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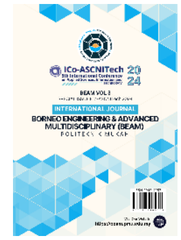

Full Paper

Transforming Waste into Tables with Recycled Drink Cartons and Natural Fibres

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Abstract

Drink cartons, typically crafted from composite materials, offer the advantage of extended lifespans with minimal maintenance compared to wood. However, the prevalent issue of unrecycled waste cartons contributes significantly to landfill accumulation. The project's focus lies in repurposing waste drink cartons and natural fibres, specifically banana stem, sugarcane bagasse, and paddy husk, while utilising corn flour as a bonding agent to make tables. Each natural fibre plays a crucial role in the composite mixture, contributing to the tables' strength, durability, and environmental sustainability, albeit with varying degrees of effectiveness and suitability. Thus, the primary objective of this study is to identify the most suitable natural fibre for table production, considering factors such as strength, moisture content, and flammability. The manufacturing process encompasses blending, spreading, compacting, drying, and shaping. Results revealed that sugarcane bagasse exhibited the highest tensile strength at 743.165N, followed closely by banana stem fibre at 728.368N, while paddy husk showed the lowest strength at 338.302N. Furthermore, banana stem fibre exhibited the lowest moisture content at 33.34%, compared to sugarcane bagasse at 43.20% and paddy husk at 48.34%. The flammability test indicated that paddy husk ignites easily and emits a paper-like odour, whereas sugarcane bagasse and banana stem fibre demonstrated greater resistance to ignition. Consequently, sugarcane bagasse and banana stem fibre are deemed suitable for table production, which helps maintain the durability and longevity of the tables, especially in humid environments. This project underscores the potential of composite materials derived from waste drink cartons and natural fibres as a promising alternative to wood in table production.

Keywords: - Waste drink cartons, banana stem, sugarcane bagasse, paddy husk, tables

1. Introduction

Packaging is crucial in preserving and protecting products throughout the supply chain, from manufacturing to consumer use. Cartons are widely utilised among the various packaging materials due to their efficiency in preventing damage and spoilage during transportation, handling, storage, and retail sales (Escursell et al., 2021). Typically, cartons are constructed from thick cardboard, paperboard, liquid packaging board, or corrugated fiberboard, making them popular for storing perishable goods like milk and fruit juice. Standard drink cartons are composed of a composite material consisting of approximately 75% cardboard, 20% polyethene (plastic), and 5% aluminium foil (Versino et al., 2023). The presence of polyethene layers on the carton's inner and outer surfaces provides protection against moisture and air, thereby extending the shelf life of the contents.

Despite the benefits, the composite nature of drink cartons poses significant challenges for recycling. The separation of aluminium and plastic layers from the paper fibres requires additional pre-pulping material preparation and time-consuming pulping processes (Vera et al., 2020). Consequently, the global recycling rate for drink cartons remains low, at around 27%, with the remainder ending up in landfills. Here, they decompose slowly, releasing methane and contributing to environmental pollution. The prolonged decomposition time of cartons, attributed to their plastic coatings, exacerbates land pollution issues and highlights the need for alternative disposal methods to mitigate the environmental impact (Jacob et al., 2022). The single-use nature of drink cartons and their complex material composition limit their reuse potential, raising concerns about environmental sustainability and resource efficiency in packaging practices.

Natural fibres from plants, animals, or geological processes present a viable alternative due to their biodegradability, strength, and accessibility. Common natural fibres include jute, flax, hemp, bamboo, cotton, and sisal, primarily composed of cellulose. These fibres are categorised into seed, leaf, bast, and stalk fibres. This study uses natural fibres such as sugarcane bagasse, banana stem, and paddy husk for their strength, biodegradability, and availability (Subagyo & Chafidz, 2018; Mahmud & Anannya, 2021). These fibres are known for their minimal deformation, size stability, lightweight properties, and biodegradability (Abdalla et al., 2023; Karimah et al., 2021). Moreover, research into natural adhesives aims to enhance adhesive strength and extend product shelf life while reducing dependency on synthetic counterparts. Plant resins, animal glue, and starch-based adhesives are among the natural alternatives being explored. For instance, corn flour derived from maise kernels is known for its strong bonding properties, non-toxicity, and eco-friendly attributes (Maulana et al., 2022; Watcharakitti et al., 2022).

Despite the widespread use of drink cartons and their significant environmental impact, the recycling and repurposing of these materials remain challenging and underexplored. Existing studies have primarily focused on recycling plastic and aluminium components of drink cartons to produce new materials. However, these processes are often energy-intensive, require complex separation techniques, and yield low-purity products (Martínez-Barrera et al., 2019; Şahin & Karaboyacı, 2021). Furthermore, the potential for repurposing drink cartons into durable and sustainable products, such as furniture, has not been extensively investigated. While natural fibres have been recognised for their strength, biodegradability, and availability, their application in combination with drink cartons remains largely unexplored. There is a need to explore the feasibility of integrating natural fibres with drink carton materials to create new, eco-friendly products.

Additionally, materials produced by combining more than two components are classified as composite materials, offering advantages such as mechanical strength, lightweight properties, and extended lifespan (Karaboyacı et al., 2017). In particular, the suitability of different natural fibres for table production has not been thoroughly examined. Natural fibres such as sugarcane bagasse, banana stem, and paddy husk possess distinct properties that may enhance the final product's mechanical strength, stability, and environmental sustainability. Understanding which natural fibres are most effective when combined with recycled drink cartons can provide valuable insights into sustainable material innovation and improve the practicality and durability of the resulting furniture.

Hence, this study aims to address these gaps by investigating the incorporation of waste drink cartons and three different natural fibres (banana stem, sugarcane bagasse, and paddy husk) into table production, utilising corn starch as a binding agent. Furthermore, the performance of these tables is evaluated through tests of tensile strength, moisture content, and safety flammability. By exploring these aspects, this study seeks to provide a sustainable and practical solution for reducing the environmental impact of drink carton waste. The research aims to demonstrate that combining waste drink cartons with natural fibres and using corn starch as a binder can result in a viable material for furniture production. This innovative approach not only helps in managing waste but also promotes the use of renewable resources, contributing to circular economy principles. Additionally, the findings of this study will contribute to the body of knowledge on innovative recycling and repurposing techniques, potentially inspiring further research and development in sustainable materials and eco-friendly manufacturing practices

2. Methodology

The experimental procedures in this study are divided into three main stages: the production of blocks, the testing of sample blocks, and the construction of tables.

2.1 Production of Blocks

Dried natural fibres, including sugarcane bagasse, banana stem, and paddy husk, were first blended into small pieces. Concurrently, drink cartons were blended with water to form a paste. For each batch, a mixture comprising 30 g of one type of blended natural fibre (either sugarcane bagasse, banana stem, or paddy husk) and 130 g of the drink cartons paste was prepared. This mixture was then supplemented with 120 ml of corn starch solution to enhance its binding properties. The resulting composite mixture was poured into moulds and subsequently dried in an oven at 180°C for 2 hours. This temperature and duration were selected to maintain the desired properties of the composite material and ensure its stability, performance, and durability in practical applications. This process produced solidified blocks, each made from a different type of natural fibre. These blocks were then ready for further testing and analysis.

2.2 Testing of Sample Blocks

Once dried, these blocks were subjected to a series of tests to evaluate their properties. The first test was the tensile strength test, conducted using a universal testing machine (UTM) to measure the blocks' resistance to tension. The second test involved measuring the moisture content of the sample blocks to assess their water retention. The oven-drying method was employed for this purpose. Initially, the blocks were weighed to obtain their initial mass. They were then placed in an oven set to 150°C for 90 minutes. After drying, the blocks were weighed again to determine their final mass. The difference in mass, or weight loss, was calculated using the wet basis formula to ascertain the moisture content of the blocks. Lastly, the sample blocks were subjected to safety flammability tests to assess their fire resistance. In this test, a lighter was placed at each block. Observations were made to determine whether the block burned slightly, propagated the flame, or exhibited any other reactions. Additionally, any resulting smell was noted to evaluate the flammability characteristics of the blocks further.

2.3 Construction of Tables

They were prepared for assembly after ensuring the blocks met the necessary quality and safety standards through rigorous testing. A strong adhesive was carefully applied to the surfaces of the blocks to ensure a secure bond. Each block was meticulously aligned and pressed together to form a cohesive structure. This assembly process was repeated for all the blocks, ensuring they fit together seamlessly. Once the adhesive had fully cured, the assembled blocks formed the final structure of the table, showcasing the combined strength and durability of the natural fibres and drink carton composite material.

3. Result and Discussion

The results of this study, focusing on the production of tables from waste drink cartons with natural fibres, highlight several important findings related to the properties and suitability of different natural fibres, as shown in Table 1. These findings are crucial for understanding the practicality and performance of these materials in furniture manufacturing. Fig. 1 to Fig. 3 illustrate the sample block made from drink cartons with sugarcane bagasse, banana stem, and paddy husk, respectively.

Fig. 1. Block made from drink cartons and sugarcane bagasse

Fig. 2. Block made from drink cartons and banana stem

Fig. 3. Block made from drink cartons and paddy husk

Table 1. Performance evaluation of composite blocks made from natural fibers and drink cartons

Sample	Maximum load (N)	Moisture content (% wet basis)	Flammability
Sugarcane Bagasse	743.165	43.2	Difficult to ignite. Does not smell.
Banana Stem	728.368	33.3	Difficult to ignite. Does not smell.
Paddy Husk	338.302	48.3	Ignites slightly. Smells like burning paper.

3.1 Tensile Strength Test

The tensile strength test conducted on the sample blocks revealed that sugarcane bagasse fiber exhibited the highest maximum load capacity at 743.165N, which signifies its exceptional ability to withstand tensile forces before failure. This high load capacity makes it particularly suitable for producing tables that need to support significant weight without breaking. With a maximum load capacity of 728.368N, banana stem fibre also shows considerable strength, though slightly lower than that of sugarcane bagasse. This level of tensile strength indicates that banana stem fibre is also a viable material for table production, capable of supporting substantial weights. However, when comparing the two, sugarcane bagasse offers a marginally better performance in terms of load-bearing capacity.

Paddy husk fibre, with a maximum load capacity of 338.302N, demonstrated significantly lower tensile strength than the other two fibers. Tables made from paddy husk fibre may not be able to support as much weight and could be prone to bending or breaking under heavy loads. These factors collectively contribute to its reduced ability to withstand tensile loads, making it the least suitable option among the fibres tested for applications with a crucial load-bearing capacity. Therefore, these findings suggest that sugarcane bagasse is the most suitable fibre for applications requiring high load-bearing capacity.

3.2 Moisture Content Test

The moisture content test is critical because it directly impacts the dimensional stability and strength, which are essential properties for producing durable and reliable tables. The sample block made from paddy husk fibre exhibited the highest moisture content at 48.34%, followed closely by sugarcane bagasse fibre at 43.20%. These high levels of moisture contents suggest that paddy husk and sugarcane bagasse are more prone to expansion and contraction with changes in humidity and temperature. When the moisture content is high, the fibre tends to absorb more water, causing it to swell. Conversely, when the environment is dry, the fibre loses moisture and shrinks. These fluctuations can lead to warping and distortion of the material, compromising the structural integrity and longevity of the tables produced from these fibres. Thus, while paddy husk might be readily available and cost-effective, its high moisture content poses a significant challenge to its use in stable, long-lasting table production. Despite this, sugarcane bagasse has other beneficial properties, such as higher tensile strength and stiffness, which might offset some of the disadvantages related to its moisture content. The fibre's overall high tensile strength is maintained due to its robust structural composition and high cellulose content. Nonetheless, careful consideration and potential treatment to reduce its moisture content might be necessary to enhance its suitability for table production.

The sample block made from banana stem fibre showed the lowest moisture content at 33.34%, making it the most stable among the three fibres tested. The lower moisture content means that banana stem fibre is less likely to undergo significant dimensional changes due to environmental humidity variations. This stability is crucial for maintaining the structural integrity and longevity of the tables produced from banana stem fibre. The lower moisture content reduces the risk of warping and distortion, ensuring that the tables remain flat and structurally sound over time. Therefore, banana stem fibre, with its inherent dimensional stability, is theoretically preferable for table production

3.3 Safety Flammability Test

The safety flammability test is crucial for assessing the fire safety of tables produced from these natural fibres. The test results indicated that paddy husk burns slightly and emits a smell reminiscent of burning paper. This high flammability is a concern because it poses a greater risk in environments with fire hazards. The composition of paddy husk, primarily cellulose, makes it more susceptible to ignition. Cellulose-based fibres are known to have lower ignition temperatures and higher flammability rates, which explains why paddy husk catches fire more easily and burns more readily than the other fibres tested. The ignition temperature for paddy husk is between 205 and 236ºC, making it less fire-resistant and a less safe option for producing tables where fire safety is a priority.

Sugarcane bagasse demonstrated better resistance to ignition compared to paddy husk. This improved fire resistance is attributed to its unique composition, which includes cellulose, hemicellulose, and lignin. These components contribute to a higher ignition temperature range (250 to 260ºC) and burnout temperature range (357 to 377ºC). The presence of hemicellulose, which has an amorphous structure, and lignin, which adds to the fibre's thermal stability, enhances the fire resistance of sugarcane bagasse. This balance of strength and safety makes sugarcane bagasse a favourable choice for table production, as it provides mechanical strength and improved fire safety.

Banana stem fibre also exhibited high resistance to ignition, similar to sugarcane bagasse. The ignition temperature for banana stem fibre ranges from 318 to 364ºC, with burnout temperatures between 380 and 415ºC. These higher temperatures indicate that banana stem fibre is less likely to catch fire, making it a safer option for applications where fire resistance is important. Banana stem fibres, classified as bast fibres, have a composition that includes a higher percentage of cellulose and lower amounts of lignin. Despite the lower lignin content, the high ignition and burnout temperatures contribute to the material's overall fire resistance, making it a viable option for producing safe and durable tables.

Based on these test results, sugarcane bagasse and banana stems have been identified as suitable materials for incorporation with drink cartons in the production of tables. These natural fibres exhibited favourable characteristics such as strong tensile strength, adequate moisture retention properties, and satisfactory safety flammability ratings. The assembled blocks, bonded with a strong adhesive, successfully formed the final, sturdy structure of the table, demonstrating their potential for sustainable composite material applications. Fig. 4(a) and Fig. 4(b) illustrate the finishing table made from drink cartons with sugarcane bagasse and banana stems, respectively.

(a) (b)

Fig. 4. Table made from drink cartons and natural fibre (a) sugarcane bagasse (b) banana stem

4. Conclusion

The comprehensive analysis of tensile strength, moisture content, and flammability clearly explains the suitability of different natural fibres incorporating drink cartons to produce tables. The block made from paddy husk and drink cartons exhibited the highest moisture content (48.34%), low tensile strength (338.302N), and poor fire resistance, making it less suitable for table applications. In contrast, the block made from sugarcane bagasse and drink cartons demonstrated the highest tensile strength (743.165N), medium moisture content (43.20%), and good fire resistance, ideal for durable and safe table production. The block made from banana stem and drink cartons, with the lowest moisture content (33.34%) and good fire resistance, also showed respectable tensile strength (728.368N), offering stability and safety, especially in environments where dimensional stability is critical. Consequently, sugarcane bagasse and banana stem fibres emerge as suitable materials for integrating with drink cartons in stable and reliable table production, while paddy husk is less suited for demanding applications. These insights guide the selection of natural fibres for sustainable and durable furniture production.

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