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PRODUCTION OF VALUE-ADDED DECORATIVE FURNITURE ITEMS FROM RECOVERABLE WOOD WASTES FROM CONSTRUCTION SITE

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ABSTRACT

The cost of wood and non-wood lignocellulosic materials continues to escalate yet the demand keeps rising at the face of the climate change problem aggravated by unsustainable tree removal across the world. Lignocellulose waste is unavoidably generated during construction. The viability of producing decorative furniture items from recoverable wood wastes from a construction site was investigated. Ten construction sites were randomly chosen, for on-the-spot assessment to obtain information on characteristics of bio-wastes originating from construction sites. A 6-flat-storey building was selected for an in-depth study. Data were collected on the composition of bio-wastes, Retrievable volume, and exposure and deterioration status. Redundant fragments of wood wastes were retrieved and processed into glue-laminated panels, constituting intermediate raw material that was used for manufacturing three decorative furniture items. Although a wide range of bio-wastes was generated at the construction sites, wood, bamboo, and medium density fibreboard, wastes were generated more substantially and in decline order, respectively. Most of the bio-wastes had largely deteriorated, but about 60 % of the wood wastes can still be recovered for re-use. Re-using recovered wood for decorative furniture items may save as much as 73 % of the actual cost of wood needed for production, with a negligible increase in labour cost. Glued-laminated panels were used to manufacture shelves installed for office use. The study suggested that more values may be obtained from bio-waste reuse if retrieved without delay.

Keywords: Bio-waste, construction site, decorative furniture, laminated panel, lignocellulosic residues, recoverable wood waste, waste valorisation.

INTRODUCTION

Waste generation is an inherent characteristic of production and human activities. The exponential growth of the global population has undoubtedly influenced the substantial volume of waste generated on a global scale (Mehta and Monteiro 2006, Akinkurolere *et al*. 2013, Alam and Ahmade 2013). Within this context, construction activities significantly contribute to the immense waste generated worldwide (Lennon 2005). This assertion finds support in Economic and Social Commission for Asia and the Pacific's (ESCAP 2005) observation that waste is an inevitable by-product of almost all human involvement. While waste is commonly regarded as unwanted or non-useful, a technical perspective unveils the potential for added value by utilizing and repurposing almost all types of waste, as aptly noted by Agarwal *et al.* (2015).

In the area of construction, solid waste holds a dominant position, and it has been identified by Agarwal

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et al. (2015) as having significant potential for reuse. Solid waste, categorized as organic or inorganic, is often deemed of no value by its generators, yet it possesses intrinsic value for end users (Robinson 1986). Specifically, recoverable wood waste (RWW) falls under the category of solid waste and is abundantly generated during construction activities. Recent studies have proposed innovative applications for reusing RWW, such as in pulp and paper manufacturing, charcoal production, and biofuels, among other possibilities (Ben-Iwo *et al.* 2016, Sun and Cheng 2002, Popoola *et al.* 2019).

Construction sites, particularly in developing countries such as Nigeria and more specifically at academic environments, witness a substantial generation of RWW. For instance, Adewole *et al*. (2018) estimated the volume of lignocellulosic waste generated at 10 construction sites in the University of Ibadan (UI) to be 192,5m^2. However, despite this significant volume, the potential for creating value-added products such as decorative furniture through the reutilization of RWW remains largely unexplored until recently (Grotowska and Beer 2023. van Hees *et al.* 2024). Instead, the University bears a considerable financial burden in waste disposal, disregarding the opportunities to extract valuable materials that could be developed into intermediate raw materials for producing various innovative items (Wahab and Lawal 2011, Aderibigbe *et al*. 2017).

Therefore, this study aims to address this prevailing issue by proposing an appropriate avenue for the re-use of RWW. This will optimise space utilisation, mitigating fire risks, and preventing waste from breeding grounds for hazardous vectors and other unfavourable consequences (Eze *et al.* 2017). In doing so, this research endeavours to develop intermediate raw materials from RWW samples generated at selected construction sites in UI, which were then utilized in the production of highly demanded and innovative decorative furniture items. By embarking on this journey, we strive to unlock the potential of RWW, transforming it from a burden into a resource, while simultaneously promoting sustainable practices and engineering solutions within the construction industry.

MATERIALS AND METHODS

This study selected ten construction sites at random from the main campus of the UI for an on-the-spot assessment of the characteristics of bio-wastes. A careful examination of types, volumes, and duration of exposure to bio-wastes was considered. The level of deterioration, quantity, and dimensions of reusable bio-wastes in relation to the target reuse were also investigated. The site shown in Figure 1 was picked with a bias for the guidance by the UI Maintenance Department and information retrieved from Adewole *et al*. (2018) for the experimental study.

Figure 1: Site chosen in university of Ibadan main campus for the experimental study.

Information relating to wood and other lignocellulosic materials brought to the site was retrieved from site record books. Data on wood species, utilization purpose(s), processing activities, types, and volume of associated wastes, among others, were also retrieved. Waste wood volume was estimated in accordance with Wright *et al*. (2010) (Equation 1, Figure 2). The RWWs were collected and transported from the site to the Wood Utilisation Workshop of the University for further Studies. The RWWs were stacked for drying before estimating the recovered volume (Equation 2). Samples were taken to the wood utilization lab for authentication after sorting and physical categorisation (Figure 3). The moisture content (MC) and density of the five predominant species were determined in accordance with BS 373 (1957) Equation 3.

$$V = \frac{\left(\pi\, x\, H\, x W\, x\, L\right)}{6} \qquad (1)$$

$$\text{Vol.s.wood}\left(\text{m}^3\right) = \text{ Length x width x thickness} \qquad (2)$$

$$MC(\%) = \left(\frac{m_1 - m_2}{m_2}\right) x100 \qquad (3)$$

Where: MC = moisture content, M_1 = Initial mass of timber before oven drying, and m_2 = final mass of timber after oven dried.

Figure 2: Cross section of LBW (a), sotted out for re-use at construction site (b).

Figure 3: (a) Stacking, (b) planing and (c) identification process at the university utilisation lab.

After stacking the RWW for 4 weeks to allow for synchronisation with the environment, the samples where sorted and examined for extraneous materials such as nails used in the construction site. The wood samples where then planned to enable gluing adopting the same method used by both Adewole and Olayiwola (2011) and, Adewole and Bello (2013), the glued samples where reprocessed to achieve uniformity in size. A summarised flow chart for the development of the laminated panel is presented in Figure 4, basic carpentry facilities were utilized to produce glue laminated panels as intermediate raw material from RWWs with urea-formaldehyde resin adhesive (Figure5).

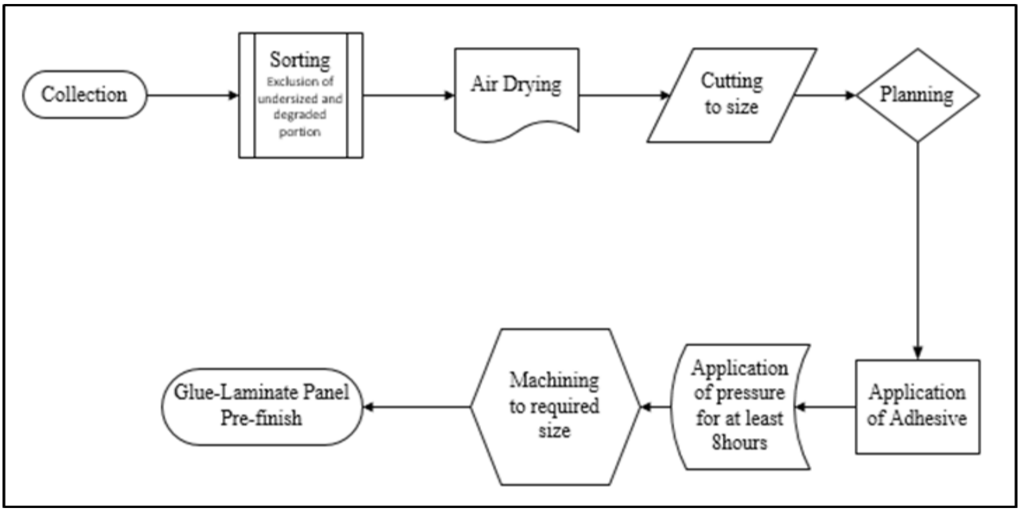

Figure 4: Illustration of procedure for generating laminated panel from wood wastes.

Figure 5: Glulam panel-making processes (a). Gluing, (b). planning (c) Trimming (d) Spraying at the university carpentry workshop.

Three pieces of decorative furniture items were architecturally designed using AutoCAD inventor: a standing magazine shelf, arc pigeon-hole shelf and cantilever.

The cutting list of the furniture components of the fabricated pieces of decorative furniture was prepared with the cost of materials used for fabrication. They were fabricated using the glulam panel produced from recovered wood wastes and installed in an office at the University (UI).

RESULTS AND DISCUSSION

Characteristics of bio-wastes generated in UI construction sites

The results of our investigation coincided with previous findings in several key ways. Like Adewole *et al*. (2018) and other studies (Forest Products Laboratory 2021; Eze *et al.* 2017), we observed that bio-waste is produced in large volumes and is rarely repurposed into value-added products. In our study, bio-waste was typically left on-site for an average of 18 months before being disposed of primarily through burning or evacuation for fuel, a practice that mirrors the waste handling behaviours documented in earlier research.

This consistency suggests that the challenges associated with bio-waste management in construction settings are systemic rather than isolated incidents. The significant bio-deterioration observed—ranging from discoloration to insect infestation, cracking, and splitting—indicates that prolonged on-site storage adversely affects the quality of the waste, potentially limiting its reuse potential. In contrast to other contexts where bio-waste is immediately processed (e.g., for composting or energy recovery), the delayed disposal practices observed in our study is unique to the regions and construction practices examined. This discrepancy highlights the need for improved waste management strategies that prioritize timely processing and recycling of bio-waste to mitigate environmental impacts and enhance material recovery.

A closer examination of the pile-up of bio-wastes revealed that it comprised mostly of offcuts, mis-manufacture with 25 mm x 300 mm boards of different lengths, varying lengths of 50 mm x 75 mm wood pieces, bamboo of varying lengths and sizes.

Some of these were originally utilized for temporary facilities of short duration/activities like fences, formwork, and shades, among others. Because most of the bamboo wastes have been abandoned for too long, they were highly infested by insects and fungi, and could not be recovered for any valuable use besides fuel. This attested to the perishability of bamboo because of its possession of high carbohydrates that attract vectors. Though engineered boards were not significantly infested, nail damages and splits were re-use limitations of the boards. Wood residues were of better appearance and quality than both the bamboo and engineered boards. They had fewer splits and nail damage and were better looking in appearance and, with rules of thumb, better strength-wise. The wood residues' form, shape, and state fit target re-use.

Characteristics of bio-wastes retrievable from experimental construction site

A 6-flat multistorey building cited in Elliot was constructed between May 2017 and June 2018. Site records revealed that bio-materials brought to the site included: MDF boards, Wood, and Bamboo. They were bought for pegging, boarding, formwork, bracing, frame, and roofing. The wood materials brought to the site were of different species of hardwoods. Table 1 presents a record of the bio-materials collected at the site. The dimensions of wood supplied to the site vary in size, as shown in the Table. The total cost of bio-materials bought to the site was estimated at ($7463,94). Wood is frequently subjected to re-conversion to desired dimensions on site.

Table 1: Range of lignocellulosic materials brought to site.

Lignocellulosic Materials	Dimensions (mm)	Quantity (pieces)	Unit Cost USD ($)	Total Cost USD ($)
MDF boards	1220x2240x6	25	26,26	635,96
Bamboo	Not Applicable	420	0,68	287,21
Wood	25x300x3650	850	3,28	2790
Wood	75x100x3650	75	2,05	153,86
Wood	50x150x3650	150	2,19	1750,59
Wood	50x100x3650	400	1,23	492,35
Wood	50x75x3650	1100	0,96	1053,09
Wood	50x50x3650	440	0,68	300,88
Total cost of lignocellulosic materials				7463,94

Retrieval, sorting, cost analysis and preparation of wood wastes for re-use

Majority of the lignocellulosic-based wastes had been on site for about four months and had suffered considerable deterioration. Planks of dimension 50 x 75 mm appear fit for re-use. In a day, the appreciable quantity of wood waste estimated to be enough for the target re-use was retrieved. The greatest loss of material was bamboo, followed by engineered boards. The retrieved wood wastes were sorted for re-use.

The volume of the retrieved wood waste, before processing, was estimated at 697 x 10^8 mm^3. If the same volume of wood were to be procured from the market during the same period, it would be worth $83,43 as of August 2018. Comparing the cost of retrieving from the site, the activities involved in recovering to the processing location cost less than $ 21,88. This implied that the study had saved about 73 %. A total of six species were readily identified after planning: Ire (*Funtumia africana* (Benth.) Stapf), mahogany (*Khaya grandifoliola* C.DC.), ita (*Celtis mildbraedii* Engl.), obobo (*Ficus mucuso* Welw. ex Ficalho), iroko (*Milicia excelsa* (Welw.) C.C. Berg), and ayunre (*Albizia lebbeck* (L.) Benth.). The percentage of the wood species by volume that was retrieved for re-use is presented in Figure 6.

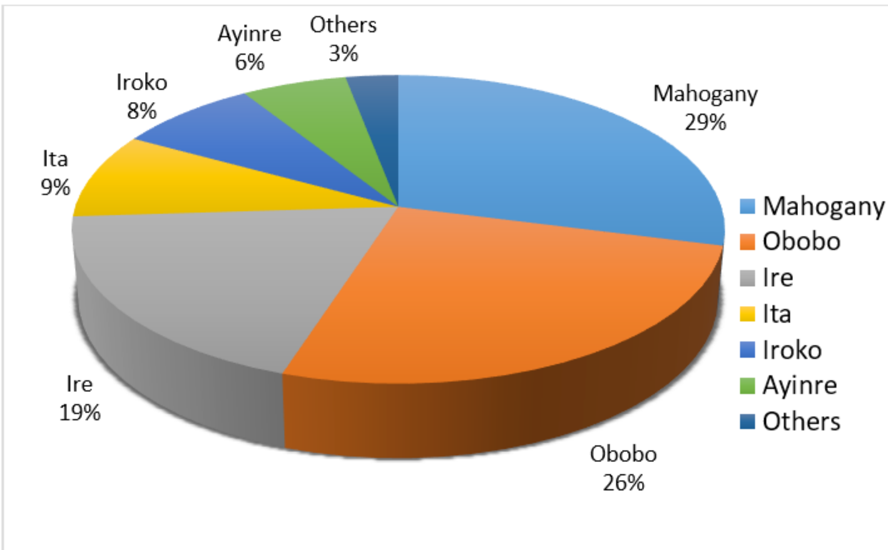

Figure 6: Percentage volume of recovered wood by species

It was observed that the wood wastes were stained. The stain affected the appearance of the wood without a significant effect on its mechanical properties (Adewole and Icha 2021). Although the stain on a considerable proportion of the wood was removed with planning. The remaining proportion that the stain could not be removed with plaining was not discarded but arranged purposely during glulam production to enhance its decorative appearance, as shown in Figure 7.

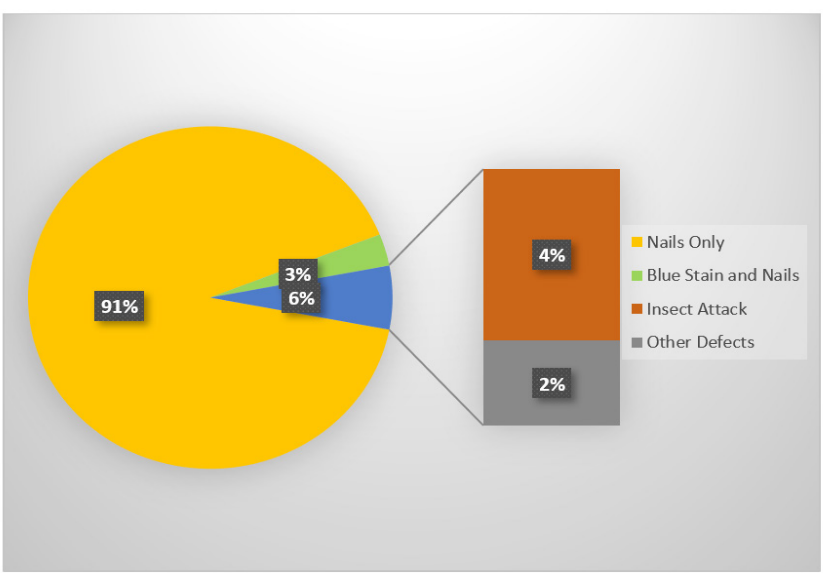

Figure 7: (a) Wood samples with stain before and (b) after lamination process.

Another critical defect was splitting; split on the recovered wood was mostly caused by nailing processes and improper handling of the wood at the construction sites. However, with careful selection, defected wood wastes can be avoided. After planning, infested wood had to be set aside. Summarily, about 6 % of the total wood volume recovered was considered unfit for use due to defects, 3 % had fungi stain, and 91 % was free of other defects apart from nails (Figure 8). All wood samples with nail defects were treated as clear wood samples and considered of no defect, except in cases where the defects could not be ignored.

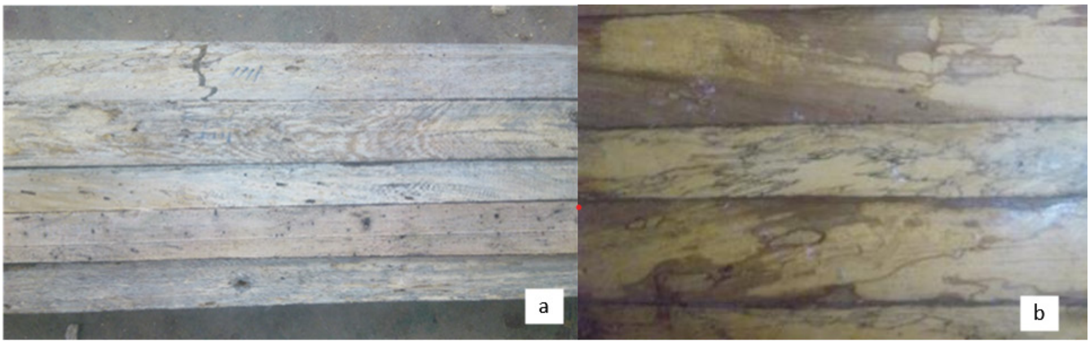

Figure 8: Percentage representation of defects in the recovered wood.

Manufacturing and installation of the decorative furniture items

The three decorative furniture items manufactured using the intermediate raw material: laminate panels produced from the recovered wood were standing magazine shelves, cantilever magazine shelves and arch pigeonhole shelves. The cutting list as well as the material costing is presented in Table 2. During the fabrication process, it was observed that the processed wood was slightly more brittle than normal and this made the processing with hand tools more difficult.

Table 2: Cutting list for standing shelf with costing for three furniture items.

Description	Dimension (mm)	Quantity	Material	Cost USD ($)
Stand/Legs	20 x 40 x 150	4	Glossy lacquer	4,92
Panel sits	20 x 230 x 300	6	Sanding sealer	4,92
Up and down bracer	20 x 40 x 230	2	Thinner	6,84
T bracer	10 x 10 x 230	1	Sanding dick	7,11
Cutting list for cantilever shelf			Sand paper	1,09
Suspender stand	20 x 230 x 800	1	Nails and screws	2,74
Cantilever base	20 x 230 x 900	4	Top bond	19,15
Cutting list for arc shelf				
Inner hold	20 x 70 x 200	14	Recovered wood	=
Panel sits	20 x 120 x 200	15	Recovered wood	=
Up and down bracer	20 x 250 x 200	15	Total	46,77

The furniture readily absorbed the finish and dried rapidly. The cantilever and standing shelves were both installed as functioning decorative furniture in the office of the Head of the Department of Wood Products Engineering, Faculty of Technology, University of Ibadan (Figure 9a and Figure 9b) while the Arc pigeon-hole shelf was installed in the Secretary's office (Figure 9c). The furniture had been in service for about 5 years without any sign of failure as depicted in Figure 9d, Figure 9e and Figure 9f. The durability of furniture products bult from waste wood in comparisons with other studies is a research area for further studies.

Figure 9: Manufactured decorative shelves designed (a), (b), (c) and installed (d), (e,), (f) at the departmental office of the university.

CONCLUSIONS

This study confirmed the generation of bio-wastes in appreciable and re-usable quantities at construction sites of developing countries, particularly in their universities.

Bio-wastes include pieces of fibreboard, plywood, bamboo and wood in order of increasing quantity respectively.

Leaving bio-wastes for up to four months and more on-site automatically reduces their re-use potential for decorative furniture items. However, after 4 months of bio-waste retention on site, about 60 % of the wood waste components are recoverable and suitable for decorative furniture items production.

Stain, brittleness and split caused by nailing were constraints to the re-use of the recovered wood waste. These limitations were, however, minimized during the glue-laminated panel production.

73 % of the total wood materials cost was saved using recoverable wood waste to produce decorative furniture pieces, with negligible increase in labour cost.

Our study suggest that more values may be obtained from bio-waste reuse if it is retrieved for reuse without delay.

Authorship contributions

N. A.: Conceptualization, Supervision, project administration, writing - review and editing

A. I.: Conceptualization, investigation, formal analysis, methodology, validation, writing - original drafting, and resources.

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