

# Development of a Tertiary Packaging Material using Sugarcane Bagasse

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## Abstract

The growing environmental concerns associated with plastic waste have intensified the demand for sustainable packaging alternatives. This study focuses on the development of a biodegradable packaging material using sugarcane bagasse, an abundant agro-industrial byproduct of the sugar industry. Sugarcane bagasse, rich in cellulose fibers, was processed and converted into molded packaging sheets through pulping, binding, and drying techniques. The physical, mechanical and biodegradable properties of the developed material were evaluated.

Obtained results indicate that the bagassebased packaging exhibits adequate strength, which is suitable packaging applications. The utilization of sugarcane bagasse not only offers an eco-friendly packaging solution but also adds value to agricultural waste. This development promotes waste minimization, sustainability, and supports the transition toward greener packaging technologies.

## Introduction

The escalating environmental impact of conventional petroleum-based plastics has driven global research toward sustainable alternatives, particularly in packaging materials. Non-biodegradable plastics contribute significantly to pollution, persisting for decades in landfills and ecosystems. It pollutes landfills, oceans, and various ecosystems. Our reckless plastic use and consumption has driven the world to generate approximately 400 million tonnes of plastic waste each year to keep up with demand, 60% of which (Pathak et al., 2023) ends up in our natural environment or landfills. In contrast, biodegradable materials degrade naturally, reducing ecological burden. Sugarcane bagasse the fibrous residue left after juice extraction from *Saccharum officinarum* is an abundant agro-industrial by-product with significant potential for value-added applications. Chemically, bagasse is a lignocellulosic biomass composed primarily of cellulose (approximately 40– 50%), hemicellulose (around 25–35%), and lignin (about 20–30%), with minor fractions of ash and extractives. The high cellulose content provides a robust fibrous



structure, making bagasse suitable for conversion into biodegradable composites. Its utilization in packaging leverages renewable biomass, minimizing agricultural waste, and supports circular economy principles.

Ongoing studies demonstrate that bagasse based packaging material increases the utilization of byproduct and enhances biodegradability, indicating a viable pathway for sustainable packaging solutions. It will also reduce the cutting of trees required to make packaging material.

## 2. Materials and Methods

### 2.1 Materials

The sugarcane bagasse was obtained from the waste of a local sugarcane juice vendor in Loni Kalbhori, Maharashtra. The chemicals required were used from the laboratory of MIT School of Food Technology, MIT ADT, Loni Kalbhori.

### 2.2 Methods

#### 2.2.1. Drying

The sugarcane bagasse procured from the sugarcane juice vendor. Taken fresh, clean and dried overnight at 55°C in hot air oven for about 12 hrs for further processing.

#### 2.2.2 Grinding

The dried sugarcane bagasse collected and grinded to obtain fine powder.

#### 2.2.3 Pulping

The ground sugarcane bagasse was then heated along with water and sodium hydroxide (NaOH), 18(w/w), to carry out pulping. The sodium hydroxide breaks down the lignin and hemicellulose present in the cell walls, leaving behind only cellulose giving the material its strength. Pulping is carried out at 140°C for 1 hr. The formulation was given in the table 2.1

Table 2. Pulping formation

Components	Quantity
Sugarcane bagasse (g)	30
Water(g)	100
Sodium hydroxide (g)	5.4

#### 2.2.4 Refining

After the pulping process the pulp is beaten vigorously to create fine fibers to strengthen the pulp. The beating was carried out for 5 min with the help of a beater.

#### 2.2.5 Molding, Forming and Drying

The pulp is poured out into an oven to form a sheet of the packaging material. It is then dried in a hot air oven to set the packaging material. Drying is carried out at 105°C for 1 hr 30 mins.

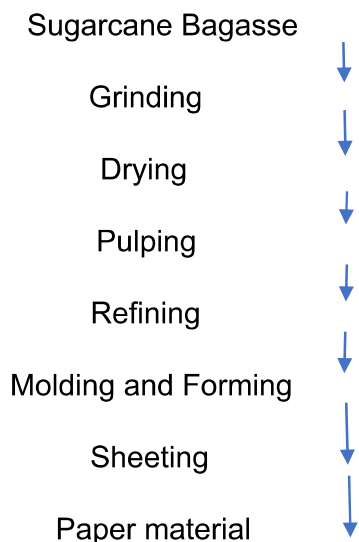


Fig 2. Flowchart of the Paper Processing

**2.2.6 Evaluation of physical properties**

*2.2.6.1. GSM (grams/ square metre)*

The samples are cut by selecting the suitable template considering the type of the sample. For heavy paper (weighing above 100 GSM) template of the size 10 cm x 10 cm is taken and hung on one of the arms of the instrument.

GSM= Weight of the sheet / Unit Area of the sheet.

*2.2.6.2. Thickness*

The thickness of the packaging material was analyzed with the help of a digital vernier caliper. Cut a piece from sample without any irregularities of size 10 cm x 10 cm. Place the specimen between two points of the micrometer, one of which has to be lifted gently to insert the paper and note the corresponding reading. The thickness can

be expressed in any unit such as micron, inches, mil etc.



Fig. 1. Bagasse Sheet

*2.2.6.3. Bursting Strength (IS 10091966 Part I)*

The bursting strength of the packaging material was analyzed on a digital bursting strength tester. The sample is fixed between clamps. The area exposed is 10 x 10 cm. The sample is subjected to steadily increasing pressure hydraulically exerted on a rubber diaphragm beneath the sample until it ruptures. The maximum pressure required to rupture the sample is automatically recorded by a pressure gauge. This test is of importance in routine quality check of packaging material during manufacture. Eg. Corrugated Boxes. (IS 10091966 Part I).

*2.2.6.4 Tearing Strength*

The Elmendorf tearing tester has two grips set side by side with only a small separation. One grip is stationary and is

mounted on an upright on the instrument base. The second grip is movable and is mounted on a pendulum. The pendulum is mounted on a frictionless bearing and swings on a shaft. The sample of 50 x 62 mm size is clamped in the two grips and a cut is made using a sharp knife fixed on the tester. When the pendulum is released, it swings down on pre-cut sample. This indicates the residual energy lost in tearing and expressed in mN (milli Newton) (ASTM, D 68979 Part 20).

### 3. Result and Discussion

#### 3.1. Physical properties

The GSM and thickness of the material determine the durability, strength, and appearance of the packaging material. The bursting strength of the material is analyzed to determine the pressure it can handle before rupturing ensuring product safety. The tearing strength of the material is analyzed to determine the material's resistance to tearing or rupturing when a force is applied.

Table 3. Physical and Mechanical properties of packaging materials

Parameter	Paper packaging material	Cardboard packaging	Sugarcane bagasse packaging
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		material	material
<b>GSM</b>	30-120 g/m <sup>2</sup>	200-600g/m <sup>2</sup>	1821g/m <sup>2</sup>
<b>Thickness</b>	0.05-0.3 mm	0.5-7mm	7.27mm (mean value)
<b>Bursting Strength</b>	1-5kg/cm <sup>2</sup>	7-16kg/cm <sup>2</sup>	2.15kg/cm <sup>2</sup>
<b>Tearing Strength</b>	20-100mN	200-800mN	863mN

Comparative evaluation of the physical and mechanical properties of the sugarcane bagasse based biodegradable packaging material relative to conventional paper and cardboard packaging materials represented in Table 3 & Fig.1. The selected parameters grammage (GSM), thickness, bursting strength, and tearing strength are widely recognized as critical performance indicators for packaging materials, particularly in secondary and protective packaging applications (Jedlicka, 2008; Thomas et al., 2025).

A pronounced variation in GSM values was observed among the evaluated materials. Conventional paper exhibited a GSM range of 30-120 g/m<sup>2</sup>, while cardboard ranged

between 2000-600 g/m<sup>2</sup> (Idris et al., 2021; Tenhunen-Lunkka et al., 2024). In contrast, the sugarcane bagasse-based material demonstrated a substantially higher GSM value of 1821 g/m<sup>2</sup>. This might be due to the variation in diameter of the packaging material. Also, increase in GSM can be attributed to the high cellulose content inherent to bagasse and the limited fiber dilution during sheet formation, characteristics commonly reported for agro-residue-based packaging materials (Elkayaly et al., 2022; Aguiar et al., 2022; Kalita et al., 2024). From an application perspective, elevated GSM values correlate with enhanced rigidity, load-bearing capacity, and resistance to structural deformation, making the developed material particularly suitable for secondary packaging applications such as outer cartons, trays, and protective inserts, where mechanical stability is prioritized over lightweight design (Kozik, 2020; Ibrahim et al., 2022).

Thickness analysis further underscores the structural robustness of the bagasse-based material. While paper and cardboard typically exhibit thicknesses ranging from 0.05-0.3 mm and 0.5-7 mm, respectively (Idris et al., 2021; Tenhunen-Lunkka et al., 2024), the developed material displayed a mean thickness of 7.27 mm, positioning it at the upper threshold of conventional

cardboard materials. Increased thickness is directly associated with improved cushioning properties, impact resistance, and dimensional stability attributes that are particularly advantageous for packaging fragile or heavy goods during handling and transportation (Jedlicka, 2008; Dewangan and Bhattacharjee, 2025).

Bursting strength, an indicator of resistance to multidirectional compressive forces, revealed moderate performance for the sugarcane bagasse-based material. While cardboard exhibited higher bursting strength values (716 kg/cm<sup>2</sup>) and paper ranged from 45 kg/cm<sup>2</sup> (Idris et al., 2021; Tenhunen-Lunkka et al., 2024), the developed material showed a bursting strength of 2.15 kg/cm<sup>2</sup>, comparable to that of conventional paper. This relatively lower value may be attributed to non-uniform fiber bonding, absence of chemical strengthening additives, and the manual pulping and molding process adopted during fabrication (Patil et al., 2023; Kalita et al., 2024). Nevertheless, the observed bursting strength remains acceptable for low to moderate load secondary packaging applications, particularly where environmental sustainability and biodegradability are prioritized over high compression resistance (Boz et al., 2020; Ibrahim et al., 2022).

In contrast, tearing strength results strongly favor the sugarcane bagasse based material. While paper and cardboard exhibited tearing strength ranges of 200 mN and 200-800 mN, respectively (Cheng, 2024; Tenhunen-Lunkka et al., 2024), the developed material achieved a tearing strength of 863 mN, surpassing both conventional materials. High tearing resistance is indicative of strong fiber entanglement and effective stress transfer along cellulose fiber networks, a characteristic commonly reported for natural fiber reinforced biocomposites (Aguiar et al., 2022; Patil et al., 2023). Enhanced tearing strength improves durability during handling, folding, and die cutting operations, thereby reducing the risk of edge failure and mechanical damage during distribution (TAPPI T414, 2012; Cheng, 2024).

Overall, the comparative assessment demonstrates that the sugarcane bagasse based packaging material outperforms conventional paper and cardboard in terms of GSM, thickness, and tearing strength, while exhibiting moderate bursting strength. These findings highlight the potential as a sustainable alternative for secondary and protective packaging applications, contributing to agricultural waste valorization and reduced dependence on petroleum based and non-renewable

packaging materials (Kozik, 2020; Ibrahim et al., 2022; Elkayaly et al., 2022). With further process optimization and mechanical reinforcement, the developed material shows strong potential to replace conventional cardboard in selected packaging applications while aligning with life-cycle sustainability principles (ISO 14040, 2006; Kalita et al., 2024; Dewangan and Bhattacharjee, 2025).

Physical properties of packaging material were calculated by using GSM calculator, thickness tearing strength, bursting strength and thickness of the packaging material was analyzed. Digital equipment was used for the analysis.

### Conclusions

Based on the obtained results, the packaging material developed from sugarcane bagasse exhibits distinct physical and mechanical characteristics when compared with conventional paper and cardboard packaging materials. The sugarcane bagasse packaging shows a significantly higher GSM (1821 g/m<sup>2</sup>) and thickness (mean value of 7.27 mm), indicating a dense and rigid structure suitable for applications requiring cushioning and structural stability. Although its bursting strength (2.15 kg/cm<sup>2</sup>) is lower than that of cardboard, it is comparable to or slightly higher than basic

paper packaging, suggesting moderate resistance to applied pressure. Notably, the tearing strength of the sugarcane bagasse material (863 mN) exceeds that of both paper and cardboard, demonstrating excellent resistance to tear propagation. These results indicate that sugarcane bagasse based packaging possesses favorable mechanical properties, particularly in terms of thickness and tear resistance, making it suitable for protective, disposable, and eco-friendly packaging applications. Overall, the study confirms the potential of sugarcane bagasse as a sustainable alternative to conventional packaging materials, contributing to waste valorization and environmental sustainability.

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