ONLINE ISSN 2069-7430
ISSN-L 1841-4737
PRO LIGNO
www.proligno.ro
Vol. 21 N° 1 2025
pp. 3-14

DEVELOPMENT OF A BAMBOO CULM SPLITTER FOR THE SMALL-SCALE FURNITURE INDUSTRY IN NIGERIA

Abel O. OLORUNNISOLA*
Department of Wood and Biomaterials Engineering, University of Ibadan, Nigeria
Dominion University, Ibadan, Nigeria
E-mail: abelolorunisola@yahoo.com

Ahmed T. ABU
Department of Wood and Biomaterials Engineering, University of Ibadan, Nigeria

Esther A. OYELEYE
Department of Wood and Biomaterials Engineering, University of Ibadan, Nigeria

Abstract:
Furniture production is one of the oldest forms of product manufacturing in Nigeria. The small-scale wooden furniture industry has also remained a major source of employment generation for ages. However, the industry has been facing the challenge of growing scarcity of wood for over two decades now. A way out is the use of substitute renewable materials such as rattan and bamboo. Bamboos, in particular, are still available in the country in large quantities for utilisation in furniture production. The aim of this study, therefore, was to develop and evaluate a semi-mechanised culm splitter for small-scale bamboo furniture production. The splitter was able to produce 30cm long and 29-37mm wide strips from dry and wet bamboo culms, with and without nodes. Wet culms were split faster than air-dry culms. Generally, wet culms with nodes took about twice the time required for samples without nodes, while dry culms with nodes took about thrice the time required for dry culms without nodes. The dried bamboo strips were laminated and used for the production of an 800mmx1000mmx300mm bamboo-lumber hybrid bookshelf. Coating of the bamboo strips with a thin film of thermocol, an expanded polystyrene dissolved in gasoline, enhanced physical appearance, dimensional stability and resistance of the strips to insect infestation.

Key words: *Bamboo, Culm splitter, Bamboo coating, Furniture.*

INTRODUCTION

The global furniture industry can be divided into different sub-groups based on production material, i.e., wood and wood products, metal, concrete, plastic, cane, bamboo, and similar materials. For many years, wood was the predominant material for furniture production in Nigeria. About 60% of wood produced in Nigeria was consumed in the furniture industry thirty years ago (Lucas and Olorunnisola 2002, Olorunnisola and Adewole 2016, Olorunnisola 2023). In many of the furniture workshops, lumber, plywood and particleboard were/are commonly utilized. The wide availability, cheapness, aesthetic appeal, flexibility, and renewability of lumber in particular set it apart from other furniture production materials. Another favourable factor is the possibility of producing strong wooden furniture items even with the cruddiest of tools and at locations where electricity power is completely absent or unreliable (Olorunnisola and Adewole 2016). Hence, small-, medium- and large-scale furniture workshops abound in the country. By the late 1990s, about 200 large-scale wooden furniture establishments were in operation in the country (Olorunnisola 2000, 2005). However, the wooden furniture industry in Nigeria is currently facing an existential challenge because of the progressive decline in wood and wood products supply for over five decades.

The massive exploitation of timber resources of the country between 1950–1970 laid the foundation for the current deficits in timber supply and rapidly escalating cost of lumber. Arowosoge *et al.* (2009) also observed that only fifteen species are considered suitable for furniture making in the country. This figure constitutes only a small percentage of the total known wood species that abound in the Nigeria forest. To make matters worse, deforestation and desertification have now become a major challenge. The local rattan resources have also been over-exploited for furniture and handicraft production and are becoming increasingly scarce (Olorunnisola and Adewole 2016, Olorunnisola 2024).

Bamboos are tall grasses that occur mostly in natural vegetation and are widely available in wild in many parts Nigeria. The two main varieties widely available are *Bambusa vulgaris* and *Oxystenanthera abyssynica* (Ogunwusi 2014, Ogunsanwo *et al.* 2015). The former attains a height of between 14 - 20m at maturity with a girth of about 20cm, while the latter reaches between 8 - 12m at maturity (Liese, 1986, 1987, Ogunsanwo *et al.* 2015). The two varieties grow naturally in the forests below River Niger and in Taraba State, mostly around river courses (Ogunwusi 2014, Ogunsanwo *et al.* 2015, Adewole *et al.* 2017). The

*Corresponding author

maturity circle of three to five years is very short when compared to wood which takes 20-25 years to attain full maturity. Unlike trees, bamboo grows initially at full width, with no tapering or horizontal growth. Also, a bamboo forest can be harvested every six years, while hardwood forests may require decades between harvests. Again, unlike most timber, bamboo is self-regenerating; new shoots that appear annually ensure future raw material after mature culms are harvested (Olorunnisola 2006, Atanda 2015).

To expand the raw material base for the wooden furniture industry in Nigeria, there is a need for raw material substitution. A major viable substitute is bamboo, from which different products can be obtained such as strips, different laminated bamboo products plywood (plybamboo), oriented strand board, fibreboard, and medium density fibreboard (Liese 1987, Adewole and Olayiwola 2011, Adewole and Bello 2013, Adewole *et al.* 2017, Olorunnisola and Omotayo 2020). Fig. 1 shows the processes for producing laminated products from raw bamboo.

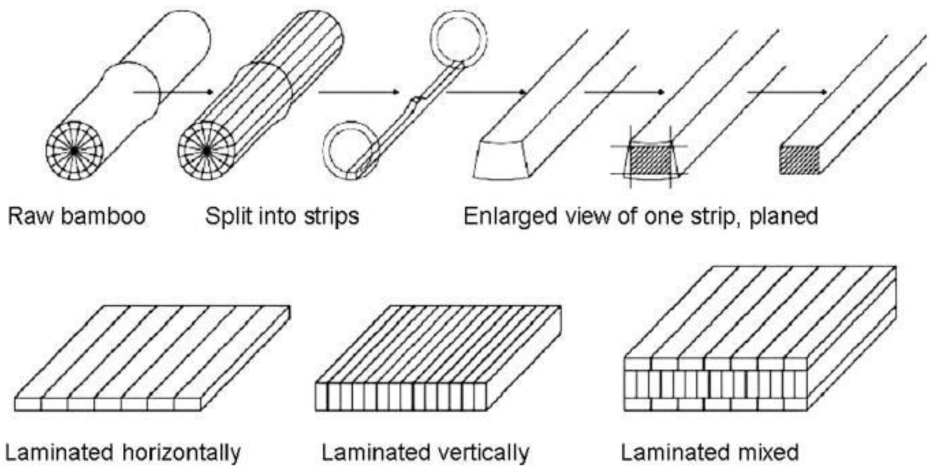


Fig. 1.
Processes for producing laminated products from raw bamboo.

For small-scale furniture production, manual processing of bamboo into strips can be time-consuming and difficult. Most of the craftsmen sustain injuries in the process. Also, most of the splinted culms tend to be imprecise and irregular in shape. Automated bamboo processing machines, including bamboo culm splitters have been developed and are now available in the international market. They are, however, not readily applicable in the small-scale furniture workshops in Nigeria. The typical manual bamboo splitter is simple in design but very labour intensive in operation.

One of the drawbacks of bamboo utilization, however, is that it has less natural durability than most wood species and is more prone to both soft rot and white rot because of its lack of toxic constituents. The presence of considerable quantities of starch in green or dry bamboo also makes it attractive to termites and borer beetles. The good news is that preservative treatment could greatly prolong the service life of bamboo culms and their corresponding structures by up to 15 years in exterior exposure and up to 25 years under cover. Common bamboo culm preservatives in use include oil-based, oil-soluble, water-soluble, and boron-based chemicals (Abd. Latif 1991, Janssen 2000). However, the relatively high silica content of the outer layer of bamboo, while providing good resistance to water and insects, sometimes prevents proper infiltration of preservative chemicals. In addition, the inner layer of bamboo is impermeable. Also, infiltration of preservative can only occur through the ends of the culm and the conducting vessels which tend to close within 24 hours of harvest, making it imperative that the treatment process must occur shortly after harvest and before seasoning (Janssen 2000). One of the more effective methods of bamboo protection against insect attack is adhesive polymer impregnation. Preechatiwong *et al.*, (2006) reported that adhesive polymer impregnation of bamboo strips enhanced their durability against fungi.

Thermocol (Fig. 2) is a synthetic, non-biodegradable and photo-resistant plastic produced from a complex material called polystyrene which transforms into liquid state on heating at more than 100^{o}C and returns to solid state on cooling. It is made up of small spherical shaped particles that contain around 98% air and 2%. It is used for food packaging, plates, glasses, et c and frequently discarded after usage, thereby contributing significantly to global plastic waste pollution (Vadiya *et al.* 2018). It dissolves in acetone, alcohol, and chloroform (Suhad et al. 2016). A liter of gasoline is enough to dissolve 50368.1cm^3 or 420g of thermocol sheets (Aggarwal *et al.* 2020). When dissolved in gasoline, it is commonly used as a cheap adhesive in households and cottage industries in Nigeria. Alaka (2022) also reported that dissolved thermocol used as coating inhibited algae growth in a clay-cement composite water tank. Hence, its use as a relatively cheap preservative coating for bamboo strips was explored in this study.

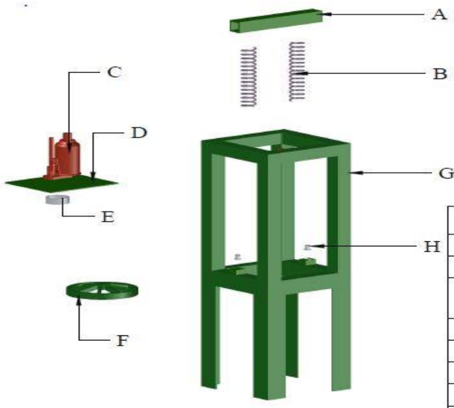
Fig. 2.
Stacks of disposed polystyrene (thermocol) waste.

The general objective of this study, therefore, was to develop and evaluate a culm splitter and bamboo strip coating material suitable for adoption in small-scale furniture workshops in Nigeria.

MATERIALS AND METHODS
Bamboo Culm Splitter Design Considerations

The following are the various factors considered in designing and fabricating the bamboo culm splitter:
- Simplicity of design and operation.
- Relatively low cost of production.
- Relatively low maintenance cost.
- Ease of construction.
- Ease of replacement of components, i.e., the splitter components should be easy to replace in case of failure.
- The splitter should be devoid of belt, pulley, shaft power and electric motor.
- The splitter should be able to split both wet and dry bamboo.

Component Parts of the Bamboo Culm Splitter
The bamboo splitter was designed to split 30cm long dry and wet bamboo culms into six strips. The component parts of the splitter include the main frame, the splitter die, cup to hold the bamboo on the splitter and hydraulic or screw jack (Figs 3 and 4). The steel skeletal frame of the splitter provides rigidity and also allows the opportunity to incorporate other parts to the splitter. The splitter die is the splitting unit of the splitter. It enables the bamboo to be split into six numbers of equal sizes. The cup is required to hold the bamboo culm in position perpendicular to the splitter. The steel cup was made from a hollow pipe and welded to the 6mm plate that houses the jack. Provision was made for two types of jacks, i.e., a hydraulic jack (Fig. 5) and a mechanical (scissors) screw jack (Fig. 6) in the culm design to act as culm drivers when operating the splitter. This was done to take care of different categories of end users. Hydraulic jack offers the advantages of minimal effort due to the principle of hydraulic pressure magnification and ease of use. Scissor jack, on the other hand, has the advantages of lightweight and low cost, though it could be slower to operate and may require more manual effort compared to hydraulic jacks.



Parts and Name	
A	Top Bar
B	Extensive Spring
C	10 tonnes Hydraulic Jack
D	Base Plate
E	Culm Holder
F	Splitter Dies
G	Splitter Frame
H	Bolt and Nuts

Fig. 3.
An exploded view of the culm splitter.

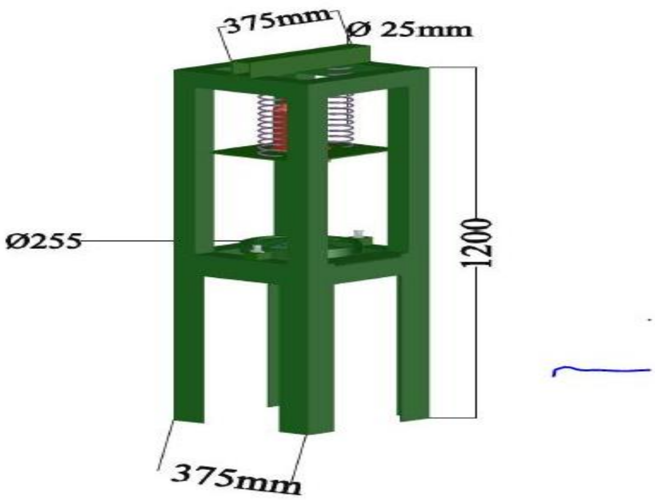


Fig. 4.
A solid view of the culm splitter.

Fig. 5.
Hydraulic jack.

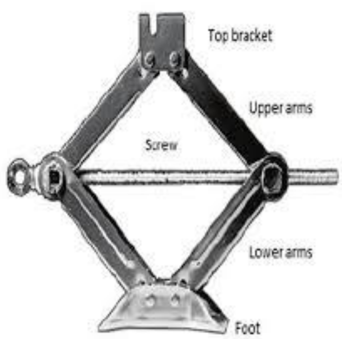


Fig. 6.
Scissors screw jack.

In order to determine the capacity of the jacks required, the forces required to split bamboo culms must be known. As a natural product, the shear strength of bamboo varies depending on the species, moisture content, test method, and location of the sample. Preliminary experiments conducted showed that the average shear force required to split dry *Bambusa vulgaris* was 2 KN. Hence, any hydraulic or screw jack with a rated capacity of at least 3 KN is recommended for operating the culm splitter. Figs 7 and 8 show on the splitter being operated with hydraulic and screw jacks respectively.

Performance Evaluation of the Bamboo Culm Splitter

The splitter was tested with mature, wet (45%-52% moisture content) and dry (12-15% moisture content) culms of *Bambusa vulgaris* harvested from a natural plantation in the Faculty of Technology, University of Ibadan, Nigeria. The culms were cross-cut into 30cm billets, with an average of 25 billets per culm. The billets were fixed to the culm holder and held perpendicular to the splitter die, while the jack was placed on the 5mm steel plate suspended by four helical springs. The jack was operated to push the culm through the splitter die to produce bamboo strips shown in Fig. 9. Only one billet could be split at a time and each billet was split into six strips by the splitter. The splitting durations (measured with a stop watch) of ten samples each of wet and dry of bamboo culms of varied thicknesses, with and without nodes, were determined.

Fig. 7.
Splitter being operated with hydrauic jack.

Fig. 8.
Splitter being operated with a screw jack.

Fig. 9.
Raw bamboo strips.

The bamboo strips were stacked on a flat surface and air-dried for six weeks under a shed to prevent rapid shrinkage. They were then planned on both sides using a portable planer so as to remove the waxy layer and also achieve a flat strip. The thickness measured with a Venier caliper before planing ranged from 6mm to 12mm while the thickness measured after planing ranged from 4mm to 8mm.

Bamboo Strip Coating and Evaluation

About 50g of the polystyrene was dissolved in 200g of gasoline. The mixture was stirred continuously until the completely dissolved polystyrene turned sticky (Fig. 10). The mixture was then left for a period of 20 hours to cure. The planed clean (un-infested) bamboo strips were, thereafter, coated with a thin film of the mixture to investigate its efficacy as preservative protection against attacks by termites and other insect. The coating was manually applied on both sides and edges of the bamboo strips using a hand brush (Figs 11-13). The coated strips were air-dried for four days as shown in Fig. 14. To investigate the effects of coating on insect activities, coated samples of clean strips and strips pre-infested by powder post beetle were examined from periodically for four years.

Fig. 10.
Dissolved Polystyrene.

Fig. 11.
Un-coated strips.

Fig. 12.
Coating the strips.

Fig. 13.
The coated strips.

Fig. 14.
Air-drying the coated bamboo strips.

Both coated and uncoated bamboo strip samples were tested for moisture absorption and thickness swelling. Five samples each of 300mm long coated and uncoated were weighed on the mini-electronic weighing balance. For the water absorption measurement, the samples were soaked in water for 24 hours after which their weights were measured. For thickness swelling determination, the thicknesses at three different points of each strip (top, middle and bottom) were taken with a Venier caliper before and after soaking in water for 24 hours.

Water Absorption (WA) was calculated using equation 1:

$$WA = \frac{Wf - Wi}{Wi} x\ 100 \qquad [1]$$

where: W_i = initial weight before soaking.
W_f = final weight after 24hours.

Thickness Swelling (TS) was computed using equation 2:

$$TS = \frac{Tf - Ti}{Ti} x\ 100 \qquad [2]$$

where: T_i = value of the thickness swelling before soaking.
T_f = value of the thickness swelling after 24hours of soaking.

Bamboo Strip Lamination

A synthetic adhesive was manually applied to the edges of uncoated bamboo strips for lamination. The strips were then arranged edgewise using a jig frame. A dead weight of 500N was placed on the glued strips to prevent warping. The clamped strips were left in position for three days after which the dead load was removed and flat laminated bamboo (Fig. 15) was obtained.

Fig. 15.
The laminated bamboo strips.

Bookshelf Design

An 800mmx1000mmx300mm bookshelf (Fig. 16) was designed based on standard engineering design principles. The hybrid bookshelf comprised a set of six *Gmelina arborea* lumber pieces acting as the beams (length = 300mm; width = 25mm; thickness 5mm), another set of four *Gmelina arborea* lumber pieces acting as beam-columns (length = 800mm; width = 45mm; thickness = 20mm), and laminated bamboo strips acting as the slabs as well as the side covering. Only non-infested laminated bamboo strips were laminated. The choice of *Gmelina arborea* was based on availability, strength, ease of nailing, and cost. Each layer of the laminated bamboo slab was joined to the *Gmelina arborea* lumber frame using end-to-end butt joint technique. The connection was reinforced with nails after glue application. The nails were selected based on their holding power and penetrative ability. The stability of the bookshelf was further improved by bracing with wedge-like corner pieces. The estimated load carrying capacity of the bookshelf is 0.4kN.

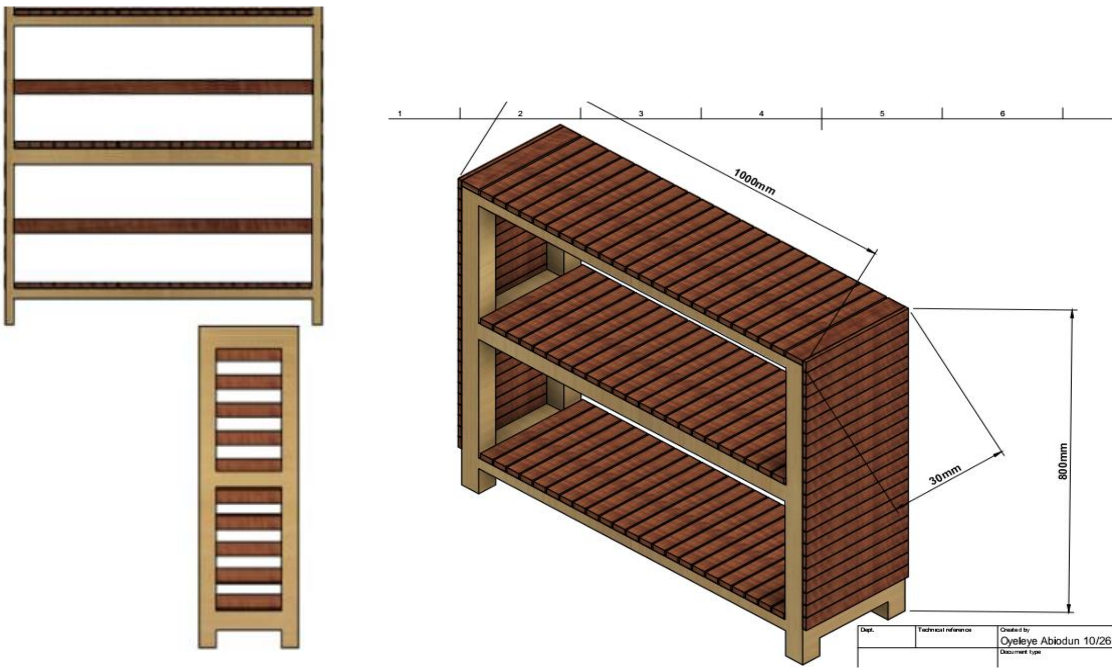


Fig. 16.
Different views of the designed bookshelf.

RESULTS AND DISCUSSION

Strip Recovery

The splitter was successfully used to convert bamboo billets into strips. A total of one hundred and fifty (150) strips were obtained per culm. As shown in Table 1, the strip recovery efficiency was 100%, which is 18% higher than the recovery efficiency of 82% reported by Olorunnisola and Omotayo (2020) for manual conversion of *Bambusa vulgaris* into strips. There was no record of splitting losses or injuries that are commonly associated with the manual splitting process.

Table 1

Strip Recovery Efficiency

Parameters	Values
No of culms	4
No of expected strips	600
No of recovered strips	600
Percentage recovered	100%
Percentage loss	0%

Effects of Culm Geometry, Node Presence and Moisture Content on Splitting

As shown in Table 2, the girths of the wet culms in the 30cm long billet form were larger, the mean being about 203mm compared to the mean value of 192.5 recorded for the dry culms. Also, the walls of both wet and dry culms with nodes were generally thicker than those without nodes. Nevertheless, the mean width of the bamboo strips produced by the splitter only differed by about 2mm, the values ranging between 32 and 34mm. The splitting time of the wet culms with nodes ranged between 85 seconds and 117 seconds, the average being 99 seconds, while the splitting time of the wet culms without nodes ranged between 45 seconds to 65 seconds the average being 55 seconds. The dry culms took a longer time to split, the range of values being 180 - 356 seconds for culms with nodes, and 65 to 120 seconds for culms without nodes. Generally, wet culms with nodes took about twice the splitting time required for samples without nodes, while dry culms with nodes took about thrice the time required for dry culms without nodes. There was an inverse relationship between wet culm thickness and duration of splitting- the thicker the culm, the longer the splitting time. Reverse was the case with the dry culms- thicker dry culms split faster than the thinner culms.

Dry culms without nodes split faster than the wet culms of about the same thickness that had nodes. This shows the critical effects of node presence on culm splitting. The average splitting duration of dry culms without nodes was 82 seconds while that of the wet culms with nodes was about 99 seconds. The splitting time of dry culms with nodes was longer than that of the wet culms with nodes of the same wall thickness. This, expectedly, shows that moisture content has an effect on culm splitting. The ease of splitting is a direct result of the linear arrangement of the fibres, and the resistance to splitting at the nodes is a result of the crossing over of these fibres across the diaphragm. Also, the position of the nodes on the culm hindered the rate of splitting. The culms were much more difficult to split when the nodes were at the centre than when they were located at the peripheral of the culms.

Table 2

Effect of Culm Geometry and Moisture Content on splitting Time

Culm Condition	Presence of Nodes	Culm Girth (mm)	Culm Thickness (mm)	Width of Strip Produced (mm)	Splitting Time (sec)
Wet	Yes	Range: 175-219 Mean: 202 SD: 13.5	Range:7.3 – 12.5 Mean: 9.3 SD: 1.5	Range:29-37 Mean: 34.0 SD: 2.3	Range: 85 – 117 Mean: 99 SD: 10
Wet	No	Range:188-219 Mean: 203 SD:13.0	Range:7.3 – 10.4 Mean: 8.8 SD: 1.2	Range:29 – 37 Mean: 34.0 SD: 2.9	Range:45 – 65 Mean: 55 SD: 8
Dry	Yes	Range: 194- 213 Mean: 192.5 SD:12.4	Range: 6.3 – 13.8 Mean: 10.0 SD:2.4	Range: 32 - 37 Mean: 34.0 SD: 1.4	Range:180 – 356 Mean: 266 SD: 58
Dry	No	Range:175 - 206 Mean: 192.5 SD: 12.4	Range:6.3 – 12.5 Mean:8.5 SD:2.2	Range: 29 - 34 Mean: 32.0 SD: 2.1	Range:65 – 120 Mean: 82 SD: 16

Effects of Coating on the Appearance of the Bamboo Strips

Coating of the bamboo strips with the dissolved polystyrene-gasoline mixture impacted glossiness into the bamboo strips, making them more attractive. There was no objectionable smell in the coated strips since thermocol is known to be tasteless and odorless (Subhan 2016). What this suggests is that the coating could be used as a glossy finishing material in bamboo furniture production.

Effects of Coating on Water Absorption and Thickness Swelling of the Bamboo Strips

The water absorption (WA) observed in the uncoated strips ranged from 21.1 to 33.3% with a mean of 26.0%, while that of the coated samples ranged from 20.0 to 25.9% with a mean of 22.6%. The relatively higher mean WA of the uncoated samples suggests that the coating reduced the water absorption capacity of the bamboo strips. The Thickness Swelling (TS) of the uncoated samples ranged from 7.0 to 12.6% with a mean of 9.0%. However, the TS of the coated samples was zero, indicating that the coating effectively eliminated thickness swelling in the bamboo strips. These findings are in consonance with the practical knowledge that a plastic coating primarily acts as a protective barrier for a fibrous material, significantly increasing its resistance to moisture, warping, rot, and scratches by encapsulating the fibers and creating a hydrophobic layer, essentially making the material more durable and dimensionally stable.

Efficacy of the Thermocol Coating in Inhibiting Insect Infestation

There were no traces of insect or fungal infestations on the coated bamboo strips four years after coating. This suggests that the gasoline-dissolved polystyrene mixture has some preservative potentials. Subhan (2016) had noted that thermocol has some fungi-resistant properties. However, the powder post beetle-infested bamboo strips that were coated after infestation showed evidence of continued insect activity despite the coating (Fig. 19). Since a combination of thermocol and gasoline produces a chemical glue and thermocol is not inherently toxic, what this finding suggests is that the coating acts more like a thin film physical barrier against insect infestation than a toxic insecticide. It, therefore, cannot stop the progression of pre-existing infestation. Hence, coating of only un-infested bamboo strips is recommended.

Fig. 19.
Insect activity in coated bamboo strips pre-infested by powder post beetle.

Unique Features of the Composite Bookshelf

Figs 17 and 18 show the bookshelf before and after the bamboo laminations were coated. The natural colour of the uncoated bamboo laminates was yellowish. The coating, however, impacted a brownish colouration and glossiness on the laminates. The brown colouration resulted from the brownish nature of the dissolved thermocol mixture, while the glossy appearance is attributable to the plastic nature of the coating material. It is expected that the coating would result in improved durability of the bamboo since it is a well-known fact that plastic coating enhances the resistance wood and other biomaterials to water intrusion, weathering, scratching, and abrasion. The current bookshelf design incorporating the use of lumber and laminated bamboo strips differs from the composite bamboo bookshelf reported by Olorunnisola and Omotayo (2020) produced from a hybrid of un-laminated boric acid/borax -treated bamboo strips, lumber and plywood. Lamination of the bamboo strips in this design should enhance the strength of the bookshelf. Also, the exclusion of boric acid/borax solution and plywood would likely reduce the overall cost of production.

Fig. 17.
Bookshelf with un-coated laminations.

Fig. 18.
Bookshelf with coated laminations.

CONCLUSIONS

Bamboo is abundantly available in Nigeria and can serve as a complimentary, if not a complete replacement material, for lumber in bookshelf production. A jack-operated culm splitter has been developed bamboo processing in small-scale furniture workshops in Nigeria. The culm splitter that has been developed can be used to produce 30cm long bamboo strips with no splitting loss or injury to the operator. The possibility of modifying the splitter to allow production of longer strips is currently being explored. Findings showed that thermocol, an expanded polystyrene sheet dissolve in gasoline, could be used as an aesthetically appealing coating for bamboo strips to prevent thickness swelling and insect infestation, and that the laminated strips could be used for bookshelf fabrication. It is recommended, however, that the coating should be done as quickly as possible after lamination since thermocol appears to be ineffective in protecting bamboo strips already exposed to insect infestation.

REFERENCES

Abd.Latif M, Khoo KC, Nor Azah MA (1991) Carbohydrates in Some Natural Stand Bamboos. Journal Tropical Forest Science 4(4):310-316.

Adewole NA, Olayiwola HA (2011) Production of Bamboo-Lam from Flat Bamboo Strip Prepared from *Bambusa vulgaris* (Schrad) In: Proceedings of the 10th Nigerian Materials Congresses. Akure, Nigeria: Materials Science & Technology Society of Nigeria; 21-24 November 2011. pp. 346-350.

Adewole NA, Bello KO (2013) Recycling of bamboo (Bambusa vulgaris Schrad) Recovered from Scaffold into Material for Furniture Production. Innovative Systems Design and Engineering, 4(9):73-79.

Adewole NA, Etta PN, Ibor BB (2017) Characteristics of Selected Properties of Parquet Laminate produced from *Bambusa vulgaris* (Schrad) Harvested from Akamkpa Local Government Area, Calabar, Nigeria. International Journal of Emerging Trends in Engineering and Development, 3(7):183-192.

Aggarwal T, Aggarwal S, Gupta A (2020) Adhesive from Waste Petrol and Waste Thermocol. International Journal of Trend in Scientific Research and Development. 4(4):1022-1024.

Alaka AC (2022) Development of a Composite Tank for Household Water Storage. PhD Thesis, Faculty of Technology, University of Ibadan, Nigeria. 248 pp.

Arowosoge OGE, Ogunsanwo OY, Popoola L (2009) Prioritization of Wood Species Utilized for Furniture Making in Selected Cities in Nigeria. Journal of Research in Forestry, Wildlife and Environment, 1(1):7-17.

Atanda J (2015) Environmental Impacts of Bamboo as a Substitute Constructional Material in Nigeria. Case Studies in Construction Materials, 3:33-39. DOI: 10.1016/j.cscm.2015.06.002 2214-5095/$.

Janssen JJA (2000) Designing and Building with Bamboo: INBAR Technical Report 20. International Network for Bamboo and Rattan, Beijing, China, 211 pp.

Liese W (1986) Characterisation and Utilisation of Bamboo. In: Proceedings of Project Group, P.5-04. Ljubljana, Yugoslavia: IUFRO World Congress; pp. 11-16

Liese W (1987) Research on Bamboo. Wood Science and Technology: 21:189-209.

Lucas EB, Olorunnisola AO (2002) Wood Processing and Utilization in Nigeria: The Present Situation and Future Prospects in: Ajav, E.A., Raji, A.O., and Ewemoje, T.A. (eds.) Agricultural Engineering in Nigeria: 30 Years of University of Ibadan Experience, Published by the Department of Agricultural Engineering, University of Ibadan, Nigeria, pp. 98-109.

Ogunsanwo OY, Terziev N, Panov D, Daniel G (2015) Bamboo (*Bambusa vulgaris* Schrad.) from moist forest and derived savanna locations in south West Nigeria – Properties and gluability. BioResources, 10(2):2823-2835. DOI: 10.15376/biores.10.2.2823-2835.

Ogunwusi AA (2014) Unlocking the Potential of Bamboo in Nigeria. Venus Multimedia Development Services Ltd. Abuja, Nigeria, pp. 203.

Olorunnisola AO (2000) Workshop Structure in the Small-Scale Furniture Industry in Ibadan Metropolis. Journal of Tropical Forest Resources 16(1):46-57.

Olorunnisola AO (2005) An Investigation on the Small-Scale Wooden Furniture Production Practices in Osogbo, Osun State. Journal of Forestry Research and Management 2:42-51.

Olorunnisola AO (2006) The Potentials of Bamboo as a Novel Building and Furniture Production Material in Nigeria. In: Proceedings of the 5th Nigerian Materials Congress. Abuja: Nigeria Materials Science & Technology Society of Nigeria, 15-18, November 2006. pp. 180-185.

Olorunnisola AO, Adewole NA (2016) Small-Scale Wooden and Rattan Furniture Production in Nigeria, *in Olorunnisola, A.O. (ed.),* Renewable Natural Resources Engineering: Essays in Honour of Canon Prof. E. Babajide Lucas. Published by Zenith BookHouse Publishers, Ibadan pp. 123-138.

Olorunnisola AO, Omotayo R (2020) Development of a Composite Bookshelf with Bamboo (*Bambusa vulgaris*) Strips, Lumber and Plywood. Pro Ligno, International Journal of Wood Engineering 16(1):11-16.

Olorunnisola AO (2023) The Past, Present and Future Outlook of the Wood Industry in Nigeria in *Guanben Du (ed.)* Wood Industry - Past, Present and Future Outlook Published online and in hard copy by INTECHOPEN. DOI: 10.5772/intechopen.109199.

Olorunnisola AO (2024) Recent Advances in Bamboo Research, Product Development and Utilisation in Nigeria. in *Mustapha Asniza (ed.)* Bamboo - Recent Development and Application Published online and in hard copy by INTECHOPEN. DOI: 10.5772/intechopen.105794.

Preechatiwong W, Malaniti P, Kyokongi B, Kamlangdee N (2006) Effect of Polymer Impregnation on Properties of Bamboo. Walailak J Sci & Tech; 3(1):79-91.

Subhan M (2016) Experimental Study of Light Weight Aggregate Concrete. International Journal of Scientific Engineering and Technology Research, (5)7:1347-1351.

Suhad M, Abd DM, Dunya K (2016) Effective Replacement of Fine Aggregates by Expanded Polystyrene Beads in Concrete. International Journal of Engineering Research and Science and Technology. 5(3).