to the environmental sustainability in the efforts of utilizing discarded refuse by means of minimizing waste, ecological sustainability and producing environment-friendly vegan material for use.

This research examines the possibility of using Java cotton as a raw material to create vegan leather. The study endeavors to create processing techniques that refine and extract the properties of cellulose fibers with regard to texture, durability, and aesthetic value in order to produce a material that can potentially be used as a viable and sustainable substitute for traditional leather. Furthermore, this research offers insights into the production of vegan leather from Java cotton to support sustainable strategies in the textile and fashion industries while minimizing the use of dangerous animal-derived materials and synthetic plastics.

II. Methodology

A. *Collection of Raw Materials*

Java cotton was collected and harvested from a local area. For use in the experiment, the java cotton fiber was extracted from its seeds and outer pods. The pods and seeds were discarded while the fiber was sun dried before utilizing.

B. *Preparation of Tratment Groups*

The java cotton fibers were separated finely by hand for faster absorption. These were mixed with glycerin, sodium alginate, calcium chloride, vinegar, coconut oil, liquid food color and water in measured amounts. Three different mixtures were prepared by changing how much java cotton fiber was added while also changing the amount of composite materials.

C. Fabrication Molds

Three types of the same size stainless molds were used. All three was used to produce large rectangular vegan leather then cut into smaller sizes for testing.

D. Ratio Selection

At the start of the experiment, different combinations of materials were tested based on the study by Rimantho et al. (2018). Their research involved reinforcing the orange peel-based materials with Dacron fabric and assessing their mechanical properties. Among those samples, the pomelo-based vegan Leather exhibited the highest elongation at approximately 67.28%, indicating superior flexibility.

These early tests used many different types of citrus peels. However, problems were soon noticed during mixing and drying. The mixtures were difficult to handle, and the vegan leathers did not bind and dried properly, even after several days of monitoring. The results showed that the quality and strength of the samples were not consistent or acceptable.

Due to these challenges, the researcher referred to the recommended mixing guide from Scanning Electron Microscopy (SEM) analysis which provides tested and reliable analysis for fibrous and porous structure conductive to forming interfacial bonds with the Dacron reinforcement. The structural features contributed significantly to the overall mechanical and physical performance of the vegan leather samples. The use of fruit waste, particularly orange peels, not only provides a sustainable and eco-conscious alternative to animal leather. Rimantho's research contributes to the growing body of knowledge on biodegradable and plant-based materials for future innovation in sustainable fashion, automotive, and other industries reliant on leather substitutes.

E. Casting/ Pouring of Mixture

The materials were mixed together until smooth and evenly combined. The mixture was poured into the molds, tapped to remove air pockets, and leveled. Enough vegan leathers were made to meet the testing needs for all groups.

F. Testing Process

Each group of vegan leather included samples for checking appearance and measurements without breaking and tearing them, and other samples for tests that involved applying stress or exposure to water, flammability, hardness and texture.

G. Curing Process

After being shaped, the vegan leather were left to dry in the air for seven days. Then, they were cut into pieces to be used for the different testing.

H. Replication

The entire process was repeated for each group to make sure the results were fair, reliable, and consistent.

I. Mechanical Test for Vegan Leathers

Test:

Ten (10) replicates per embodiment (R1, R2, and R3) were randomly selected and inspected for structural defects (cracks, thickness and strechability).

Water Resistance Test

Water resistance of each replicate were measured through soaking in the water for two minutes then weighed to determine the sample's change in weight. It was computed as:

$$W = \frac{\text{Sample Dry Weight - Sample Wet Weight}}{\text{Sample Dry Weight}}\ x\ 100 \quad (1)$$

Thickness Test

The thickness of the samples was measured using a digital caliper. It was computed by:

$$Tave = \frac{\text{Summation of Individual Thickness Measurement}}{\text{Number of Trials}} \quad (2)$$

Measurement of Tensile Strength Test

The vegan leather sample were clamped between two binder clips, one was attached to a hanging scale and the other connected to a weight so the force needed to stretch or break the leather could be recorded. It was calculated using:

$$\text{TS} = \frac{\text{Force}}{\text{Width x Thickness}} \quad (3)$$

Measurement of Elongation Test

The elongation of the vegan leather was measured by applying a pulling force and recording how much it stretched before breaking, indicating its flexibility and ability to deform under tension. Determined using:

$$\text{Y} = \frac{\text{A}}{\Delta L/L0} \quad (4)$$

J. Physical Testig for Vegan Leathers

Tear Resistance

The tear resistance of the vegan leather was tested by applying force to a pre-cut section of the material to measure how much stress it could withstand before the tear extended, indicating its durability against ripping. It was measured using:

$$\text{TR} = \frac{\text{Maximum Load}}{\text{Thickness of the Sample}} \quad (5)$$

Flammability Test

The flammability was tested by exposing a sample to an open flame to observe how quickly it ignites, burns, or self-extinguishes, assessing the fire resistance and safety. Determined by recording the time it took to ignite under two minutes of exposure.

Hardness Test

Was tested by pressing the sample material with a Durometer Shore A into the surface to measure its resistance to indention, indicating the material's firmness and surface durability. It was measured using:

$$\text{Have} = \frac{\text{Summation of Hardness Per Sample}}{\text{Number of Trials}} \quad (6)$$

Texture Test

The texture of the vegan leather was evaluated through visual and tactile inspection to assess its surface feel, smoothness, and similarity to natural leather.

Data Analysis

Data were analyzed using descriptive statistics and ANOVA. Normality and homogeneity tests were applied; otherwise, Kruskal-Wallis test ($\alpha = 0.05$) was used. Analysis was aided by online tools such as Statistical Kingdom.

III. Results and Discussion

The results of this study present the performance of the three TexTILES embodiment (E1, E2, E3, and Control) based on a series of standardized destructive and non-destructive tests. Data were analyzed to assess normality and homogeneity, followed by the appropriate statistical tests to determine significant differences among embodiments. Rankings were then established to evaluate overall material performance in terms of durability, dimensional stability, and resistance to physical and chemical exposure.

TABLE 1. Ranking of Vegan Leather Materials

Properties	Ratio 1	Ratio 2	Ratio 3
Biodegradability			
a. Visual Inspection for biodegradation	3	2	1
Water Resistance (%)	1	2	3
Thickness Test (mm)	1	2	3
Tensile Strength ***(N/mm^2)***	1	2	3
Elongation Test (*mm^2*)	3	2	1
Tear Resistance	1	2	3
Flammability (*s*)	1	2	3
Hardness *(HA)*	1	2	3
Texture	1	3	2
Total Score:	**13**	**19**	**22**
Overall Ranking:	**3rd**	**2nd**	**1st**

Table 1 The evaluation of the three ratios on its biodegradability property focuses on the sample material's ability to biodegrade or deteriorate in the shortest period of time once being disposed. Ratio 1, which achieved the earliest signs of biodegradation demonstrates the superior performance in the deterioration process which is an ideal material for landfilling. Hence, Ratio 1 ranked 3rd on the overall parameters as it failed to perform the mechanical and physical properties required by its parameters except for the elongation test under mechanical properties where the ratio scored the highest with 3 points, outperforming the Ratios 1 and 2.

Ratio 2, however ranked 2nd with a total score of 19 points performed moderately well where the ratio scored 2 points across all parameters including the biodegradability, mechanical and physical properties except for the texture test where it scored the highest, outperforming Ratio 1 and 2. On the other hand, Ratio 2 exhibits moderate degradation on the biodegradability test where the samples from the ratio took 5 days to show visible signs of deterioration such as cracking and slightly changing its color.

Ratio 3, ranked 1st on the overall parameter test except for the biodegradability test where the ratio took the longest time to show signs of deterioration, cracking and discoloration which is not ideal for landfilling. The ratio scored the highest with 3 points under the mechanical properties on water resistance test, thickness test, tensile strength test, as well as in physical properties on tear resistance test, flammability test, hardness test, and texture test. The ratio was outperformed by Ratio 1 on the elongation test where Ratio 3 scored 1 point as it failed to perform well on the process of the elongation test.

IV. Conclusions

The conclusions were drawn after the data were analyzed from the conducted study.

1. *Biodegradability Properties:*

Ratio 1 showed the best biodegradability performance, with samples decomposing quickly within about 2 weeks and requiring up to 50% less landfill space. This indicates that the treatment ratio was effective, and the added composite materials were optimal for enhancing breakdown.

2. *Mechanical Properties:*

2.1 Water Resistance

Ratio 3 exhibits the best results in resisting water when tested while Ratio 2 showed average performance in resisting water. Ratio 1 has the lowest performing vegan leather samples where the material absorbed water instead of resisting when soaked into the water. The associate p-value = 0.06 exceeds the normal level of 0.05 indicates sustainability of java cotton.

2.2 Thickness

The result from ratios 1,2, and 3 shows that the sample materials failed to pass the standard thickness for either real, synthetic or vegan leathers where the standard measures about 0.9 mm to 1.2 mm, hence the results of thickness for these ratios does not neglect the fact that leather thickness is depending on the type of use. For leathers which measures between 1.78 mm to 3.11 mm, this material is called Thick Leather. Ratio 3 sample thickness however is used for strong, durable heavy-duty bags, tool purses, saddles and sturdy belts where the sample's thickness is measure between 2.3 mm to 4.8 mm with resulting p-value = 0.000512872, lower than the normal level of 0.05 indicates significant difference between the groups.

2.3 Tensile Strength

The tensile strength results for Ratio 1 averaged about 11.48 N/mm2 which indicates that Ratio 1 is not suggested for such any type of leather use as it is weak and easily tears apart when in stress. Ratio 2 results from Ratios 2 and 3 proposed notable results as both can withstand a 4.93 N (0.5 kg) to 12.32 N (1.26 kg) of weight before breaking or tearing with p-value = 0.3109 which is higher than the typical 0.05, strongly suggests a significant difference.

2.4 Elongation

Ratio 1 showed the highest results on the elongation test conducted. With the results ranges from 60.81 mm2 to 771.43 mm2. This is because of the rubbery and starchy consistency from the composite material sodium alginate and glycerin of the sample materials making it more stretchable and flexible than that of Ratio 2 and Ratio 3. The resulting p-value = 0.001053 which is lower than the 0.05 normal level suggests that the variation within the group is larger.

3.0 *Physical Properties:*

3.1 Tear Resistance

Ratio 3 demonstrates good performance on tear resistance test where the results range from 1.82 N/mm to 3.15 N/mm, suggesting that this ratio may not be as stretchable as Ratio 1 but can withhold such weight or stress before tearing or breaking apart. Notably with p-value = 2.49001E-06, exceeding the normal level of distribution at 5%.

3.2 Flammability

Ratio 1 exhibited early signs of ignition when lit with candle flame, this is because the composite material and java cotton did not combine well. However, Ratio 2 displayed moderate signs of ignition or burning at 28.4 seconds when lit with flame. The resulting p-value = 1.72326E-05 strongly suggests that it's higher distribution level of 0.05. Overall, Ratio 3 performed well in the flammability test where the sample materials took quite long time before burning or igniting.

3.3 Hardness

The outcome of hardness for Ratio 1 with 0.326 HA indicates that the material composition did not binned well together as the additives were also excessive. p-value = 2.39932E-05 strongly suggest there is no significant difference at 5% significance level. Ratio 2 and 3 however displayed the best performance in the hardness test where both shows rigidity and firmness due to the addition of sodium alginate into the vegan leather mixture.

3.4 Texture

The texture of the samples was unusual especially of Ratio 1, it is starchy thick, gooey-like texture and the appearance was sloppy while Ratio 2 and Ratio 3 is rubbery-like texture that is quite similar to a manufactured vegan leather.

4.0 The results suggest that the utilization of java cotton as raw material for this study has a potential on the production of vegan leathers especially on Ratio 3 with 50% java cotton and 50% composite material content. Ratios 1 and 2 on the other hand exhibits insufficient performance on the results to be considered effective due to the excessive amounts of composite materials being added.

APPENDICES

Figure 1. Preparation of Materials

Figure 2. Preparation of Materials: Separating the Seeds from the Java Cotton Fiber

Figure 3. Mixing of the Raw Material and Composite Materials

Figure 4. Pouring/ Flattening of the Vegan Leather

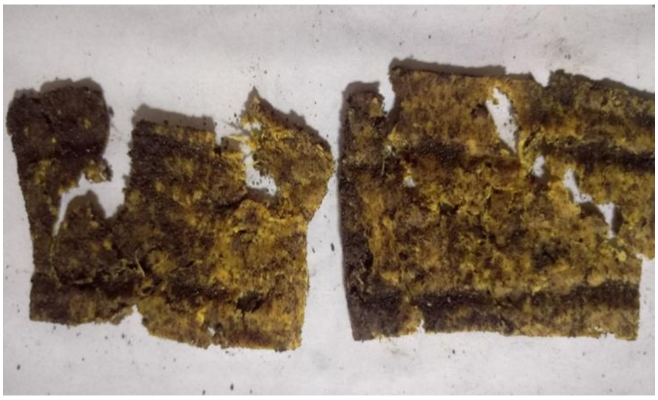

Figure 5. Biodegradability Test via Burial

Figure 6. Mechanical Property: Water Resistance Test

Figure 7. Mechanical Property: Thickness Test

Figure 8. Mechanical Property: Tensile Strength Test

Figure 9. Mechanical Property: Elongation Test

Figure 10. Physical Property: Tear Resistance Test

Figure 11. Physical Property: Flammability Test

Figure 12. Physical Test: Hardness Test

Figure 13. Physical Test: Texture Test
Note: The sample material used to determine sample's flammability was also then used for texture test as it did not affect the entire sample material.

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