Bioresources and Environment 2025, 3(3) 22-33.

Content list available at BioEnv

Bioresources and Environment

Journal homepage: www.bioenvuitm.com

Assessment of Surface Finishing Quality of Kelempayan *(Neolamarckia cadamba)* Wood for Furniture Components

Nur Hannani, A.L.[1]*, Nor Syahirah Jaus[1], Junaiza, A.Z.[1], Nik Hazlan, N.H.[1], Amran Shafie[1] and Ahmad Fauzi Awang @ Othman[1]

[1]*Faculty of Applied Sciences, Universiti Teknologi MARA Caw. Pahang Kampus Jengka, 26400 Bandar Tun Abdul Razak Jengka, Pahang Darul Makmur, Malaysia.*

Received September 3, 2025, Accepted in revised form October 7, 2025
Available online October 28, 2025
DOI: 10.24191/bioenv.v3i3.114

ABSTRACT. Kelempayan *(Neolamarckia cadamba)* is a fast-growing plantation species with increasing potential for Malaysia's furniture sector. Despite its advantages of rapid growth and light colour, its relatively may challenge finishing processes, especially in achieving high-quality coated surfaces due to low density and coarse texture. This study examines the influence of different abrasive papers and finishing systems on the surface quality of Kelempayan wood (*Neolamarckia cadamba*). The sawn timbers were conventionally kiln dried to 12% moisture content before being cut to end size. Then, the samples were sanded using two different types of abrasive papers which are silicon carbide and aluminum oxide. Two finishing systems were then applied which involved System 1 (applying a single coat of varnish following sanding) and System 2 (two cycles of sanding and varnishing). After that, three types of finishing testing were conducted to assess the surface finishing quality of the samples. The finishing tests were the pencil hardness test, adhesion tape (cross-cut test) and surface roughness test. Sixty samples in all were prepared and tested. The results indicated that both abrasive paper and the finishing system variables highly influenced the surface quality of samples. The application of aluminum oxide paper resulted in better performance of pencil hardness and surface roughness tests than those sanded with silicon carbide. Finishing System 2 also provided a similar pattern of results, which improved the toughness, and the surface roughness was reduced to 0.38 µm compared to System 1. In the cross-cut adhesion test, both variables provided good coat adhesion, with less than 5% to no flaking. Overall, it can be concluded that the combination of aluminum oxide abrasive paper and multicoat finishing can greatly improve the durability and surface appearance of Kelempayan for furniture components.

Key words: Surface finishing quality, kelempayan wood, varnish, silicon carbide, aluminum oxide, finishing system

1. INTRODUCTION

The furniture industry is one of the fastest-growing sub-sectors of the wood-based industry that contributes to Malaysia's economy through local and export markets (Ratnasingam et al., 2018). Previously, this sector relied on tropical hardwood due to its good properties and high availability, but there is a depleting supply of the source due to the rising demand. At the same time, new technologies have enabled the use of mixed materials to suit evolving consumer lifestyles, where design, function, and visual appeal are equally important (Zhang et al., 2020). A variety of resources, such as solid wood, wood-based composites, metal, plastic, and cement, are now used in modern furniture production. However, with the rising cost of commercial solid wood timbers, attention has shifted to alternative species that are more cost-effective. Recently, Kelempayan *(Neolamarckia cadamba),* a lightweight timber, is a promising option for furniture applications. (Krisnawati et. al., 2015).

*Corresponding author: Tel.: +601132391309
E-mail address: *hannani@uitm.edu.my* (Nur Hannani Abdul Latif)

This timber species is suitable for forest plantations because of its fast growth, can reach heights of 20 to 45 m and girths of 2.0 to 2.5 m. In Malaysia, it is predominantly grown in Perak, Pahang, Sabah, and Sarawak (Nordahlia et al., 2014). Its ability to adapt to local conditions has further encouraged planting on a larger scale. In addition, it had been widely used for building materials, furniture, and pulp production (Rahman et al., 2015). These characteristics emphasize its use not only as a plantation species but also as a sustainable raw material for wood-based industry. Economically, its fast-growing nature provides returns within eight to ten years, offering both economic and environmental benefits (Ahmad et al., 2018). However, its relatively low density and coarse texture often reduce its surface quality and durability compared to traditional hardwoods (Razak et al., 2019).

In the furniture industry, finishing is not only concerning the decorative but also functional. A smooth and well-prepared surface ensures that coatings bond effectively, improving both visual quality and resistance to everyday wear (Budakci et al., 2016). Sanding is one of the most important preparation steps because it directly controls surface roughness, which in turn affects coating penetration and overall finishing quality (Ratnasingam et al., 2018). Types of abrasive paper used during sanding, along with the sequence of operations, can provide a significant difference in the result. There two most common types of abrasives paper used in furniture manufacturing are aluminum oxide and silicon carbide. Each of them has distinct cutting properties whereas aluminum oxide is durable and suited for heavier sanding, while silicon carbide has sharper edges and is more effective for fine finishing (Camargo et al., 2021). Aluminum oxide is valued for its toughness and long lifespan. This durability also makes it more cost effective when larger surfaces need to be processed. Previous research indicates that aluminum oxide often produces smoother surfaces in the early sanding stages, while silicon carbide is valuable when a refined surface is needed for coating application (Ratnasingam et al., 2018). The finishing system that is applied on wood surfaces greatly influences how the furniture looks and how well it works overtime. The number of sanding and finish layers plays an important role in the final performance of furniture components. Adding more than one layer of varnish or coating not only improves the film thickness, hardness, shine and colour consistency levels but also provides essential protection against wear, moisture and environmental factors that could otherwise compromise performance (Nordahlia et al., 2014). On the other hand, the application of an unsuitable finishing system can result in uneven surfaces, which can reduce coating adhesion, increasing maintenance costs and wasting resources. In short, emphasizing the right finishing system for the type of wood species, intended use and the conditions in which it will be used is important to achieve the best performance and long-lasting wood products.

This study aims to evaluate the effects of abrasive paper types (aluminum oxide and silicon carbide) and finishing systems on the surface finishing quality of Kelempayan wood. The outcomes of this work are expected to provide practical recommendations for enhancing this wood species in furniture production, helping to transform this fast-growing species into a more competitive material in the market.

2. METHODOLOGY

2.1. Preparation of Raw Material

In this study, Kelempayan *(Neolamarckia cadamba)* wood was harvested from Forest Reserve UiTM Pahang. Then, the harvested logs were converted into sawn timbers through   Thereafter, they were kiln-dried for roughly about 14 days until the moisture content was below 15%. In total, there were 60 replicates prepared with standard measurements of 300 mm (length) × 100 mm (width) × 20 mm (thickness) for surface finishing evaluation. All sample preparation processes were conducted at the Wood Industry Workshop, UiTM Pahang.

2.2. Sample's Preparation

i) Sanding and Finishing Process

The surface of each sample was carefully cleaned to ensure the removal of dust and dirt before the sanding process. It was wiped with a clean dry cloth to eliminate any residual particles. The samples were sanded using two different types of abrasive papers, which are silicon carbide and aluminum oxide, with two grit numbers (80 grit for coarse sanding and 320 grit for fine sanding). It started with 80 grits, which is commonly used for initial sanding to remove rough surfaces, followed by 320 grit that was applied for the final sanding before applying a finish to achieve a smooth surface and remove any remaining imperfections. It is also important to sand along the grain direction of samples to minimize surface defects. After completing the sanding process, all samples were coated with polyurethane varnish. There were two types of finishing system that were applied: System 1 is a single sanding sequence and one coat of varnish, while System 2 is two sanding and varnishing cycles. The varnish was applied by using a brush. With each varnish application, the samples were left to air-dry at room temperature for about 1 to 2 hours for curing purposes. Then, the samples required about 24 hours duration before undergoing surface finishing testing. In total, 30 samples were sanded using silicon carbide abrasive paper, while the remaining 30 samples were sanded using aluminum oxide abrasive paper. Each group of 40 samples was further subjected to two finishing systems (System 1 and System 2).

ii) Surface Finishing Testing

The quality of the surface finish was assessed through four standardized testing methods, each of them providing a different perspective on the performance of the coated Kelempayan wood samples. The testing methods that had been selected were pencil hardness, cross-cut adhesion and surface roughness, as visually presented in Table 1.

Table 1. Experimental design of surface finishing evaluation of Kelempayan wood

Abrasive Paper	Finishing System	Finishing Testing	No. of Samples
Aluminum oxide	**System 1:** Sanding (1x) + Varnish coat (1x)	Pencil Hardness	5
		Cross-cut Adhesion	5
		Surface Roughness	5
	System 2: Sanding (2x) + Varnish coat (2x)	Pencil Hardness	5
		Cross-cut Adhesion	5
		Surface Roughness	5
Silicon carbide	**System 1:** Sanding (1x) + Varnish coat (1x)	Pencil Hardness	5
		Cross-cut Adhesion	5
		Surface Roughness	5
	System 2: Sanding (2x) + Varnish coat (2x)	Pencil Hardness	5
		Cross-cut Adhesion	5
		Surface Roughness	5

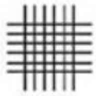
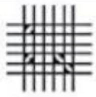
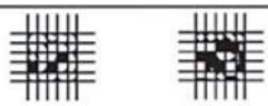
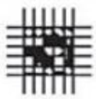
a) Pencil Hardness Test

This test was conducted to determine the resistance of the sample's coating to surface scratching and indentation in accordance with ASTM D3363 (2022). Pencil leads with different hardness levels were sharpened to a flat, smooth edge and placed against the coated surface at a 45° angle. The test started with the hardest lead and was then followed by the softer one. Each pencil was drawn across the surface under consistent pressure. The hardest pencil that left no visible scratch was used to determine the hardest grade of the sample.

b) Cross-cut Adhesion Test

Adhesion between the varnish coating and the sample's surface was examined using the cross-cut adhesion test method following ASTM D3359 (2017). A lattice pattern was cut on the coated surface using a sharp cutter to ensure that the cuts penetrated through the coating to the underlying wood. Adhesive tape was then firmly pressed onto the grid and quickly peeled off at a uniform angle. The amount of coating removed from the grid area was evaluated and rated based on the standard classification rating (higher ratings indicated stronger adhesion between the varnish film and the wood surface), as shown in Table 2.

Table 2. Standard classification of cross-cut adhesion

Classification	Percent Area Removed	Surface of Cross-Cut Area From Which Flaking has Occured for Six Parallel Cuts and Adhesion Range by Percent
5B	0% None	
4B	Less Than 5%	
3B	5-15%	
2B	15-35%	
1B	35-65 %	
0B	Greater Than 65%	

c) Surface Roughness Test

A portable roughness tester was used to determine the roughness of the coated surface. In this test, measurements of average surface roughness (Ra) were recorded at five different points on each sample. The diamond stylus was moved across the surface of the sample to record variations in height. The average value of these measurements was used to identify the roughness of each specimen. Lower Ra values indicated a smoother surface, reflecting both the effectiveness of sanding and the uniformity of the varnish application.

3. RESULTS AND DISCUSSION

3.1. Analysis of Variance (ANOVA)

The results tabulated in Table 3 shows the effect of abrasive paper and the finishing system on the surface finishing quality of Kelempayan wood. The results indicate that there are highly significant differences ($p < 0.01$) for both abrasive paper and the finishing system in relation to the pencil hardness and surface roughness tests. In contrast, the cross-cut adhesion test was not significantly affected by either variable, which indicates that the adhesion strength of the applied coating was relatively consistent regardless of sanding or finishing variations. Meanwhile, for the interaction between abrasive paper and the finishing system, it was significant for pencil hardness ($p < 0.05$) and surface roughness ($p < 0.01$), but not for cross-cut adhesion, implying that the combined effects of sanding and finishing are more relevant in enhancing hardness and surface smoothness than in improving adhesion performance.

Table 3. Statistical Analysis of F-Vaalue on Surface Finishing Quality of Kelempayan Wood

Source of Variable (SoV)	df	Pencil Hardness	Cross-cut Adhesion	Surface Roughness
Abrasive Paper	1	5.000**	0.195^{ns}	7.873**
Finishing System	1	28.800**	1.759^{ns}	413.173**
Abrasive Paper * Finishing System	1	0.200*	4.887^{ns}	1.236**

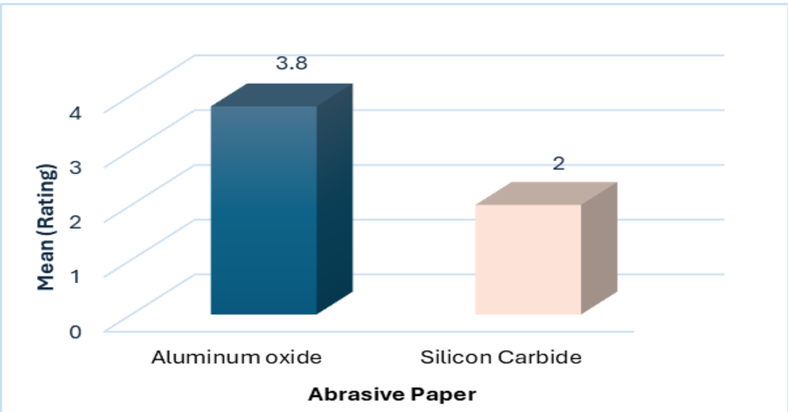
Notes: $P \leq 0.01$: Highly significant (**), $P \leq 0.05$: Significant (*) and $P > 0.05$: Not Significant $^{(ns)}$

3.2. The Effect of Different Types of Abrasive Paper on The Surface Finishing Quality of Kelempayan Wood

The pencil hardness test clearly shows the differences between surfaces sanded with aluminum oxide and silicon carbide abrasive papers. The aluminum oxide consistently produced higher hardness grades (ranging from 3H to 4H, with an average of 3.8H), while silicon carbide yielded comparatively lower values (ranging from 1H to 3H, averaging 2.0H) as presented in Table 4 and Figure 1. This suggests that aluminum oxide, owing to its toughness and self-sharpening ability, produced a more uniform surface that improved coating adhesion and film integrity, thus enhancing the surface hardness. It tends to produce a smoother and more compact surface capable of resisting scratches and wear, whereas the sharper cutting action of silicon carbide may introduce micro-roughness, leading to reduced hardness values that cause deeper scratches. These results align with a previous study on other tropical hardwood timbers, where abrasive type was shown to directly affect finishing performance. The coating on rougher surface is also more likely to wear out quickly (Bekhta et al., 2022). Aluminum oxide abrasives generally produce lower surface roughness and stronger coating adhesion compared to silicon carbide, primarily due to differences in grain toughness (Nasir et al., 2019). Consequently, the use of aluminum oxide abrasive may contribute not only to enhanced mechanical performance but also to greater sustainability by minimizing material waste and the environmental burden of frequent surface refinishing or replacement.

Table 4. Pencil hardness test results using two different types of abrasive papers

Abrasive Paper	S1	S2	S3	S4	S5	Mode	Median	Range
Aluminum Oxide	4H	4H	3H	4H	4H	4H	4H	3H-4H
Silicon Carbide	2H	2H	2H	1H	3H	2H	2H	1H-3H

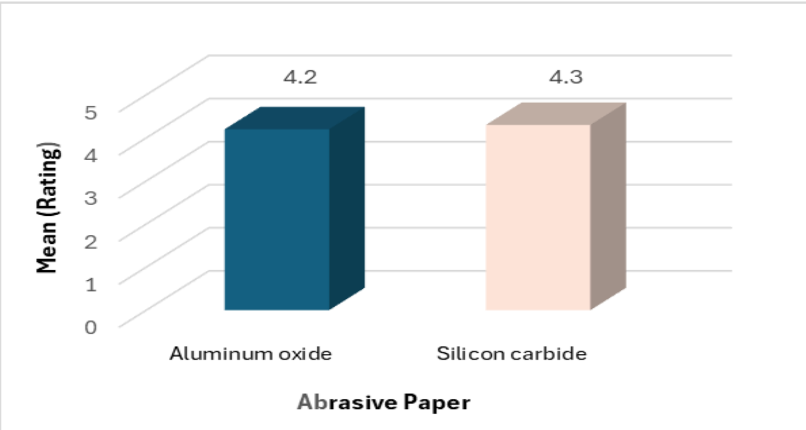


Notes: Rating 1 = 1H, 2 = 2H, 3 = 3H and 4 = 4H

Figure 1. The effect of abrasive papers on the surface hardness of samples

While, the cross-cut adhesion test indicated that both aluminum oxide and silicon carbide abrasive papers provide slightly similar results, with mean ratings of 4.2 and 4.3, respectively, as shown in Figure 2. The results are classified within the 4B-5B range according to the standard classification in Table 2, which represents excellent coating adhesion with less than 5% to no flaking. This suggests that the type of abrasive paper does not have a major influence on adhesion. It is a known fact that anatomical structure is one of the major parameters influencing overall interaction between coating and substrate (Ozdemir et al., 2015). The strong adhesion is likely due to the porous structure of Kelempayan, which allows the coats to deeply penetrate into the samples.

Figure 3 illustrates the surface roughness of samples that were applied with aluminium oxide, which showed a lower mean roughness if compared to silicon carbide, with mean values of 1.2 µm and 1.4 µm, respectively. It is because aluminum oxide is tougher and can keep its cutting edges sharp for longer, so it removes wood more evenly. Meanwhile, silicon carbide grains break easily, which can produce small grooves and result in a rougher surface. Camargo et al. (2021) also stated that the surface roughness is highly affected by the type of abrasive paper, with aluminum oxide usually producing smoother results than silicon carbide.



Notes: Rating 1 = 1B, 2 = 2B, 3 = 3B, 4 = 4B and 5 = 5B

Figure 2. The effect of abrasive papers on the coating adhesion of samples

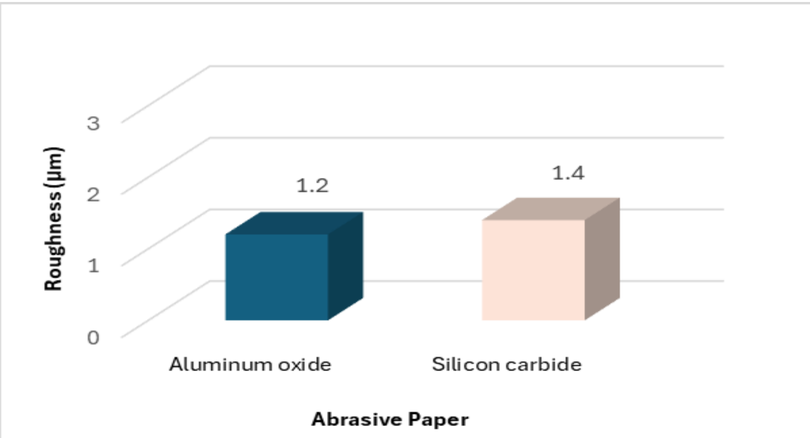


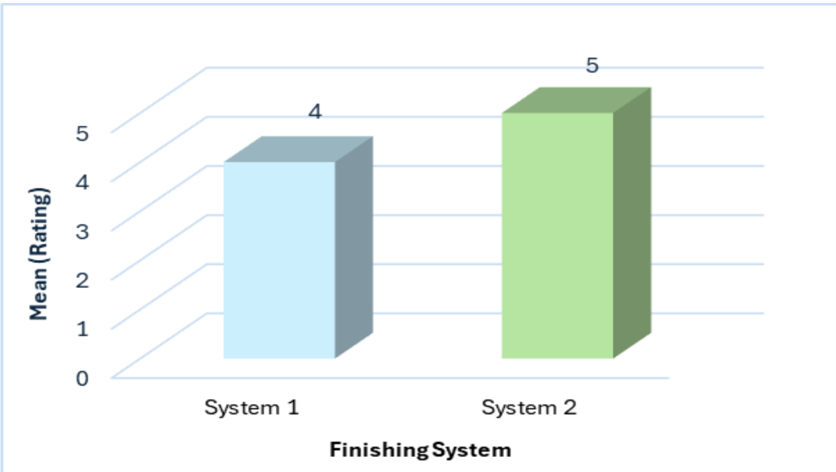
Figure 3. The effect of abrasive papers on the surface roughness of sample

3.3. The Effect of Different Types of Finishing System on The Surface Finishing Quality of Kelempayan Wood

The finishing system was found to have a highly significant effect on the overall surface finishing quality of Kelempayan wood, as reflected in the pencil hardness test. Samples coated with finishing System 2 consistently achieved higher hardness ratings, ranging from 4H to 6H, with both the mode and median at 5H, indicating a more durable and scratch-resistant surface as tabulated in Table 5. In contrast, System 1 maintained uniform hardness grades of 4H across all samples, suggesting a less protective finish that may be more prone to wear and mechanical abrasion over time. Average hardness values for both System 1 and 2 are 4H and 5H, respectively, as illustrated in Figure 4. This shows that System 2 resulted in a tougher and more scratch-resistant surface, likely because it adhered better and formed a stronger coating. System 1, which produced lower hardness, suggests its finish was less protective and might wear down more quickly. The repetition of the sanding process after the first varnish coat provided a more uniform surface. The second coat of varnish formed a thicker and harder layer that resisted to indentation more effectively. Kilic & Sogutlu (2022) stated that the application of multiple coating layers significantly improved the hardness and protective performance of wood surfaces.

Table 5. Pencil hardness test results using two different types of finishing system

Finishing System	S1	S2	S3	S4	S5	Mode	Median	Range
System 1	4H	4H	4H	4H	4H	4H	4H	4H
System 2	5H	5H	5H	4H	6H	5H	5H	4H-6H

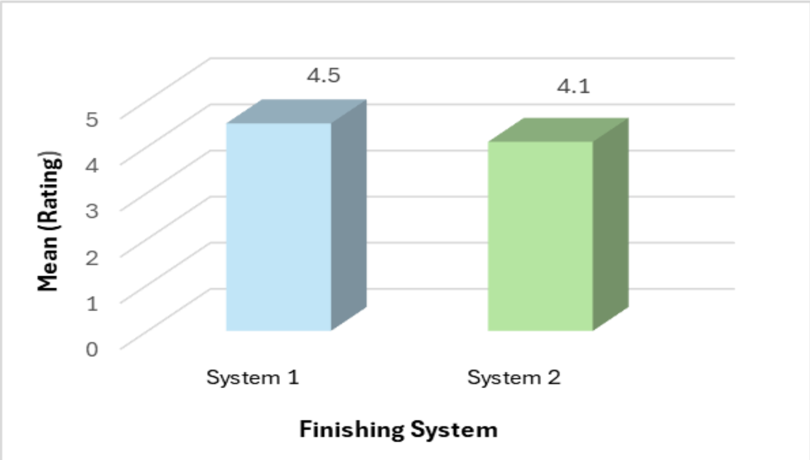


Notes: Rating 1 = 1H, 2 = 2H, 3 = 3H, 4 = 4H and 5 = 5H

Figure 4. The effect of finishing system on the surface hardness of samples

Finishing System 1 obtained a mean rating of 4.5, which is slightly higher than finishing System 2 with a mean score of 4.1 for cross-cut adhesion test as shown in Figure 5. According to the ASTM D3359 classification scales, both ratings are considered good adhesion, meaning only small flakes (less than 5%) of coating detach along the cut edges. The slightly reduced adhesion in System 2 also might be due to the thicker coating layer. These observations are supported by the research findings by Kudela & Kubovsky (2016), who stated that excessive coating thickness can sometimes weaken adhesion despite improved hardness.

Figure 6 indicates the results of the surface roughness test, which showed better performance of finishing System 2, with a mean surface roughness value of only 0.38 µm, compared to 2.3 µm for finishing System 1. The additional sanding procedure helped remove surface irregularities and, while the second varnish coat filled in the pores, leveled the wood fiber thus giving a smoother finish. This smoother surface improves the wood appearance and coating performance, that results in higher-quality furniture that may positively influence consumers' purchasing decisions (Latif, et al., 2024). De Moura & Hernandez (2016) also found that both sanding quality and the number of finishing cycles highly influence the final surface smoothness of hardwoods.



Notes: Rating 1 = 1B, 2 = 2B, 3 = 3B, 4 = 4B and 5 = 5B

Figure 5. The effect of finishing system on the coating adhesion of samples

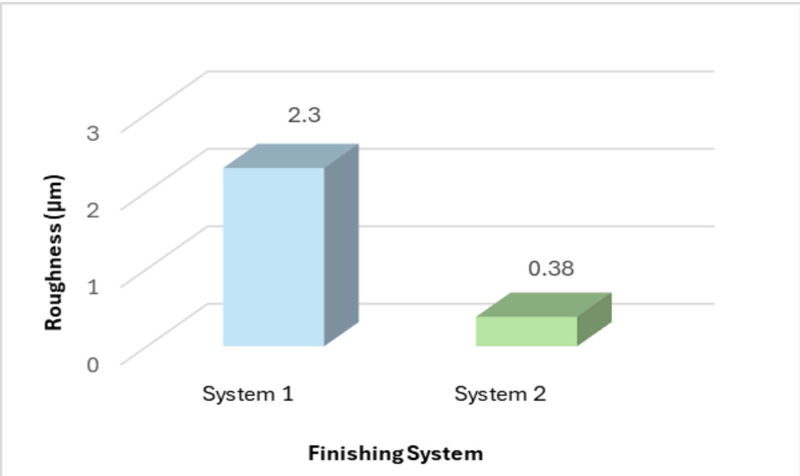


Figure 6. The effect of finishing system on the surface roughness of samples

4. CONCLUSION

The assessment of the surface finishing performance of Kelempayan wood samples had been successfully conducted and analyzed. Type of abrasive paper and finishing system significantly influenced the hardness and roughness of wood surfaces. Aluminum oxide abrasives worked better compared to silicon carbide, which tended to leave deeper scratches and uneven coats. The finishing system factor also plays an important role in the surface quality. The application of double sanding combined with two coats of varnish in System 2 had achieved a more uniform, harder, and smoother surface compared to the single cycle in System 1. While adhesion strength remained consistently high in both applications due to the natural characteristic of Kelempayan. Sanding using aluminum oxide and a multilayer finishing method can enhance the surface quality of Kelempayan wood, thus highlighting the Kelempayan as a highly potential material for furniture components. Further research should explore advanced surface analysis methods, as it could provide better determination to optimize finishing systems for fast-growing timbers in furniture production.

ACKNOWLEDGMENTS

The authors would like to acknowledge the staffs of Wood Industry Study Centre, Universiti Teknologi MARA (UiTM), Pahang Branch, for their assistance and support in the completion of this research.

AUTHOR CONTRIBUTIONS

Nur Hannani Abdul Latif: Methodology, data analysis, writing original draft. **Nor Syahirah Jaus**: Methodology, data analysis. **Junaiza Ahmad Zaki:** Material preparation. **Nik Hazlan Nik Hashim:** Writing review. **Amran Shafie:** Material Preparation. **Ahmad Fauzi Awang @ Othman:** Methodology.

FUNDINGS

This research did not receive any financial funding.

DATA AVAILABILITY

Not applicable.

COMPETING INTEREST

The authors declare that there are no competing interests.

COMPLIANCE OF ETHICAL STANDARDS

Not applicable.

SUPPLEMENTARY MATERIAL

Not applicable

REFERENCES

Ahmad, Z., Lum, W. C., Lee, S. H., & Mahyiddin, W. F. W. M. (2018). Behaviour of Walls Constructed Using Kelempayan (*Neolamarckia cadamba*) Wood Wool Reinforced Cement Board. *Sains Malaysiana*, *47*(8), 1897–1906.

ASTM D3359. (2017). Standard Test Methods for Rating Adhesion by Tape Test. American Society for Testing and Materials, West Conshohocken, Pennsylvania, United States.

ASTM D3363. (2022). Standard Test Method for Film Hardness by Pencil Test. American Society for Testing and Materials, West Conshohocken, Pennsylvania, United States.

Bekhta, P., Lis, B., Krystofiak, T., & Bekhta, N. (2022). Surface Roughness of Varnished Wood Pre-Treated Using Sanding and Thermal Compression. *Forests*, *13*(5), 777. https://doi.org/10.3390/f13050777

Budakci, M., Pelit, H., Sönmez, A., & Korkmaz, M. (2016). The Effects of Densification and Heat Post-Treatment on Hardness and Morphological Properties of Wood Materials. *BioResources*, *11*(3), 7822-7838. https://doi.org/10.15376/biores.11.3.7822-7838

Camargo, R. F., Gonçalves, M. T. T., Gonçalves, D., Gava, M., & Garcia, R. A. (2021). Analysis of the parameters affecting the surface sanding of Pinus elliottii and Corymbia citriodora wood species. *BioResources*, *16*(1), 1385–1398. https://doi.org/10.15376/biores.14.2.2773-2783

De Moura, L. F., & Hernandez, R. E. (2016). Effects of Sanding and Coating Cycles on The Surface Properties of Hardwoods. *European Journal of Wood and Wood Products*, *74*(4), 517–525. https://doi.org/10.3390/coatings10090856

Kilic, K., & Sogutlu, C. (2022). Surface Hardness of Three Types of Varnish Applied to Fresh and Naturally Aged Wood. *Kastamonu University Journal of Forestry Faculty*, *22*(2), 125–134. https://doi.org/10.17475/kastorman.1179043

Krisnawati, H., Kallio, M., & Kanninen, M. (2015). *Anthocephalus cadamba* Miq.: Ecology, Silviculture and Productivity. CIFOR, Bogor, Indonesia.

Kudela, J., & Kubovsky, I. (2016). Adhesion Of Coatings to Wood Substrates: Influence of Surface Treatment. *Wood Research*, *61*(5), 815–824.

Latif, N. H. A., Hamdan, M. H., Zaki, J. A., Shafie, A., Fauzi, A. & Kamarudin, N. (2024). Consumer's Perceptions and Buying Intentions for Furniture Made from Recycled Wood Slabs. *Bioresources and Environment*, *2*(3) 143-154. https://doi.org/10.17475/10.24191/bioenv.v2i3.73

Nasir, V., Nourian, S., & Cool, J. (2019). The Influence of Sanding Parameters on Surface Quality of Wood and Wood-Based Composites: A Review. *Wood Material Science & Engineering*, *14*(3), 129–141. https://doi.org/10.1080/17480272.2016.1266511

Nordahlia, A. S., Lim, S. C., Hamdan, H., Anwar, U. M. K. (2014). Wood Properties of Selected Plantation Species: *Tectona grandis* (Teak), *Neolamarckia cadamba* (Kelempayan/Laran), *Octomeles Sumatrana* (Binuang) and *Paraserianthes falcataria* (Batai). Timber Technology Bulletin No. 54, Forest Research Institute Malaysia, Kepong.

Ozdemir, T., Hiziroglu, S., & Kocapinar, M. (2015). Adhesion Strength of Cellulosic Varnish Coated Wood Species as Function of Their Surface Roughness. *Advances in Materials Science and Engineering*, *2015*, 525496. https://doi.org/10.1155/2015/525496

Ratnasingam, J., Chin, K. A., Latib, H. A., Subramaniam, H., & Khoo, A. (2018). Innovation in the Malaysian furniture industry: Drivers and challenges. *BioResources*, *13*(3), 5254–5270.

Rahman, S. S. A., Muhammad, N., Hassan, N. H., Ismail, H., Abdullah, N., Yahya, M. F., Basir, N., & Awan, M. A. (2015). Development of *Neolamarckia cadamba* (Kelempayan) Tissue Culture Techniques for Sustainable Supply of Planting Materials for Commercial Plantation. *Jurnal Teknologi*, *77*(24), 159–163. https://doi.org/10.11113/jt.v77.6725

Razak, W., Amin, M. N. M., Hashim, W. S., & Hashim, R. (2019). Enhancing The Properties of Fast-Growing Wood Species Through Modification for Better Utilization. *Journal of Tropical Forest Science*, *31*(1), 1–12.

Zhang, L., Yang, Q., Zhang, K., Liu, J., Feng, C., Hou, W., & He, X. (2020). Research on The Integration of Industrial Design and Mechanical Product Design. *IOP Conference Series Materials Science and Engineering*, *772*(1), 012100. https://doi.org/10.1088/1757-899X/772/1/012100