

## Biocomposite Material Using Sugarcane Bagasse and Modified Starch for Potential Packaging in Agroindustry

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### GRAPHICAL ABSTRACT



### ABSTRACT

The widespread use of petroleum-based plastics in packaging has raised significant environmental concerns due to their non-biodegradability and detrimental ecological impacts. This study explores the development of an eco-friendly biocomposite material using sugarcane bagasse and cassava starch as potential alternatives for agro-industry packaging. The research objectives include characterizing the morphological properties of modified and unmodified sugarcane bagasse, analysing the thermal and physical properties of the resultant biocomposite, and evaluating its potential as a sustainable packaging material. A set of samples experiment were investigated using a constant ratio of distilled water to cassava starch which is 3:1 and 5 different ratios of acetic acid to bagasse. The morphological properties of biocomposite material which are sugarcane bagasse and cassava starch were examined using a Field-Emission Scanning Electron Microscope and Fourier Transmission Infrared Spectroscopy. Thermogravimetric Analysis (TGA) and Tensile strength were used to analyse thermal and physical property. Subsequently, the assessment of environmental friendliness was conducted by biodegradability testing. The results indicate that the most optimal biofilm, in terms of flexibility, thermal stability, and decomposition speed, was achieved with a ratio of (2:1) and (3:1) of acetic acid to bagasse. The results obtained suggest that sugarcane bagasse, when combined with cassava starch, can serve as an effective, biodegradable packaging material, potentially mitigating the environmental impact of conventional plastics in the agro-industry.

*Keywords:* biocomposite, biodegradable packing, thermal stability, sugarcane bagasse and cassava starch

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## 1. INTRODUCTION

The worldwide population depends on the agro industry to supply packaging material and other agricultural items. Most packaging materials produced were made used conventional packaging. Nevertheless, the agro-industry employment of conventional packaging materials offers several environmental challenges, such as waste and contamination. To tackle these difficulties and assured the agro-industry long-term development, sustainable packaging was essential [1]. Packaging materials that were sustainable, recyclable, biodegradable, and kind to the environment. Natural fibres and biodegradable polymers were combined to generate bio composite materials, which

provided a feasible solution for traditional packaging materials [2].

A typical plastic packaging item was the manufacture of biocomposite materials for packaging that used modified starch and sugarcane bagasse. They were constructed of natural fibres and biodegradable polymers. Biocomposite materials gave a more environmentally friendly and sustainable solution for packaging than conventional packaging materials [3]. Biocomposite materials were an innovative class of materials developed through combining natural fibres or particles with a matrix. By utilising their inherent durability and ecologically advantageous features of natural resources, these materials may construct composites with exceptional mechanical attributes. Moreover, there were natural resources that been employed

as biocomposite material such as wheat straw-based composites, rice husk composites and kenaf fibre composites. Along with that flow of natural resources the utilisation of sugarcane bagasse and modified starch was a vital component in the production of bio composite materials was the main aim of this work [4].

Considering this, sugarcane bagasse was a copious agro-industrial waste product that had been explored for employment in biocomposite materials designed for packaging applications due to its abundance as a resource, non-toxic, lightweight, ecological acceptable and a low cost by-product making it economically advantageous for large-scale production [5]. Modified starch, on the other hand, was a biodegradable polymer that may be manufactured from starch, a renewable resource industry [6]. Characterization procedures for biocomposite materials are critical in selecting optimal biomaterials for specific applications, emphasising its importance in innovative packaging solutions [7]. Overall, the exploitation of biocomposite materials in packaging corresponds with the increased consumer and industry desired for greener, more sustainable packaging choices, makes it a significant area of research and development in the agroindustry and packaging sectors [8].

## 2. EXPERIMENTS

### 2.1 Preparation of sample

The sugarcane bagasse was properly cleansed and grinded into little pieces before the drying process began. The sugarcane bagasse was then dried in an oven at 105°C for 24 hours to eliminate the moisture content and water. After the drying process, the sugarcane bagasse was grinded using a grinder to put it into powder form. Next, the sugarcane bagasse powder was sieved into 250 microns.

Cassava starch was sourced from a nearby store. For biofilm formulation, a constant ratio of 60 ml distilled water to 30 grams starch, along with 3 ml glycerol, was used. Samples with different ratios of acetic acid to bagasse (Table 1) were mixed in a beaker and heated on a hot plate with a magnetic stirrer at 85°C for 25 minutes until gelatinized. The thick solution was then poured onto a petri dish and left to dry.

**Table 1.** Samples with different ratios

Sample	Ratio	Acetic Acid (ml)	Bagasse (gram)	Glycerol (ml)
A	1:1	1	1	3
B	1:2	1	2	3
C	2:1	2	1	3
D	3:1	3	1	3
E	1:3	1	3	3

### 2.2 Morphological analysis of sugarcane bagasse and cassava starch

#### 2.2.1. Field Emission Scanning Electron Microscope (FESEM)

The surface morphology of the biocomposite material was determined by Field Emission Scanning Electron Microscopy (JOEL-7800F Prime). The biocomposite material of sugarcane bagasse and cassava starch was placed in a holder before being inserted into the Field Emission Scanning Electron Microscopy to examine the sample's shape, size, and relative particle sizes. The surface morphology was examined at various magnifications during the analysis.

#### 2.2.2. Fourier Transform Infra-Red (FTIR) Analysis

Fourier transform infrared spectroscopy is an important analytical tool for determining the presence of functional groups associated with the adsorbent. The annotated spectrum of FTIR show the wavelength of light that is absorbed, indicating the chemical bond in the AC. The surface functional groups of the bagasse and cassava starch were identified via FTIR analysis using an FTIR spectroscope, where spectra were obtained from 4000 to 650  $\text{cm}^{-1}$ .

### 2.3 Thermal and physical property analysis

#### 2.3.1 Thermogravimetric Analysis (TGA)

Thermogravimetric Analysis (TGA) was a potent method for evaluating a material's heat-related properties. It offered important details regarding the material's thermal stability and breakdown characteristics. The TGA curve's shoulders or peaks could point to certain thermal phenomena. The typical temperatures of constituents, such as cellulose, hemicellulose, or starch, could be utilized to determine their state of decomposition.

#### 2.3.2 Universal Testing Machine (UTM)

The most significant mechanical characteristics of the bioplastic packaging material were its tensile strength and elongation at break, which were assessed using the UTM. Thus, it was favoured to describe the prepared biofilms in terms of their tensile strength and elongation at break. Tensile strength was described as the strength of material in terms of force per unit area of cross section while applying force in a straight direction.

#### 2.2.4 Evaluation of Eco-Friendliness

Biodegradability testing was a crucial aspect of assessing the environmental impact of sugarcane bagasse-based packaging. The goal was to evaluate how well the material broke down into natural elements under different environmental conditions, particularly simulating scenarios like soil burial. 5 samples were prepared and exposed to identical soil conditions, with a uniform depth of 10 cm, and maintained at a constant ambient temperature of 27°C. This

experiment was conducted over a period of 7 days to assess the rate of degradation of different bioplastics.

### 3. RESULTS AND DISCUSSION

#### 3.1 FTIR Characterization

Figure 1 shows the FTIR spectra of bagasse and cassava starch feature distinct absorption bands that reveal the chemical structure of starch molecules. Both materials show similar peaks, with a prominent peak at  $3300\text{ cm}^{-1}$  indicating O-H stretching vibrations, suggestive of hydroxyl groups within the starch molecules [9]. An absorption band between  $2000$  to  $1500\text{ cm}^{-1}$  corresponds to C=O stretching vibrations, typically found in esterified starches [10]. Additionally, a peak at  $1000\text{ cm}^{-1}$  signifies the anhydro glucose ring O-C stretch, a trait of cassava starch.

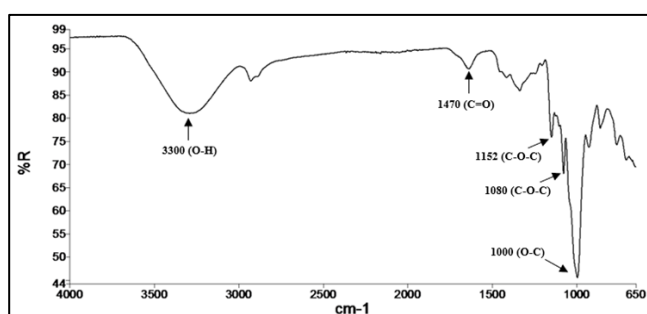


Fig. 1. FTIR of spectrum sugarcane bagasse and starch

Figure 2 shows the combined spectrum of sugarcane bagasse, starch, and glycerol includes peaks for cellulose at  $1160\text{ cm}^{-1}$ , hemicellulose at  $1740\text{ cm}^{-1}$ , and lignin between  $1500$ - $1600\text{ cm}^{-1}$  [11]. Cassava starch shows peaks for O-H stretching at  $3300\text{ cm}^{-1}$ , C=O stretching around  $1740\text{ cm}^{-1}$ , and C-O stretching at  $1080\text{ cm}^{-1}$ . Glycerol's spectrum includes O-H stretching between  $3200$ - $3600\text{ cm}^{-1}$ , C-H stretching at  $2900\text{ cm}^{-1}$ , and C-O stretching between  $1100$ - $1300\text{ cm}^{-1}$  [12].

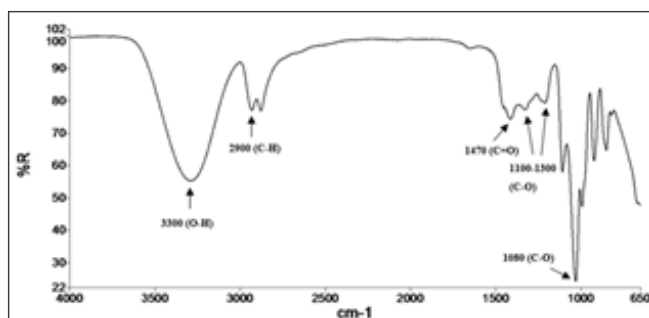


Fig. 2. FTIR spectrum of sugarcane bagasse, starch, glycerol

#### 3.2 Field Emission Scanning Electron Microscope (FESEM)

For morphology analysis, FESEM images of unmodified and modified sugarcane bagasse were obtained as shown in Fig. 3. The smooth surfaces of unmodified sugarcane bagasse were observed due to the presence of hemicelluloses and lignin (Fig. 3A) [11]. After modification, a rough surface was observed signifying the elimination of hemicelluloses and lignin from sugarcane bagasse (Fig. 3B). The FESEM image reveals that the modified sugarcane bagasse is well-bound with starch, acetic acid and glycerol, which is consistent with the FTIR results.

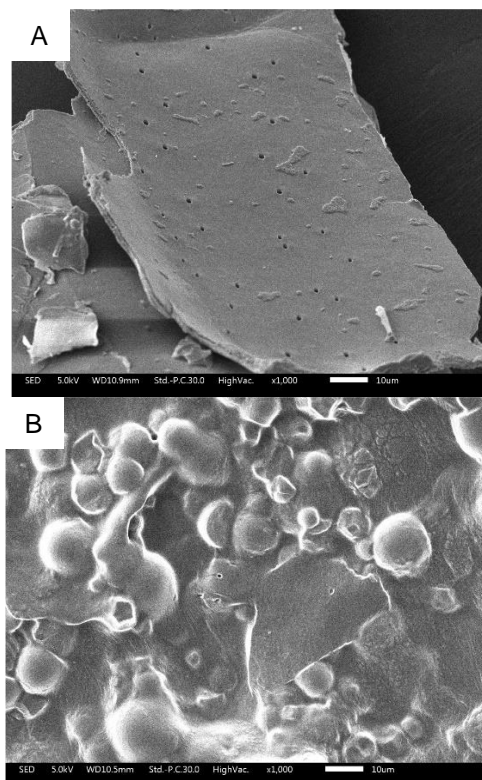


Fig. 3. FESEM images of (A) unmodified sugarcane bagasse and (B) modified sugarcane bagasse at x1000 magnification:

#### 3.3 Tensile Strength and Elongation at break

To obtain strength test results, three sets of samples were prepared, each with five samples and varying ratios. The constant ratio used was 3 parts distilled water to 1 part cassava starch (60 ml water to 30 grams starch) along with a constant amount of glycerol. Among the three sets, the best sample was chosen based on the bioplastic thickness. Figure 4 shows the Force (N) vs Displacement (mm) results for bagasse and cassava starch packaging material tested at  $10\text{ mm/min}$  at room temperature. The slope before the maximum point is the elastic slope, indicating the range in which the material can return to its original dimensions after unloading. The slope after the maximum point is the fracture slope, where the material does not return to its original dimensions once the load is removed [13]. Sample C, with a 2:1 ratio, exhibited the highest applied force of  $17.9\text{ N}$  and a

thickness of 0.94 mm, indicating its superiority over the other samples.

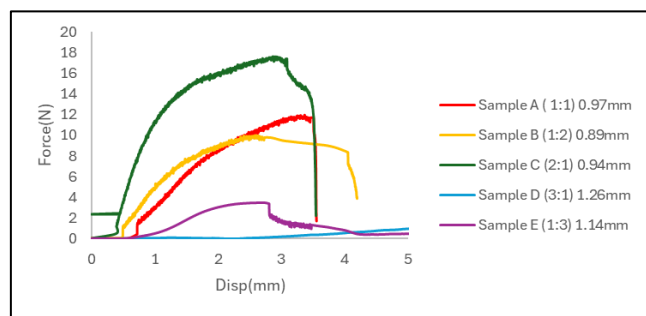


Fig. 4. Tensile strength of all the sample

### 3.4 Thermogravimetric Analysis

Figure 5 illustrates the thermal behaviour of five samples, showing a consistent pattern of gradual mass loss in distinct phases, as indicated by the TGA curves. The initial weight decreases between 80-150°C is due to the evaporation of water and volatile substances, known as the drying stage. The significant weight reduction occurs in the second phase, with temperatures ranging from 197-400°C for sample A (1:1), 193-390°C for sample B (1:2), 195-413°C for sample C (2:1), 220-415°C for sample D (3:1), and 200-398°C for sample E (1:3), primarily due to pyrolysis. Any further weight loss beyond 500°C is attributed to the decomposition of remaining carbonaceous materials.

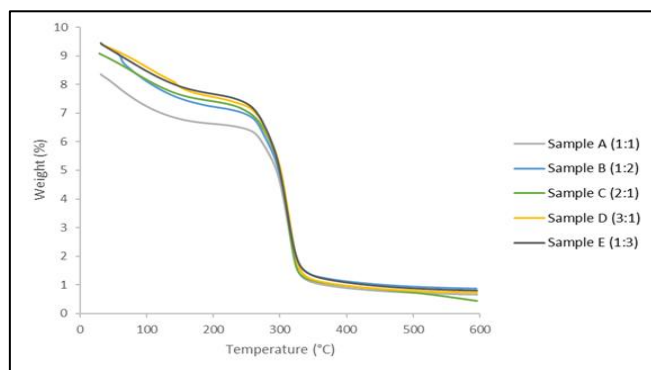


Fig. 5. Thermogravimetric Analysis

### 3.5 Derivative Thermogravimetric Analysis

Figure 6 shows prominent DTG peaks at 312.73°C, 311.99°C, 312.90°C, 313.46°C, and 310.33°C for samples A (1:1), B (1:2), C (2:1), D (3:1), and E (1:3), respectively, indicating the temperatures of maximal breakdown. Comparing the TGA and DTG curves of the five biofilm samples reveals that the temperatures for maximum decomposition rate (DTG) and thermal stability (TGA) do not follow a consistent pattern due to varying acetic acid to sugarcane bagasse ratios. Sample D, with a 3:1 ratio, shows the highest DTG value of 313.46°C and TGA values ranging

from 220-415°C. Figures 5 and 6 suggest that sample D is more thermally stable than the other samples. However, while the high degree of acetic acid enhances thermal stability, it may limit flexibility and further weaken mechanical strength, which is consistent with the tensile strength results shown in Fig. 4 [14].

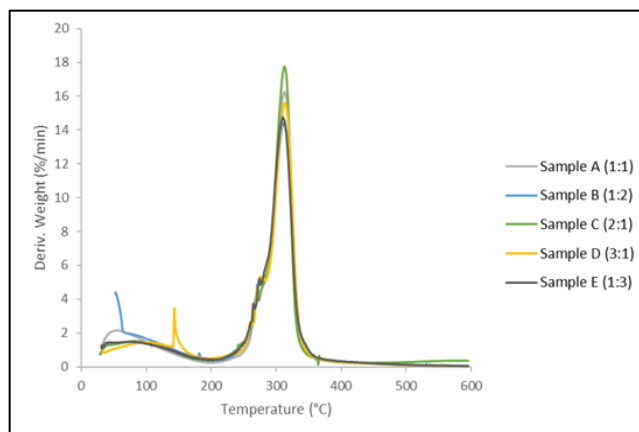


Fig. 6. Derivative thermogravimetric analysis of all the sample

### 3.6 Biodegradability Analysis

Figure 7 shows the soil burial process was used to assess the biodegradability of various bioplastics and significant degradation was noted by day 2, with sample A degrading 11.37%, sample B 2%, sample C 2.12%, sample D 1.74%, and sample E 1.13%.

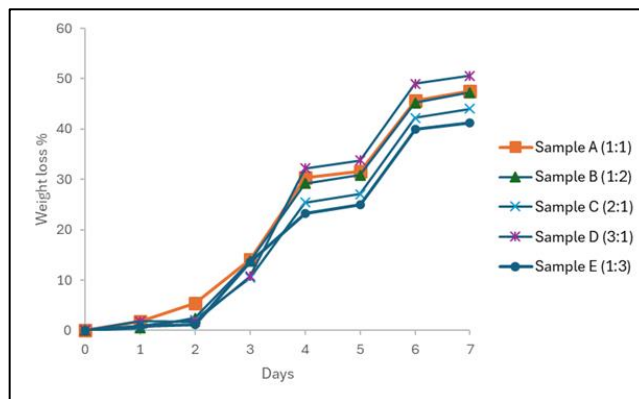


Fig. 7. Biodegradability analysis of all the sample

By day 4, sample A degraded by 30.43%, while samples B, C, D, and E degraded by 29.20%, 25.45%, 32.17%, and 23.31%, respectively. On the 7th day, weight loss ranged from 41% to 50%, with sample D showing the highest weight loss at 50%. These results indicate that sample D, with a 3:1 ratio of acetic acid to bagasse, degraded more rapidly than the other samples.

#### 4. CONCLUSION

This work effectively created and examined biocomposite materials by using sugarcane bagasse and modified starch for prospective packaging uses in the agroindustry. The structural changes between modified and unmodified bagasse were observed by morphological characterization using FTIR and FESEM. Thermal and physical property study, such as Thermogravimetric study (TGA) indicates that an acetic acid to bagasse ratio of 3:1 is more thermally stable compared to the other samples and Universal Testing Machine (UTM), indicated that an acetic acid to bagasse ratio of 2:1 had the highest mechanical strength. The biodegradability testing has verified the environmentally favourable characteristics of the biocomposite. In summary, the combination of sugarcane bagasse and modified starch has great potential as a sustainable and efficient packaging material in the agricultural business.

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