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Comparative Analysis of Calorific Value and Fire Safety of Engineered Wood and Solid Wood for Interior Applications

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Abstract

Materials used for interior designs and works within buildings significantly influence fire safety. During a fire outbreak, these materials can either function as a barrier, slowing the spread or as a catalyst, accelerating the fire. Among these materials, the role of wood, including engineering wood products, is crucial due to its variable calorific value. This paper aimed to determine the differences in calorific values of three wood derivatives: natural wood (*Tieghemella heckelii*, commonly known as Makore), plywood, and medium-density fibreboard (MDF). The study employed an experimental research design to analyse the combustion properties of the three wood types. Measurements of their calorific values were made using an oxygen bomb calorimeter following ASTM standards. *Tieghemella heckelii* exhibited the highest calorific value (18.4622 MJ/kg) and lowest ash content (0.43% - 0.48%), making it the most energy-efficient but posing higher fire risks. Plywood demonstrated moderate calorific values (16.3076 - 16.8227 MJ/kg) and ash content (1.76% - 2.63%), providing a balance between efficiency and safety. MDF had the lowest calorific values (16.0921 - 16.3098 MJ/kg) and highest ash content (6.80% - 7.22%), making it less efficient as a fuel source but highly suitable for fire-safe interior applications. Moisture content varied, with MDF exhibiting the lowest levels, enhancing its stability in diverse conditions. The findings indicated that *Tieghemella heckelii* is better suited for energy-intensive applications, while plywood and MDF are more appropriate for interior designs prioritising fire safety. The results emphasise the need for material selection based on specific application requirements and compliance with fire safety standards.

Keywords

Engineered Wood, Fuel Potential, *Tieghemella heckeli,* Plywood, MDF, Calorific Value

1. Introduction

Wood is a highly versatile and sustainable material extensively used in construction and interior applications. Its appeal lies not only in its aesthetic qualities but also in its structural properties and availability. Studies indicate that wood is one of the most environmentally friendly building materials, contributing to lower carbon footprints throughout its lifecycle, from production to operation [1]. Wood consumption for construction purposes is significant globally, with countries like the United States and Indonesia demonstrating high per capita usage, reflecting its integral role in the construction sector [2]. Moreover, wood's structural integrity, characterised by high strength-to-weight ratios, makes it suitable for various applications, including multi-story buildings and prefabricated structures [3] [4]. The growing demand for sustainable building materials has further solidified wood's position as a preferred choice, as it aligns with global efforts to enhance sustainability in construction practices [5].

The distinction between solid wood and engineered wood products is crucial in understanding their applications in interior design. Solid wood, derived from a single piece of timber, is known for its natural beauty, durability, and structural integrity, making it a popular choice for high-end furniture and flooring [6] [7]. In contrast, engineered wood products, such as plywood and medium-density fibreboards (MDF), are manufactured by binding together wood fibres or veneers with adhesives, resulting in materials that can be tailored for specific applications [8]. The manufacturing processes for these materials differ significantly; solid wood is typically cut and shaped directly from logs, while engineered wood involves layering and bonding, allowing for greater versatility in design and reduced reliance on high-quality logs [9]. Engineered products often exhibit enhanced dimensional stability and resistance to warping, making them suitable for applications where moisture fluctuations are a concern [10]. Consequently, while solid wood is known for its aesthetic appeal and traditional craftsmanship, engineered wood products are increasingly utilised in modern interior design for their cost-effectiveness and adaptability [11].

A number of factors, including calorific value, moisture content, and ash content, influence the combustion characteristics of wood. Calorific value, which measures the energy potential of wood products, plays a crucial role in assessing fire loads and compliance with fire safety standards. Higher calorific values indicate more excellent energy release during combustion, which can lead to increased fire risk if not effectively managed [12] [13]. Moisture content also significantly affects combustion efficiency; wood with high moisture content tends to burn less efficiently, producing more smoke and potentially hazardous emissions [14]. Additionally, ash content can influence the residue left after combustion, impacting the fire's behaviour and the material's overall safety profile [15]. Fire safety standards often consider calorific values to establish guidelines for material selection in construction, ensuring that the materials used do not contribute excessively to fire loads [13] [16].

The challenges associated with using solid wood in interior applications primarily stem from its higher calorific value and associated fire risks. Solid wood can ignite easily and sustain combustion, making it a potential hazard in fire-prone environments [17] [18]. Conversely, engineers design engineered wood products to improve stability and fire resistance, often incorporating fire retardants and modified compositions to mitigate these risks [19] [20]. However, these modifications can reduce energy efficiency compared to solid wood, presenting a trade-off between fire safety and performance [17].

Despite the advancements in engineered wood technology, significant gaps remain in the literature regarding the comparative fire safety and combustion properties of solid wood versus engineered wood in interior settings. Most studies focus on individual wood species or specific engineered products, leaving a lack of comprehensive data that could inform material selection for fire-safe interior designs [21]. Therefore, further empirical research is essential to understand how different wood materials behave in fire scenarios, guiding designers and builders in making informed choices that prioritise safety without compromising aesthetic and functional qualities. In this study, the researchers consider gross calorific value. The calorific value of wood is a crucial factor in determining its suitability for various applications, including interior works. This analysis contrasts the calorific values of engineered wood products with traditional solid wood, focusing on their implications for design, sustainability, and performance.

2. Literature Review

2.1. Engineered Wood vs. Solid Wood

Engineered wood products, such as plywood and medium-density fibreboard (MDF), are manufactured through specific processes that assemble wood fibres, strands, or veneers, bonded together using adhesives or resins. The production of engineered wood typically begins with the breakdown of solid wood into smaller components, which are then reconstituted and bonded under heat and pressure. This process allows for the creation of materials tailored for specific applications, enhancing their performance characteristics compared to solid wood [22] [23]. For instance, the use of phenol-formaldehyde (PF) and melamine-formaldehyde (MF) resins in engineered wood products not only improves their mechanical properties but also enhances their resistance to moisture and biological degradation [24] [25].

The physical and chemical properties of engineered wood differ significantly from those of solid wood, which impacts their calorific value and fire behaviour.

Solid wood typically contains higher amounts of cellulose and lignin, which contribute to its calorific value, while engineered wood products often have modified compositions due to the inclusion of adhesives and resins [12] [26]. For example, the calorific values of various wood species have been shown by many studies to vary based on their lignin and cellulose content, which directly influences their combustion characteristics [14]. Engineered wood products may exhibit altered thermal stability and combustion behaviour depending on their resin content. Studies indicate that the thermal degradation of wood can be accelerated by certain resins, which may lead to increased flammability [22] [27].

The use of adhesives and resins in engineered wood products also plays a crucial role in their combustion properties. For instance, phenol-formaldehyde resins, commonly used in plywood and laminated products, have been noted for their ability to enhance dimensional stability and resistance to biological agents, but they can also introduce additional flammable components into the composite structure [28] [29]. Furthermore, the incorporation of fire retardants into the resin formulations has improved the fire resistance of engineered wood products. However, the effectiveness can vary based on the type and amount of resin used [30]. Research suggests that the structural modifications induced by the resins can influence the fire performance of the composites, with specific formulations promoting self-char formation during combustion, thereby enhancing fire safety [27].

2.2. Comparative Analysis of Engineered Wood vs. Solid Wood

2.2.1. Calorific Value

The calorific value of wood is a critical factor when considering its use as a fuel source. Solid wood typically exhibits a higher calorific value compared to engineered wood products. For instance, *Tieghemella heckelii*, a solid wood species, has a calorific value of approximately 18.4622 MJ/kg, indicating its efficiency as a fuel source [31]. In contrast, engineered wood products such as Medium Density Fibreboard (MDF) and plywood have a lower calorific value, around 16.3 MJ/kg. This reduction can be attributed to non-combustible adhesives and fillers used in engineered wood manufacturing, which dilute the energy content available during combustion [32]. The implications of these differences are significant, particularly in applications where combustion efficiency is paramount. The higher calorific value of solid wood makes it a more desirable option for energy production. In comparison, the lower calorific value of engineered wood suggests that it may be less suitable for applications requiring high energy output. Furthermore, the combustion characteristics of these materials can influence their selection for specific applications, such as heating or cooking, where energy release is a critical factor.

2.2.2. Fire Safety

Fire safety is another crucial aspect when comparing solid wood and engineered wood. Solid wood tends to burn faster and releases more energy upon combustion, which can pose more significant fire risks in interior applications. The rapid combustion of solid wood can lead to accelerated fire spread, making it a less favourable option in environments where fire safety is a priority [33]. Conversely, engineered wood products are designed to burn more slowly, which can mitigate the risk of rapid fire spread. This characteristic is particularly beneficial for interior applications, where the potential for fire hazards must be carefully managed [33] [34]. Moreover, engineered wood products often undergo treatments that enhance their fire resistance, improving their safety profile. For instance, incorporating fire-retardant chemicals during manufacturing can significantly reduce engineered wood's flammability, making it a safer choice for construction in fire-prone areas [33] [34]. Thus, while solid wood may offer advantages in terms of calorific value, engineered wood's superior fire safety characteristics make it a compelling option for interior applications.

2.2.3. Moisture and Ash Content

Wood materials' moisture and ash content significantly impact their combustion efficiency and performance. Solid wood typically has a lower ash content, which is advantageous for combustion efficiency, as lower ash levels mean more energy is released during burning. However, solid wood often has a higher moisture content, necessitating drying processes to optimise energy release. The requirement for drying can complicate the use of solid wood, particularly in regions with high humidity or where drying facilities are limited [32]. In contrast, engineered wood products tend to have higher ash content due to the additives and fillers used in their production. This higher ash content can reduce combustion efficiency, as more energy is consumed in the combustion of non-combustible materials. However, these additives can also enhance the fire resistance of engineered wood, making it less likely to ignite and spread flames rapidly [32]. Therefore, while solid timber may provide better combustion efficiency under optimal conditions, engineered wood's characteristics can offer advantages regarding fire safety and stability in various environmental conditions.

2.2.4. Structural and Dimensional Stability

When evaluating structural and dimensional stability, engineered wood products outperform solid wood. Solid wood is prone to warping, shrinking, and cracking due to its natural variability and hygroscopic nature, which can lead to significant challenges in construction and design [9] [35]. These issues can compromise the integrity of structures over time, particularly in environments with fluctuating humidity and temperature. In contrast, engineered wood products are manufactured under controlled conditions, which enhances their dimensional stability. For example, laminated veneer lumber (LVL) and cross-laminated timber (CLT) are engineered wood products that exhibit superior strength and stability compared to solid wood [34] [36]. The layered construction of engineered wood allows for stress distribution across a larger area, reducing the likelihood of defects and enhancing overall structural performance [9] [36]. As a result, engineered wood is often preferred for applications requiring high structural integrity and durability, such as in multi-story buildings and other demanding environments.

2.2.5. Environmental and Sustainability Aspects

Wood products' environmental impact and sustainability are increasingly important considerations in today's construction industry. Solid wood is a renewable resource; however, its unsustainable sourcing can lead to deforestation and habitat destruction if not appropriately managed [32] [37]. The demand for solid wood can place significant pressure on forests, particularly old-growth forests, vital for biodiversity and carbon sequestration. On the other hand, engineered wood products are often considered more sustainable due to their efficient use of wood by-products and lower reliance on high-quality logs. By utilising smaller, less desirable wood pieces and wood waste, engineered wood products can reduce the demand for solid timber, mitigating some environmental pressures associated with traditional logging practices [32] [37]. However, the use of adhesives and chemicals in the production of engineered wood raises concerns regarding their environmental impact, particularly in terms of emissions and potential toxicity [32] [38].

2.3. Calorific Values of Wood Derivatives

The calorific values of wood derivatives such as natural wood (specifically *Tieghemella heckelii*, commonly known as Makore), plywood, and medium-density fibreboard (MDF) are critical for understanding their potential as energy sources. Each material exhibits distinct properties that influence its energy content, measured in megajoules per kilogram (MJ/kg).

2.3.1. Tieghemella Heckelii (Makore)

Natural wood, particularly hardwood species like Makore, typically has a higher calorific value than engineered wood products. According to [14], the calorific values of various wood species can vary significantly, with hardwoods generally exhibiting higher values due to their denser structure and higher lignin content, contributing to energy density. In the case of Makore, its calorific value is reported to be around 19.74 MJ/kg, which aligns with findings that hardwoods often range between 18 and 20 MJ/kg [39].

2.3.2. Plywood

Plywood, an engineered wood product made from thin layers of wood veneer glued together, has a calorific value that can vary based on the type of adhesive used and the quality of the wood layers. Research indicates that plywood generally has calorific values ranging from 16.8 MJ/kg to 19.74 MJ/kg, depending on its composition and treatment [39]. The presence of adhesives, particularly those containing urea-formaldehyde, can influence the overall energy content, as these materials may not contribute significantly to calorific value compared to wood fibres [40].

2.3.3. Medium-Density Fibreboard (MDF)

Medium-density fibreboard (MDF), another engineered product, is made from wood fibres bonded with adhesives under heat and pressure. The calorific value of MDF is typically lower than that of natural wood and plywood, primarily due to the presence of synthetic resins and the manufacturing process. Studies have shown that MDF can have calorific values in the range of 16.8 MJ/kg to 19.74 MJ/kg, similar to plywood, but often on the lower end of this spectrum due to the additives and the higher ash content associated with the resins used [11] [39]. Furthermore, the torrefaction process, which involves heating MDF to improve its energy properties, can enhance its calorific value by reducing moisture and carbon content [41].

2.4. Interior Application

Choosing engineered and solid wood is pivotal in interior design, as each material presents unique properties and applications tailored to specific needs. Solid wood is traditionally favoured for high-end furniture and decorative designs due to its aesthetic appeal, durability, and warmth. In contrast, engineered timber is increasingly utilised in applications such as panelling, flooring, and cabinetry, particularly in environments prone to fire hazards, owing to its enhanced stability and resistance to environmental changes.

Solid wood, derived from a single piece of timber, is renowned for its strength and natural beauty. It is often employed in creating high-end furniture, where the grain patterns and textures of the wood can be showcased effectively. The aesthetic qualities of solid wood contribute significantly to its desirability in decorative designs, as it can be crafted into intricate shapes and finishes that enhance the overall ambience of a space [42]. Moreover, solid wood's mechanical properties, such as its impact resistance and durability, make it suitable for furniture that is expected to endure daily use [43]. Natural wood materials' emotional and psychological benefits also play a role in their preference for interior applications, as studies have shown that wooden interiors can positively influence occupant well-being and comfort [44].

On the other hand, engineered wood products, which include laminated veneer lumber and plywood, are designed to overcome some of the limitations of solid wood. These products are manufactured by bonding layers of wood veneers or strands, resulting in materials exhibiting superior dimensional stability and resistance to warping and cracking [9]. This makes engineered wood particularly advantageous in applications such as flooring and cabinetry, where environmental factors like humidity and temperature fluctuations can pose challenges. For instance, engineered wood flooring, consisting of a core layer topped with a solid wood veneer, provides the aesthetic appeal of hardwood while offering excellent stability and ease of installation [45]. Furthermore, engineered wood is often treated to enhance its fire resistance, making it a safer choice in fire-prone areas [32].

The applications of engineered wood extend beyond mere structural benefits; they also contribute to sustainability in construction. The production of engineered wood utilises lower-quality wood and by-products, reducing the reliance on old-growth forests and promoting renewable resources [32]. This aspect aligns with contemporary interior design trends prioritising eco-friendly materials as consumers increasingly seek sustainable options in their home environments [46]. Additionally, engineered wood's versatility allows it to be used in various design contexts, from modern minimalist interiors to traditional settings, thereby broadening its appeal [47]. The ongoing evolution in wood technology continues to enhance the properties of both materials, ensuring their relevance in the ever-changing landscape of interior design.

3. Materials and Methods

3.1. Design and Research Approach

The study employed an experimental research design to investigate the study. This design involved systematically preparing and testing wood samples under controlled conditions to measure key combustion-related parameters, including calorific value, moisture content, and mass loss. The research approach was quantitative, focusing on numerical data collection and analysis. Measurements were made using standardised methods, such as the ASTM procedures and an oxygen bomb calorimeter, ensuring precision and replicability. This approach facilitated a comparative analysis of the different wood types' fire performance and energy potential.

3.2. Materials

Samples of *T. heckeli* (Makore), a 18 mm multilayer plywood made from *Pycnanthus angolensis*, and Medium-Density Fibreboard (MDF) made with phenol formaldehyde adhesive were oven-dried. The samples were weighed, and an oxygen bomb calorimeter (COALAB CP400 automatic bomb calorimetric system) was used to measure the calorific value of wood samples according to [48].

3.3. Methods

3.3.1. Sample Preparation

The wood samples were cut into small pieces and oven-dried at a temperature of 103 ± 2˚C to a constant weight. To maintain their dry state, the oven-dried samples were stored in sealed, moisture-free containers with silica gel. Wood shavings were produced from these wood species through drying, milling, pelletising, and cooling [49]. The calorific parameters were evaluated on two types of specimens: 10 samples of chips/chops and sawdust less than 1 g obtained by splitting with the circular machine of log ends; 20 pellets obtained from the sawdust resulted in the splitting of the log ends. Ten specimens of 25 × 25 mm were used to determine the density according to EN 323 standard [50]. The specimens used for tests were conditioned until they reached an average moisture content of 10% for all wood species. Ten other samples (for moisture content influence on calorific value) were conditioned to obtain 20% and 50% moisture content. The biomass analyses were determined by following [51] procedure for analysing wood fuels, performed at the Department of Chemical Material Engineering at Kwame Nkrumah University of Science and Technology at Kumasi in Ghana.

3.3.2. Calorimetric Measurement

The dried wood samples were weighed (0.5 - 0.8 grams) using an analytical balance and placed in the crucible of the oxygen bomb calorimeter. To ensure uniform combustion and accurate calorimetric measurements, proper control of particle size is crucial. The sample material was ground to a fine, homogeneous powder to maximize surface area and promote complete combustion and then sieved to obtain a particle size distribution within the range of 100 to 200 micrometers. This size range helps avoid incomplete burning or inconsistent heat release due to large particle agglomerates. For the grinding method a ball mill or mortar and pestle was used to achieve fine powder. The ground sample was sieved through a set of standard sieves according to [52] (mesh sizes) to isolate the desired particle size fraction. The sieved sample was mixed thoroughly to ensure uniformity. To ensure consistent sample mass and minimize air gaps that can affect combustion, the powdered sample was pressed into pellets before combustion using a hydraulic press with a pellet die to compress the powder into pellets. The pellets formed were of a diameter of 10 - 13 mm and thickness of 2 - 5 mm and a pellet density of approximately 1.0 to 1.5 g/cm^3, which provides sufficient mechanical strength and uniform packing. The mass of each pellet was between 0.5 and 1.0 grams, measured with an analytical balance to ±0.1 mg precision. The calorimeter was sealed and pressurised with oxygen. The samples' preparation for the combustion heat was determined in an oxygen bomb calorimeter. Parameters were measured by a substitution procedure in which the heat obtained from the sample was compared with the heat received from the combustion of a similar amount of benzoic acid whose calorific value is known. These measurements were obtained by burning a representative sample in a high-pressure oxygen atmosphere within a metal-pressure vessel (bomb calorimeter). During the combustion process, the energy released by this combustion was absorbed within the calorimeter, and the resulting temperature change within the absorbing medium was noted. The heat of combustion of the sample was then calculated by multiplying the temperature rise in the calorimeter by previously determined energy equivalent using [53] and [54]. The parameters measured were their moisture content, ash content, volatile matter content, and fixed carbon content.

3.3.3. Calculations

The gross or higher calorific value (GCV) value (HCV) is calculated based on the heat released during combustion. The formula generally used is:

$$GCV = Q/m$$

where **Q** is the heat released, and **m** is the mass of the sample.

3.4. Data Analysis

The data collected in the study were analysed using SPSS to evaluate the properties of the wood samples (*Tieghemella heckelii*, plywood, and MDF). Descriptive statistics were used to summarise and interpret the individual values of calorific value, moisture content, ash content, and mass loss. The analysis focused on comparing the reported values for each parameter across the three wood types, highlighting trends and differences. Tables and graphs were generated to visually compare the combustion properties, emphasising the variations observed among the tested samples. This analytical approach ensured accuracy and enhanced the interpretation of the variations in combustion properties among the different wood types.

4. Results and Discussion

The results presented in Table 1 are discussed as below.

Table 1. Calorific values and percentage ash contents of the samples.

S/N	Wood sample	Moisture Content (%)	Wt. of dried sample	Ash values	% Loss of mass	% Ash	Calorific Value MJ/Kg
1	*T. heckeli*	9.03	1.8208	41.2937	99.52	0.48	18.4622
		9.22	1.8236	39.5251	99.57	0.43	18.0240
		9.10	1.8189	37.8802	99.56	0.44	18.6999
2	Plywood	10.55	1.7936	43.1648	97.37	2.63	16.3076
		11.41	1.7744	42.2449	97.90	2.10	16.8038
		11.21	1.7816	38.3211	98.24	1.76	16.8227
3	MDF	7.39	1.8591	39.1591	93.20	6.80	16.3098
		7.10	1.8585	52.8134	92.78	7.22	16.0921
		6.92	1.8623	33.0314	92.89	7.11	16.1457

Moisture Content: The moisture content of the wood samples was measured before and after drying, as it significantly affects the calorific value. **Ash Content**: The ash content was determined by burning the sample in a calcination furnace and calculating the ratio of the ash weight to the initial sample weight. **Density**: The density of the wood samples can influence the calorific value on a volumetric basis.

4.1. Moisture Content

The moisture content varies among the samples: *T. heckeli*: 9.03%, 9.22%, 9.10%, Plywood: 10.55%, 11.41%, 11.21%, and MDF: 7.39%, 7.10%, 6.92%. As depicted in Figure 1. Lower moisture content is generally desirable for better combustion efficiency, as higher moisture content reduces the energy released during combustion as reported by [14].

4.2. Ash Content

Ash content is calculated as a percentage of the dry weight of the sample: *T. heckeli*: 0.48%, 0.43%, 0.44%, Plywood: 2.63%, 2.10%, 1.76% and MDF: 6.80%, 7.22%, 7.11% as shown graphically in **Figure 2**. Ash content affects the combustion process and energy release. Lower ash content is typically preferred as it indicates fewer non-combustible materials [15]. The results show that as ash content increases, the lower burning rate of fuel results in char particles leaving the grate without being entirely burned, causing a loss of combustible material and, therefore, reducing the combustion efficiency and increasing the burning time.

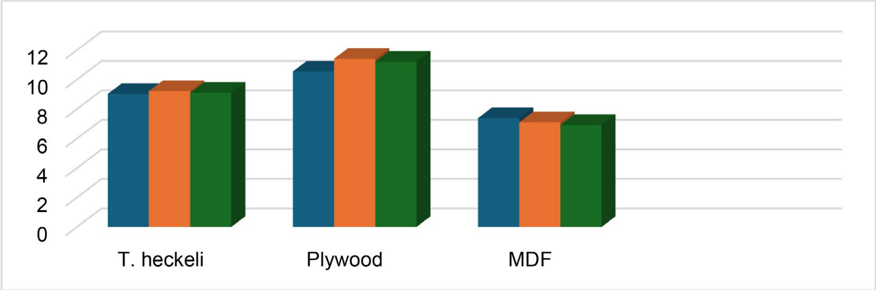

Figure 1. The moisture content of the various samples.

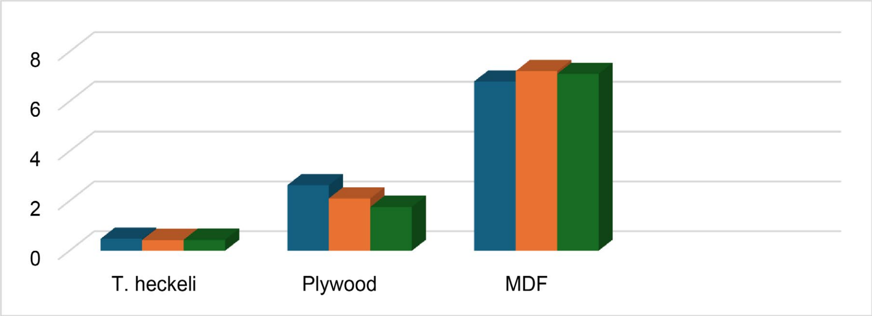

Figure 2. The Ash Content of the samples.

4.3. Calorific Value

The calorific value is the energy released per unit mass of the fuel: *T. heckeli*: 18.4622 MJ/kg, 18.0240 MJ/kg, 18.6999 MJ/kg, Plywood: 16.3076 MJ/kg, 16.8038 MJ/kg, 16.8227 MJ/kg and MDF: 16.3098 MJ/kg, 16.0921 MJ/kg, 16.1457 MJ/kg. The calorific value decreases with increasing moisture content, as depicted in **Figure 3**, other studies where higher moisture content reduces the energy released during combustion [12] [13].

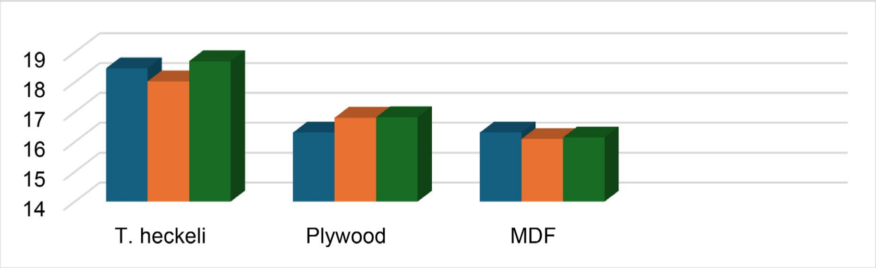

Figure 3. The Calorific values of the samples.

4.4. Comparison and Implications

- ***T. heckeli*** has the lowest moisture and ash content and the highest calorific value among the three samples. This makes it a more efficient fuel source but a risky source of products for interior applications.
- **Plywood** has moderate moisture and ash content and a lower calorific value than *T. heckeli*. Therefore, its use for interior works is at a lower risk of fire outbreaks.
- **MDF** has the highest ash content and relatively low calorific value, making it less efficient as a fuel source than the other two, but it is perfect for interior applications.

Table 2. Analysis of the various samples.

Parameter	T. heckeli	Plywood	MDF
Moisture (%)	9.12 ± 0.10	11.06 ± 0.45	7.14 ± 0.24
% Ash	0.45 ± 0.03	2.16 ± 0.44	7.04 ± 0.22
Calorific Value	18.40 ± 0.34	16.64 ± 0.29	16.18 ± 0.11
% Mass Loss	99.55 ± 0.03	97.84 ± 0.44	92.96 ± 0.22

Analysis from Table 2:

1. Moisture Content (%)

- *T. heckeli* exhibited the lowest variability (mean = 9.12%, std = ±0.10) and moderate moisture, suggesting consistent sample preparation.
- Plywood had the highest moisture (mean = 11.06%, std = ±0.45), likely due to adhesives or wood species (e.g., softwoods like pine).
- MDF showed the lowest moisture (mean = 7.14%, std = ±0.24), possibly from resin curing during manufacturing.

2. Ash Characteristics

- % Ash:
- MDF had the highest ash content (mean = 7.04%, std = ±0.22), attributable to resins and additives.
- Plywood (mean = 2.16%, std = ±0.44) and *T. heckeli* (mean = 0.45%, std = ±0.03) had lower ash, reflecting purer wood composition.
- Ash Variability: MDF ash values showed high variability (std = ±10.13), indicating inconsistent resin distribution or combustion residues.

3. Combustion Performance

- Calorific Value (MJ/kg):
- *T. heckeli* had the highest energy output (mean = 18.40, std = ±0.34), consistent with low ash and high % loss of mass (mean = 99.55%), reflecting efficient combustion.
- Plywood (mean = 16.64, std = ±0.29) and MDF (mean = 16.18, std = ±0.11) had lower values, likely due to resin interference and higher ash.
- % Loss of Mass: Correlated inversely with ash content. *T. heckeli* lost 99.55% mass (nearly complete combustion), while MDF retained ~7% ash.

T. heckeli is superior for energy production due to high calorific value and efficient combustion. MDF's resin content may have increased ash residue, reducing energy efficiency. Plywood's moderate performance aligns with its hybrid composition (wood veneers + adhesives).

5. Discussion

The results demonstrated that *Tieghemella heckelii* (solid wood) had the highest calorific value (18.4622 MJ/kg), followed by plywood and MDF, which had values around 16.3 MJ/kg. This supports prior studies, such as those by [14], highlighting that solid wood's denser structure and higher lignin content contribute to its superior calorific value. Conversely, the lower calorific values of engineered wood products can be attributed to the inclusion of adhesives and non-combustible fillers during manufacturing, as reported by [12] and [54]. While this makes engineered wood less efficient as a fuel source, it enhances its fire safety, making it more suitable for interior applications. Regarding moisture content, the study found that *Tieghemella heckelii* had approximately 9%, plywood about 11%, and MDF around 7%. This finding aligns with [55], who observed that lower moisture content improves combustion efficiency. Engineered wood products like MDF have an advantage here, as their controlled manufacturing processes ensure lower and consistent moisture levels, enhancing their stability and usability in environments with fluctuating humidity.

Regarding ash content, *Tieghemella heckelii* exhibited the lowest values (0.43%~0.48%), while MDF had the highest (6.8%~7.22%). This corroborates findings by [56], which noted that lower ash content in solid wood leads to fewer non-combustible residues and higher combustion efficiency. However, the higher ash content in MDF and plywood, due to the presence of adhesives and fillers, improves fire resistance, as observed by [32]. The study further highlights the fire safety implications of these differences. *Tieghemella heckelii,* with its high calorific value and low ash content, represents a significant fire risk in interior applications, consistent with [57], who emphasised the importance of fire load considerations.

In contrast, with their lower fire loads, MDF and plywood are more suitable for safer interior applications, aligning with [33]. The results also emphasise the practical applications of these materials, with solid wood being better suited for high-energy-output scenarios. In contrast, engineered wood's enhanced stability and fire resistance make it ideal for interior use, as [58] noted.

Practical Implications

The study highlights practical implications for material selection in construction and energy applications. *Tieghemella heckelii* is efficient for energy use but poses fire risks, while plywood balances energy efficiency and fire safety, making it suitable for interior designs. MDF, with its high fire safety and lower energy efficiency, is ideal for minimising fire risks in interiors. The results underscore the need to align material choices with specific applications, adhere to fire safety standards, and balance efficiency with safety in construction practices.

6. Conclusions

Moisture content negatively affects the calorific value, as higher moisture content reduces the energy released during combustion. Ash content is essential, as it represents non-combustible material that does not contribute to energy release and can be a contaminant. The data suggests that *T. heckeli* is the most suitable wood sample for fuel due to its low moisture and ash content and high calorific value. However, it is a high-risk material for interior applications in case of fire outbreaks. The engineered woods, plywood and MDF were more suitable for interior applications because of the minimal risk during fire outbreaks.

In summary, while engineered wood offers advantages in terms of cost-effectiveness and sustainability for interior applications, its calorific value typically falls short compared to solid wood. This is good during a fire outbreak. This difference is primarily due to variations in chemical composition and manufacturing processes. The adhesives and other binding agents in engineered wood can reduce its overall calorific value due to their differing combustion properties compared to natural wood fibres. Understanding these distinctions is essential for architects and designers when selecting materials for specific interior applications. This study contributes to the literature by providing empirical data on solid and engineered wood products' calorific value, moisture content, and ash content. It underscores the importance of balancing energy efficiency and fire safety, offering valuable insights for material selection in interior applications and sustainable energy production.

7. Limitations

The study focused on only three wood types, which may not fully represent the diversity of wood products used in interior applications. The experiments were conducted under controlled laboratory conditions, which may not reflect real-world environments where factors like humidity and temperature vary. The study did not account for chemical treatments or fire retardants commonly applied to engineered wood. It did not analyse emissions during combustion, which is crucial for understanding environmental impacts. Furthermore, the findings are based solely on combustion properties, without integrating practical fire performance testing in real applications. These limitations suggest the need for broader research to provide a more comprehensive understanding of wood materials in varying contexts.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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