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Drying method of Kelarai Bamboo panel: A moisture content analysis between sun drying and oven drying

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ABSTRACT

Drying is an important stage in the preparation of bamboo blades for kelarai panel production because it directly affects the final moisture content of the material. In current practice, conventional sun drying remains widely used by local craftsmen due to its low cost and simple application, although the method is highly dependent on weather conditions and may produce inconsistent results. This study aims to compare the moisture content of Semantan bamboo (Gigantochloa scortechinii) blades subjected to sun drying and oven drying in order to determine the more effective drying method for kelarai production. An experimental approach was adopted in which bamboo samples were dried under different conditions, namely sun drying, oven drying at 30°C for 12 hours, and oven drying at 50°C for 2 hours, with and without boron treatment. Moisture content was calculated based on the difference between initial and final weight after drying. The findings show that oven drying produced lower and more consistent moisture content than sun drying, while oven drying at 50°C for 2 hours recorded the lowest moisture content among all methods tested. These results indicate that controlled drying provides a more reliable approach for reducing moisture content in bamboo blades intended for kelarai panel production.

Introduction

Bamboo has historically occupied a pivotal position within the cultural and architectural traditions of Malaysia. Among the most distinctive bamboo-derived elements is *kelarai*, a woven blade pattern integrated into walls, partitions, and ornamental panels in traditional Malay houses, mosques, and palaces (Ahmad 2010; Harun 2011). In regions such as Perak, Kedah, and Perlis, kelarai panels continue to function as significant heritage components, appreciated for both their visual intricacy and their capacity to facilitate natural ventilation. Despite this cultural importance, the production of kelarai remains largely dependent on conventional processing techniques, particularly the sun drying of bamboo blades, which may adversely affect the long-term durability of the material.

Figure 1. Kelarai panel at Kenangan Palace, Kuala Kangsar, Perak, Malaysia

Among rural artisans and small-scale industry practitioners, sun drying persists as the predominant method due to its affordability, simplicity, and alignment with inherited cultural practices. Typically, craftsmen depend on open-air exposure over several days to reduce moisture content, a process deeply rooted in generational knowledge and local customs. While effective under optimal climatic conditions, sun drying is inherently inconsistent, as it is influenced by fluctuations in humidity, cloud cover, and ambient temperature. Such environmental variability frequently results in uneven drying, residual moisture retention, and increased susceptibility to mould growth, all of which undermine the functional lifespan of kelarai panels in interior settings (Richard 2013).

In contrast, contemporary drying technologies, such as oven drying, have not been widely embraced by traditional practitioners, largely due to financial constraints and limited access to laboratory facilities. Nevertheless, controlled drying environments such as those provided by laboratory ovens at the Forest Research Institute Malaysia (FRIM) and the Malaysian Timber Industry Board (MTIB) offer considerable advantages. Oven drying enables precise regulation of temperature and duration, leading to more uniform moisture reduction, enhanced dimensional stability, and improved mechanical performance (Zhang 2014; Richard 2013). These benefits have the potential to elevate kelarai production to a more commercially sustainable level by ensuring consistent quality and prolonged service life.

Given these divergent conditions, the present study seeks to assess the comparative effectiveness of sun drying and oven drying techniques applied to Semantan bamboo blades utilized in kelarai panel fabrication. Through a systematic examination of moisture content under varying drying environments, this research aims to determine the most dependable and practically applicable method for enhancing bamboo durability. The outcomes are expected to support not only heritage conservation efforts but also the revitalization of rural bamboo-based industries through improvements in production quality.

The importance of this investigation lies in its contribution to refining the preparation process of bamboo blades for kelarai manufacturing by establishing a clearer understanding of drying performance. Rather than addressing the entire production system, this study specifically focuses on moisture content as a quantifiable parameter for evaluating drying methods. Accordingly, it offers practical recommendations for selecting drying techniques capable of achieving more uniform moisture reduction in bamboo materials.

To accomplish this objective, a straightforward experimental framework was adopted in which Semantan bamboo blade specimens were categorized based on drying treatment, namely traditional sun drying and controlled oven drying under two temperature regimes. The initial and final masses of each specimen were recorded and subsequently used to calculate moisture content, enabling comparative analysis across all treatment groups.

Considering the contrast between uncontrolled and controlled drying environments, the study hypothesizes that oven drying will result in lower and more consistent moisture content in bamboo blades compared to conventional sun drying methods.

This research provides a targeted contribution by investigating the drying phase of kelarai bamboo production through direct comparison of moisture content between traditional and controlled techniques. It also offers valuable empirical evidence for small-scale bamboo producers in Malaysia, particularly those engaged in kelarai craftsmanship, by identifying drying approaches that may enhance consistency in material preparation while remaining aligned with local production practices. In this regard, the study bridges traditional craftsmanship with more systematic processing knowledge.

Methods

This study adopted a laboratory-based experimental design focusing on bamboo blade specimens derived from Semantan bamboo (*Gigantochloa scortechinii*), a species widely utilized in kelarai weaving due to its straight fiber structure, favorable splitting characteristics, and high workability (Harun 2011). Two principal drying techniques, sun drying and oven drying, were examined, each conducted in distinct geographical settings to represent both traditional and contemporary processing approaches.

Sample preparation

Mature culms of Semantan bamboo were processed into rectangular blade specimens by removing the outer epidermis and cutting each piece to dimensions of 30 mm × 250 mm. Careful attention was given to maintaining uniform specimen size to reduce structural variability. The preparation process took place at a bamboo workshop located in Kampung Sungai Senam, Sik, Kedah, where the culms were manually split, shaved, and trimmed into blade form. The initial mass of each specimen was recorded prior to drying to establish a baseline for subsequent moisture content calculations.

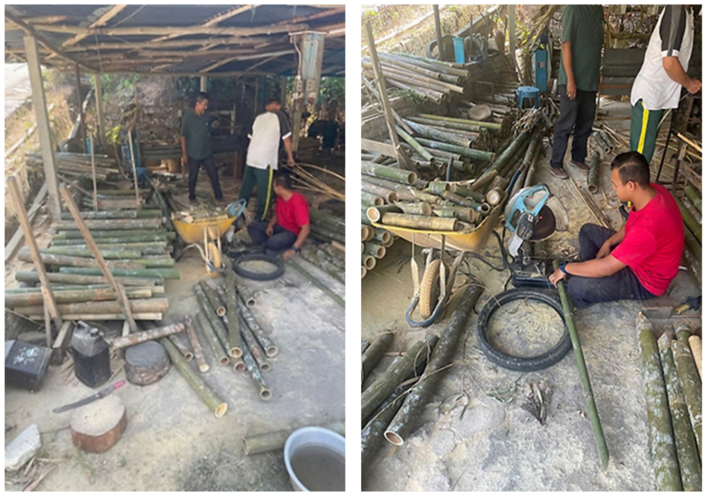

Figure 2. Workshop at Sungai Senam Village, Sik, Kedah, Malaysia for bamboo blade preparation and manual drying

Sun drying procedure

Sun drying was performed under natural outdoor conditions at the workshop in Kampung Sungai Senam, Sik, Kedah. Bamboo specimens were exposed to direct solar radiation for three consecutive days to replicate conventional drying practices. The samples were divided into untreated and boron-treated groups, with treatment applied prior to drying. The process was influenced by ambient environmental factors such as temperature and humidity.

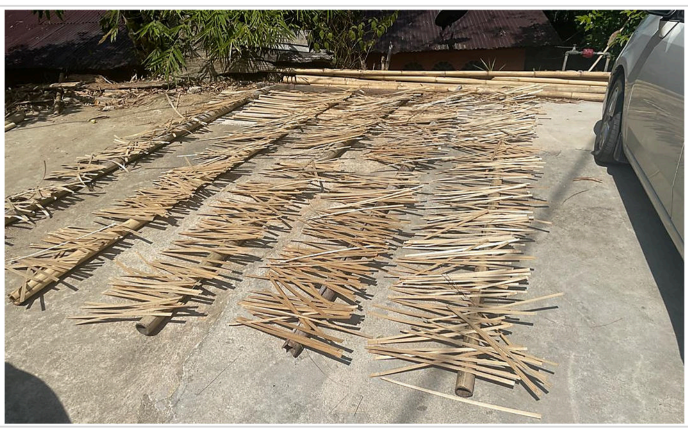

Figure 3. Sun drying at workshop, Sungai Senam Village, Sik, Kedah

Oven drying procedure

Oven drying was conducted at the Fibre and Biocomposite Development Centre (FIDEC), Malaysian Timber Industry Board (MTIB), Banting, Selangor, utilizing a Memmert Universal Laboratory Oven. Two controlled drying conditions were implemented: 30°C for 12 hours and 50°C for 2 hours. These regulated settings enabled more consistent moisture reduction compared to sun drying. Similar to the sun drying procedure, the specimens were categorized into untreated and boron-treated groups. After drying, the final mass of each specimen was measured to determine moisture content.

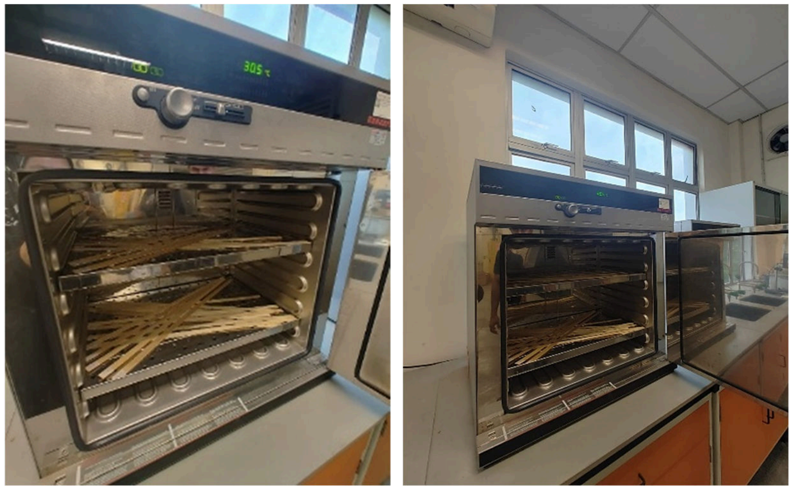

Figure 4. Oven drying machine at FIDEC, MTIB

Moisture content (MC) was calculated using the standard dry-basis formula:

$$\text{MC}\ (\%) = \frac{W_i - W_d}{W_d} \times 100$$

Note: where Wi denotes the initial mass prior to drying and Wd represents the final mass after drying. This parameter was employed to evaluate and compare the effectiveness of different drying techniques in reducing moisture content in bamboo specimens.

To further clarify the experimental configuration, table 1 presents a summary of the three drying methods employed in this study, including their respective conditions, durations, and purposes in moisture content comparison.

Table 1. Comparison of drying methods used in the study

Drying method	Condition	Duration	Setting
Sun drying	Conventional outdoor drying	3 days	Ambient environmental condition
Oven drying 1	Controlled laboratory drying	12 hours	30°C
Oven drying 2	Controlled laboratory drying	2 hours	50°C

Literature review

Bamboo species used in Malaysia

Malaysia hosts more than 70 bamboo species, among which *Gigantochloa scortechinii*, *Gigantochloa levis*, *Schizostachyum brachycladum*, and *Bambusa vulgaris* are most frequently utilized for weaving and craft-related applications (Nayak and Mishra 2016; Richard 2013). *G. scortechinii* (Semantan) is particularly valued for its thick-walled culm and high fiber strength, which provide excellent splitting properties suitable for intricate weaving patterns (Harun 2011). The selection of bamboo species is crucial, as mechanical properties, moisture absorption, and durability vary considerably among different types (Mohd Jaki 2017).

In recent years, bamboo has attracted growing interest as a sustainable material due to its rapid growth rate, renewability, and high carbon sequestration potential, making it a viable alternative to timber in construction and material production (Adebowale and Agumba 2025). However, inherent structural variability particularly in density distribution and fiber arrangement poses challenges in achieving consistent material performance during processing (Liu et al. 2025). These factors underscore the importance of proper material preparation, including drying, to ensure uniformity in bamboo-based applications such as kelarai panels.

Traditional drying methods

Drying represents a critical stage in bamboo processing, as freshly harvested bamboo typically contains high moisture levels, making it vulnerable to fungal decay and insect infestation (Rittironk and Elnieiri 2008). Traditional drying approaches, including air drying and sun drying, are widely practiced throughout Southeast Asia, especially among rural artisans. Sun drying generally requires between 3 and 12 weeks depending on climatic conditions (Richard 2013). Despite its cost-effectiveness, sun drying presents several limitations, including strong dependence on weather variability, uneven moisture distribution, increased risk of internal cracking, susceptibility to biological degradation, and dimensional instability during subsequent use.

Studies on lignocellulosic materials indicate that uncontrolled drying conditions frequently lead to uneven moisture gradients, which contribute to the development of internal stresses and surface defects (Majka and Sydor 2023). Comparable findings in plant-based materials further demonstrate that drying efficiency and quality are highly influenced by environmental variability, which is difficult to regulate under natural conditions (Babarabie et al. 2025). These constraints suggest that although sun drying remains prevalent, it lacks reliability in achieving consistent moisture reduction.

Oven drying and modern techniques

Oven drying provides a controlled environment in which temperature and humidity can be regulated, facilitating more uniform moisture reduction and shorter drying durations. Modern drying methods enable bamboo to achieve optimal moisture content levels, typically ranging from 10–15%, which are essential for stable processing and application (Zhang 2014). Additionally, controlled drying minimizes defects such as warping, cracking, and uneven shrinkage.

Research by Li et al. (2012) and Feng et al. (2012) emphasizes the significance of controlled drying in the manufacture of engineered bamboo products, including laminated and composite materials. Although these studies focus on industrial-scale applications, the underlying principles of moisture regulation and fiber stability are equally applicable to smaller-scale uses such as kelarai panel production.

Further studies indicate that bamboo drying behavior is influenced by its cellular structure and low permeability, making it prone to defects such as cell collapse and deformation when drying conditions are not adequately controlled (Xia et al. 2025). Moreover, drying temperature plays a crucial role in determining drying rate and internal stress formation, as inappropriate temperature settings may cause material damage despite accelerating moisture removal (Majka and Sydor 2023). These findings highlight the necessity of optimizing drying conditions to balance efficiency and material integrity.

Moisture content and material behaviour

Moisture content is a fundamental parameter governing the physical performance of bamboo. As a hygroscopic material, bamboo responds dynamically to environmental humidity, influencing its dimensional stability and structural behavior (Wang et al. 2024). Elevated moisture levels are associated with reduced mechanical strength, increased deformation, and altered performance under loading conditions.

Research on both bamboo and timber materials demonstrates that moisture fluctuations contribute to the development of internal stresses and influence fracture behavior, particularly during drying processes (Lu et al. 2024). Additionally, moisture gradients formed during drying may lead to differential shrinkage between surface and inner layers, resulting in internal stresses and defects such as cracking (Majka and Sydor 2023). These phenomena underscore the importance of controlling moisture content during drying.

Furthermore, drying conditions significantly affect moisture distribution within plant-based materials. Studies have shown that different drying methods produce varying moisture retention patterns depending on temperature, duration, and environmental exposure (Babarabie et al. 2025). Accurate measurement of moisture content is therefore essential for evaluating drying performance, and numerous monitoring techniques have been developed to enhance measurement precision and process control (Kubojima, Sonoda, and Kato 2024).

Chemical treatment in bamboo preservation

Boron-based compounds are widely recognized as effective preservatives for bamboo, offering protection against fungi, termites, and beetles (Richard 2013; Rittironk and Elnieiri 2008). Boron treatment does not significantly alter the color or workability of bamboo, making it suitable for decorative interior applications. When combined with controlled drying, boron treatment enhances performance by improving resistance to biological degradation.

Previous research indicates that drying conditions may influence the effectiveness of chemical treatments, particularly in terms of chemical penetration and retention within the bamboo structure (Dawson et al. 2022). Although chemical treatment is not the primary focus of this study, it remains relevant within the broader context of bamboo processing.

Research Gap: Existing studies suggest that drying conditions can affect the effectiveness of chemical treatments, particularly with respect to chemical penetration and retention within bamboo structures (Dawson et al. 2022). Although chemical treatment is not the central focus of this research, it remains relevant within the broader processing framework.

Despite extensive investigations into bamboo drying and moisture behavior, the majority of studies have concentrated on industrial-scale processing or engineered bamboo products. Comparatively little attention has been given to traditional or semi-manual applications such as kelarai panel production, where bamboo blades are prepared using conventional techniques. In particular, there is a lack of comparative research that quantitatively evaluates the effectiveness of traditional sun drying and controlled oven drying in terms of moisture content reduction.

Moreover, while prior studies have established the critical role of moisture content in influencing material behavior (Wang et al. 2024; Lu et al. 2024), there is limited empirical evidence examining how different drying methods affect moisture content specifically in bamboo blades used for weaving applications. This gap highlights the need for a focused investigation into drying performance under both traditional and controlled conditions.

Therefore, this study aims to compare the effectiveness of sun drying and oven drying techniques in reducing the moisture content of bamboo blades used in kelarai panel production. By emphasizing moisture content as a measurable parameter, the research provides a clearer understanding of drying performance within the context of traditional bamboo processing while offering practical insights for improving material preparation.

Results and discussion

Moisture content comparison

Laboratory results revealed a pronounced contrast between sun-dried and oven-dried specimens. Bamboo samples subjected to sun drying exhibited higher and more variable moisture content, largely attributable to fluctuations in environmental humidity. In contrast, oven drying at 50°C for 2 hours yielded the lowest moisture levels, demonstrating stable and uniform outcomes across all specimens. Elevated moisture content in sun-dried bamboo increases susceptibility to internal swelling, fungal infestation, and dimensional instability, critical issues affecting the durability of kelarai panels.

General moisture content patterns

The moisture content values presented in table 2 indicate several clear trends:

- Sun-dried specimens recorded the highest moisture content, generally ranging from 15% to 22%.
- Oven drying at 30°C resulted in moderate moisture reduction, with values that were lower than sun drying but still exhibited inconsistency.
- Oven drying at 50°C produced the lowest moisture levels, frequently below 10%, with a high degree of uniformity among samples.

These trends confirm that environmental control is a key factor in effective moisture reduction. Refer to table 1 for detailed parameters.

Table 2. Moisture content of bamboo samples

	Sun-dried without treatment		**Sun-dried + Treatment**		**Drying Oven 30 degree 12 hrs**	
	IW	**DW**	**IW**	**DW**	**IW**	**DW**
1	5.113	4.4495	5.812	5.4073	5.243	5.11
2	4.43	4.1753	3.462	3.303	3.458	3.33
3	5.215	4.822	4.993	4.7138	4.6809	4.27
4	3.356	2.9677	4.85	4.1503	4.8059	4.55
5	3.311	2.9468	3.832	3.372	2.6454	2.66
6	3.981	3.5772	6.256	5.9598	3.0981	2.84
7	3.612	2.9223	3.141	2.8137	3.9443	3.5
8	4.451	4.0087	3.754	3.3548	2.7254	2.35
9	4.187	3.7696	4.465	4.0742	4.7942	4.27
10	3.763	3.2848	4.876	4.4574	4.8612	4.05

	Drying Oven + Treatment (30 degree 12 hrs		**Drying Oven 50 degree 2 hrs**		**Drying Oven + Treatment 50 degree 2 hrs**	
	IW	**DW**	**IW**	**DW**	**IW**	**DW**
1	4.8299	4.14	5	3.62	4.97	4.17
2	5.963	5.06	4.61	3.24	6.58	5
3	6.1629	5.12	5.13	3.81	5.52	4.3
4	6.5861	4.69	5.86	4.11	7.17	5.95
5	5.1523	3.88	6.32	4.4	5.7	4.2
6	4.5728	3.67	5.11	3.82	6.83	5
7	4.6993	3.59	5.17	3.72	5.82	4.25
8	7.5747	6.17	5.28	3.49	6.08	4.48
9	3.8494	3.03	5.14	3.84	6.59	5.11
10	4.0142	3.92	5.64	4.33	4.33	3.49

Note: Initial Weight (IW), Dried Weight (DW), Treatment = Boron layer

Performance of sun-dried samples

The performance of sun-dried bamboo specimens highlights significant limitations associated with reliance on natural climatic conditions for moisture removal. Compared to oven-dried samples, sun drying consistently resulted in higher and more variable moisture content due to the uncontrollable nature of the outdoor environment. During the drying period, bamboo was exposed to daily humidity fluctuations, typically increasing during early morning and evening hours and decreasing only during peak daytime temperatures. These variations slowed the evaporation process and, in certain cases, led to moisture reabsorption during cooler periods.

Furthermore, intermittent cloud cover reduced both the intensity and duration of solar radiation, preventing continuous and uniform drying. As the angle of sunlight shifted throughout the day, uneven heat distribution occurred across the bamboo surfaces, resulting in inconsistent thermal exposure. Air circulation was also irregular, with stagnant, humid conditions at times limiting effective moisture dissipation.

Collectively, these environmental inconsistencies contributed to the elevated moisture levels observed in sun-dried samples, many of which remained within the range of 18%–22%. Moisture content within this range is widely recognized as critical, as bamboo becomes highly vulnerable to fungal growth, mold formation, and early biological degradation. Additionally, high moisture levels contribute to dimensional instability, including swelling, shrinkage, and warping, particularly when the material is later installed in interior environments with varying humidity conditions. Such instability undermines both the structural integrity and visual quality of kelarai panels, which depend on tightly interwoven, uniformly dried blades to maintain geometric precision.

Thus, although sun drying remains deeply rooted in traditional practices, it fails to consistently achieve the level of dryness required for producing durable kelarai panels intended for long-term indoor applications.

Oven drying at 30°C for 12 hours

Bamboo specimens dried at 30°C for 12 hours exhibited moderate improvements in moisture reduction compared to sun-dried samples. The controlled conditions of the laboratory oven eliminated environmental variability, allowing for a more consistent and gradual moisture loss process.

However, the relatively low drying temperature limited overall efficiency, resulting in moisture content levels that, while reduced, remained above the threshold required for high-quality kelarai production. Since 30°C is only slightly higher than typical ambient temperatures in Malaysia’s tropical climate, the drying process depended more on prolonged exposure than on a strong thermal gradient. Consequently, moisture evaporation occurred at a slower rate, and some internal moisture remained unextracted within the 12-hour period.

Variations in moisture content within this group may also be partially influenced by the presence of boron treatment in certain specimens. Due to its hygroscopic nature, boron can retain minor amounts of moisture during initial drying stages, potentially contributing to slightly elevated readings in treated samples. Nevertheless, despite these minor differences, the overall moisture levels in this group were more stable and predictable than those observed in sun-dried specimens.

The controlled airflow within the oven ensured even exposure across all surfaces, preventing the uneven drying patterns typically associated with outdoor methods. Despite this advantage, the resulting moisture levels were not sufficiently low to ensure long-term stability, leaving the bamboo susceptible to gradual deformation or biological deterioration if used in interior applications without further processing.

In summary, while oven drying at 30°C represents an improvement over sun drying due to enhanced consistency and reduced environmental dependence, it remains inadequate as a standalone method for achieving the low and stable moisture content necessary for durable kelarai panel production.

Oven drying at 50°C for 2 hours

Drying at 50°C for 2 hours yielded the most optimal results among all methods examined in this study. This elevated temperature facilitated rapid evaporation of both surface moisture and a substantial portion of bound water within the bamboo's cellular structure. The increased thermal energy enhanced moisture diffusion from the interior to the surface, enabling more efficient drying within a significantly shorter time frame. As a result, moisture content values consistently fell below 10%, a level widely regarded as optimal for non-structural applications such as interior kelarai panels.

Equally important was the high level of uniformity achieved. Unlike sun drying, which is influenced by environmental variability, or the 30°C treatment, which requires extended duration, the 50°C method provided a stable and controlled thermal environment that ensured consistent drying rates across all samples. The oven's regulated airflow and temperature distribution minimized the risk of uneven drying, thereby reducing internal stresses that could lead to warping or micro-cracking. Notably, boron-treated specimens did not exhibit significant resistance to moisture reduction, indicating that chemical preservation can be effectively integrated with this drying method.

The low moisture content achieved through this process has significant implications for the performance and durability of kelarai panels. Bamboo dried under these conditions demonstrates improved dimensional stability, reduced susceptibility to fungal attack, and enhanced longevity in indoor applications. Given that kelarai panels rely on tightly woven blades that must retain alignment and tension over time, achieving consistently low moisture content is essential. These findings clearly establish oven drying at 50°C as the most effective technique for both artisanal and commercial bamboo processing.

Findings

Comparative interpretation

A comparative analysis of the moisture content outcomes derived from all three drying techniques namely sun drying, oven drying at 30°C, and oven drying at 50°C clearly establishes a hierarchical order in terms of drying efficiency and consistency. Sun drying, despite its deep-rooted presence in rural bamboo craftsmanship traditions, emerged as the least effective method. Moisture levels remained elevated and highly inconsistent due to the absence of environmental regulation. Variations in humidity, inconsistent solar radiation intensity, and uneven thermal exposure collectively produced drying conditions that were neither stable nor predictable. Consequently, this method limits the applicability of sun-dried bamboo in uses that demand high dimensional stability, particularly in interior kelarai panel applications. Bamboo retaining moisture levels exceeding 18% becomes highly vulnerable to fungal proliferation and structural instability, rendering sun drying unsuitable for processes requiring dependable material performance.

In contrast, oven drying at 30°C produced moderately improved outcomes owing to the controlled conditions of the drying chamber. The removal of external environmental fluctuations enabled a more stable moisture reduction process, while extended exposure time ensured that surface moisture was considerably reduced. However, the relatively low temperature constrained the system's ability to eliminate deeply embedded bound moisture within the bamboo cellular matrix. Consequently, moisture content values within this category frequently exceeded the optimal threshold required for high-quality kelarai fabrication. Although this method represents a progression beyond sun drying, it still lacks sufficient thermal energy to achieve the dryness levels necessary for superior dimensional stability.

Oven drying at 50°C, however, demonstrated clear and decisive superiority over both alternative methods. The elevated temperature significantly increased the evaporation rate while enhancing the diffusion of internal moisture toward the external surfaces. This approach consistently yielded the lowest moisture content values across all tested samples, with minimal deviation between boron-treated and untreated specimens. Such uniformity indicates that the drying process was both efficient and highly controllable, reflecting the benefits of a precisely regulated thermal environment. These characteristics are critically important for kelarai panel fabrication, where consistent dryness ensures that woven bamboo blades maintain structural alignment, geometric stability, and long-term tension. Accordingly, the comparative assessment strongly confirms that oven drying at 50°C represents the most effective technique for producing bamboo blades suitable for durable, long-term interior applications.

Summary of findings

The results of this study clearly demonstrate that moisture content in bamboo blades is directly and significantly governed by the type of drying method applied. Among all evaluated treatments, sun drying consistently produced the highest moisture levels alongside the greatest variability. These elevated moisture conditions negatively affect the structural integrity and service life of kelarai panels, as bamboo in such a state becomes increasingly susceptible to fungal infestation, dimensional deformation, and early-stage material degradation. The inherent limitations of sun drying primarily arise from its reliance on uncontrollable environmental variables, making it unreliable for producing bamboo intended for interior architectural applications.

Oven drying at 30°C showed partial improvement by establishing a more controlled drying environment; however, the applied temperature remained insufficient to fully eliminate deeply retained moisture within the bamboo structure. While this method achieved more consistent outcomes than sun drying, the resulting moisture content still exceeded the optimal range required for durable kelarai panel production. Although the process reduced dependence on climatic conditions, its overall efficiency was constrained by a low thermal gradient and prolonged drying duration.

Conversely, oven drying at 50°C produced the most favorable results, characterized by consistently low moisture levels and minimal variation across all samples. The increased thermal input effectively facilitated the removal of both free and bound water from within the bamboo matrix over a relatively short time period. This produced a drying process that was not only more rapid but also significantly more uniform and reliable. Such qualities are essential for improving the durability and dimensional stability of kelarai panels, as bamboo conditioned to low moisture content exhibits reduced susceptibility to warping, swelling, and biological deterioration.

In conclusion, the moisture analysis clearly indicates that oven drying, particularly at 50°C for a duration of two hours, represents the most efficient and practical approach for preparing bamboo blades for kelarai production. This method ensures consistent material quality while supporting the fabrication of stable and durable panels suitable for long-term interior applications. The findings strongly suggest that replacing conventional sun drying with controlled oven drying would substantially enhance both the performance and longevity of kelarai bamboo products. These outcomes directly align with the study objectives and provide a more reliable framework for selecting appropriate drying techniques in kelarai bamboo preparation.

Conclusions

This research was conducted to assess and compare the effectiveness of different drying techniques, sun drying, oven drying at 30°C, and oven drying at 50°C, in reducing moisture content in Semantan bamboo blades used for kelarai panel production. The findings clearly indicate that the drying method plays a critical and determining role in defining the suitability of bamboo for long-term interior applications. Sun drying, although traditionally practiced in craft-based production systems, resulted in the highest and most inconsistent moisture levels due to fluctuating environmental conditions and a lack of process control. While oven drying at 30°C produced more stable and predictable results, the relatively low temperature was insufficient to fully remove internal moisture, thereby limiting its overall effectiveness. These findings emphasize the necessity of adopting a more controlled and reliable drying strategy to overcome fundamental issues of dimensional instability and biological susceptibility in bamboo materials.

Oven drying at 50°C for 2 hours emerged as the most efficient and practically applicable method, delivering consistently low moisture content across all specimens within a significantly reduced timeframe. The controlled thermal environment enabled effective removal of both free and bound water within the bamboo structure, resulting in improved dimensional stability and reduced vulnerability to fungal attack. For kelarai panels, where uniformity, structural integrity, and long-term durability are essential, this method provides a more reliable foundation for both traditional craftsmanship and contemporary production standards. Overall, the study highlights the importance of integrating controlled drying technologies into bamboo processing systems to enhance performance, reliability, and the commercial value of kelarai bamboo panels.

This study also aimed to compare moisture content across bamboo blades subjected to different drying methods in order to determine the most effective approach for kelarai panel production. The findings demonstrate that drying method significantly influences final moisture content levels. Sun drying resulted in higher and more inconsistent moisture values due to uncontrolled environmental exposure during processing. In contrast, oven drying produced lower and more uniform moisture content across all tested specimens.

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Mohd Jaki Bin Mamat contributed to the research concepts preparation, methodologies, investigations, data analysis, visualization, articles drafting and revisions.

Radhiya Binti Abd Rahim contribute to the research concepts preparation and literature reviews, data analysis, of article drafts preparation and validation.

Norhazaedawati Binti Baharuddin contribute to methodology, supervision, and validation.

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