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Effects of sawdust and adhesive type on the properties of rice husk particleboards

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ABSTRACT

This study set out to investigate the effects of adhesive type, rice husk and sawdust proportions on the properties of composite particleboards. Specimens of 200 × 200 × 24 mm were made by blending 500 g of rice husks with each adhesive type at a mass ratio of 1:1. The rest of the specimens of similar dimensions were prepared with addition of sawdust in the range of 10–40 wt%, while maintaining the ratio of biomass particles to adhesive at 1:1. Three commercial synthetic adhesives Fevicol (FV), Ponal (PA) and woodfix (WF) were used. The particle-adhesive mixtures were molded into a mat which was subsequently cold pressed at 10 MPa and left to dry in air. Density, water absorption (WA), linear expansion (LE), thickness swelling (TS), modulus of elasticity (MOE), modulus of rupture (MOR) and screw holding capacity of the specimens were evaluated. Adhesives were found to have over 42% solid content, with similar liquid constituents but in varying proportions. FTIR library search for the spectra of FV, PA and WF revealed correlations of 82.5%, 78.6% and 50.2%, respectively with polyvinyl-acetate. The developed boards had density 510–610 kg/m^3, MOE 13–26 MPa, TS 9–31%, LE 3–7%. These properties suit them for furniture boards and sound proofing. The properties improved with increasing proportion of sawdust. FV and PA-bonded particleboards exhibited higher stability and strengths than WF-bonded particleboards due to higher concentrations of polyvinyl-acetate in the latter. Blending 40 wt% sawdust, 10 wt% rice husk with 50 wt% of either FV or PA showed better prospects.

1. Introduction

Globally, about 57% of wood-based panels used are in the form of particleboards [1]. This share by particleboards increases at 2–5% annually, due to their growing demand in housing construction, furniture manufacturing and interior decoration among others [2]. As the demand for wood-based particleboards increases, there are concerns regarding sustained supply of wood raw materials [3]. These concerns have prompted research interests to find alternative raw materials, such as agricultural residues for particleboard production [4]. The use of such residues for particleboard production offers a sustainable solution to disposal challenges posed by the ever-increasing volume of agricultural residues in the environment. Key agricultural residues include bagasse [5], rice straw [6], rice husks [7], maize cobs [8], oil palm [9] and almond shells [10]. Out of these, rice husk is one of the most promising and suitable raw material for production of particleboards [11]. Besides being readily available, tough, abrasive, and resistant to weathering [12], rice husk has basic components similar to wood [13], though in different proportions, as reported elsewhere [14]. Consequently, it would be expected that rice husk behaves similarly to wood in particleboard production [7]. However, because of its typically porous structure and low bonding strength, rice husk-based particleboards exhibit lower physical and mechanical properties than wood-based particleboards [15]. More specifically, the strength of rice husk particleboards has been reported to be only 1/3 that of wood-based particleboards [16]. This limits their use in some applications. However, by blending rice husks with wood particles, coupled with suitable adhesives, composite particleboards with properties comparable to those of wood-based particleboards can be obtained [17,18].

Uganda is one of the countries under the Coalition for African Rice Development (CARD) that aims at increasing rice production in sub-Saharan Africa (SSA) from 28 to 56 million MT by 2030 [19]. With about 20% of the total paddy weight constituting rice husks [20], the total rice husk generation in SSA is projected to be 11 million tons by the

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end of 2030, suggesting a potential increase in the burden of disposing of rice husk sustainably. Elsewhere, urea-formaldehyde [21], phenol-formaldehyde [22], cement and tannin [23] have been employed as adhesives in the production of composite particleboards from rice husks and wood particles. As a contribution to sustainable utilization of the growing rice husk volumes, this study explored the possibility of employing three synthetic adhesives Fevicol (FV), Ponal (PA) and Woodfix (WF) commonly available in Uganda in the production of composite particleboards. Besides adhesive type, the effects of different proportions of rice husks and sawdust on the physical and mechanical properties of the resulting composite particleboards were investigated. The novelty of this study lies in demonstrating suitability of commercial adhesives in production of particleboards from agricultural residues.

2. Materials and methods

2.1. Materials

Rice husks (RH) amounting to 200 kg were obtained from Uganda's National Agricultural Research Organization (NARO), while 100 kg of sawdust (SD) was procured from one of the carpentry workshops in Kampala city, Uganda (See Fig. 1). The properties of rice husks and sawdust in Uganda have been reported elsewhere [24,25].

2.2. Characterization of adhesives

Adhesive samples were dehydrated at 105 °C for 8 h in an oven to obtain solid specimens. The chemical composition of adhesives was determined using X-ray fluorescence (XRF) analysis on dehydrated specimens. Additionally, about 0.1 g of each adhesive were separately loaded in a Fourier Transform Infrared (FTIR) spectrometer (Alpha II – 110,387, Germany) to determine the surface functional groups.

2.3. Sample board preparation

Particleboard specimens of 200 × 200 × 50 mm were made by blending 500 g of biomass particles with each adhesive type in a ratio of 1:1 by weight. This ratio was found to be the most appropriate after conducting a series of trials involving variations in pressure, holding time, ratios of biomass to adhesive and volume of material, not reported here. The experimental design of this study is shown in Table 1. Each treatment was replicated five times to ensure reliable data was obtained.

The blended biomass particle-adhesive mixture was transferred into the mould to form a mat. This was achieved by hand pre-pressing of the mixture from the extreme sides of the mould towards the center. The mat was then transferred into a hydraulic pressing machine and cold pressed at 10 MPa for 7 days. The formed particleboards removed from the press were left to dry at room temperature for a period of 30 days. The dried boards were then trimmed to a final thickness of 24 mm using a table sanding machine. The edges of the particleboards were trimmed before test specimens were cut off as per the standard dimensions of the tests described in section 2.4 (see Fig. 2).

2.4. Properties of particleboards

2.4.1. Physical properties

The physical properties investigated in this study include density, water absorption (WA), linear expansion (LE) and thickness swelling

Table 1
Experimental treatment combinations.

Adhesive type	Treatment combinations			
	50% RH:50%AD	40%RH:10% SD:50%AD	25%RH:25% SD:50%AD	10%RH:40% SD:50%AD
FV	FV_0	FV_1	FV_2	FV_4
PA	PA_0	PA_1	PA_2	PA_4
WF	WF_0	WF_1	WF_2	WF_4

Note: 1) RH is rice husk; 2) SD is sawdust; and 3) AD is adhesive.

Fig. 1. Raw materials used (a) saw dust, (b) rice husks, and adhesives packs (c) Woodfix, (d) Ponal, (e) Fevicol.

Fig. 2. Particleboards developed using sawdust, rice-husks and adhesives WF, PA, and FV.

(TS). The density was investigated following American Standard for Testing and Materials (ASTM) ASTM D-1037 procedures. Test pieces were cut to 50 × 50 × 24 mm. For each test, five specimens were prepared. The mass of each sample was obtained using a digital weighing scale. Density was computed by dividing mass by volume. The values reported for each test is an average of results obtained from the five test specimens.

WA, LE, and TS of the boards were determined following ASTM D-1037 methods. Test specimens of 100 × 100 × 24 mm were oven-dried for 24 h at 103 °C and weights measured. The test pieces were then soaked in water for 24 h. At the end of each immersion period, the specimens were removed from water and hanged for 10 min to allow free surface water to drain off. Measurements of length and weight of the boards were taken for each specimen. WA and TS were calculated as ratios of absorbed water and increased thickness to the values before soaking, respectively, and expressed as percentages as illustrated in Equations (1) and (2)

$$WA = \left(\frac{W_{final} - W_{initial}}{W_{initial}}\right) \times 100 \quad (1)$$

where W_{final} is weight after absorbing water and W_{inital} is initial weight

$$TS = \left(\frac{T_{final} - T_{initial}}{T_{initial}}\right) \times 100 \quad (2)$$

where;

T_{final} thickness of the board after absorbing water, $T_{Initial}$ is thickness of the particleboard.

2.4.2. Mechanical properties

The mechanical properties evaluated for the particleboards include modulus of elasticity (MOE), modulus of rupture (MOR) and screw holding capacity. These tests were carried out using Tinius Olsen H50KT Universal Testing Machine. The procedures outlined in ASTM D-1037 standard were followed. MOE and MOR tests were carried out using specimens of 100 × 70 × 24 mm and calculated according to Equations (3) and (4), respectively.

$$Modulus\ of\ Elasticity\ (MOE) = \frac{3 \times P_{bp} \times L}{(12 \times Y_p \times bh)} \quad (3)$$

where;

P_{bp} is load at the proportionality limit; L is span length in mm; b is width of the specimen in mm; h is thickness of the test specimen in mm; Y_p is deflection corresponding to load

$$Modulus\ of\ Rupture\ (MOR) = \frac{3 \times P_b \times L}{(4 \times bh)} \quad (4)$$

where,

P_b is maximum load applied; L is span length in mm; b is width of the specimen in mm; h is thickness of the specimen in mm.

The screw holding capacity of the particleboards was performed on specimens of 80 × 70 × 24 mm in both lateral and perpendicular planes. Screws of diameter 4 mm and 15 threads per inch were used.

3. Results and discussions

3.1. Adhesive characterization

3.1.1. Solid content

Solid content is a very important physical parameter for determining the quality and usage of the adhesives in board production. Adhesive FV, PA and WF had solids content of 42.96%, 45.66%, 45.28%, respectively. These values lie in the range of values reported by Oktay et al. [26]. These relatively high values of solid content imply good workability properties of the adhesives. The liquid components could be water, alcohols and other hydrocarbons with low molecular weights thus their low evaporation temperatures.

3.1.2. Functional surface groups

FTIR spectra for FV, PA, and WF used are presented in Fig. 3. For all the spectra, FTIR peaks were located at wave numbers of 3343, 1734, 1637, 1373, 1237, 1021 cm^{-1} implying similar compounds are used to develop the commercial adhesives. The possible surface functional groups were (O–H), carboxylic acids, (C=O) unsaturated ester, saturated aldehyde, (C≡C) saturated amides, alkene, (C–O) alcohols, ethers, esters, carboxylic acids, anhydrides, (C=O) alcohols, ethers, esters, carboxylic acids, anhydrides. The OH- alcohols contribute to hydrophobicity [27] of the adhesives and resultantly that of the particle boards. The peak at 1373 cm^{-1} is greatly hydrophobic due to the non-polar nature of stretching amines [28]. Also peaks at 1637 and 1373 cm^{-1} can be assigned to the stretching of carbonyl groups (C=O) and C–N stretching of secondary amines, respectively which contribute to the chemical bonding with rice husks and SD to form mechanically strong particleboards. The other observed peaks of 1237 and 1021 cm^{-1} were assigned to the C–O–C aliphatic ether. These give the adhesives its bonding ability, toughness [29] and deformation resistance [30] as they increase the viscosity due to their starchy nature [31] and methylene bridge (–NCH_2N–). The infrared spectra in Fig. 3 conforms with typical absorption peaks of urea formaldehyde resins observed in works by Roumeli et al. [32]. A library search for spectra similar to those of adhesives FV, PA, and WF revealed correlations of 82.5%, 78.6% and 50.2%, respectively with polyvinyl acetate in OPUS 8.1 software as can be seen in Fig. 4.

3.1.3. Chemical analysis of adhesives

The carbon, nitrogen, sulphur and oxygen compositions of the different adhesives are shown in Table 2. High carbon content of adhesives is desired as it enhances the intermolecular or cohesive forces.

The relatively close composition values conform with the FTIR spectra which implies that actually similar compounds are used to produce the adhesives but in varying concentrations.

XRF analysis revealed that all adhesives had calcium as the most

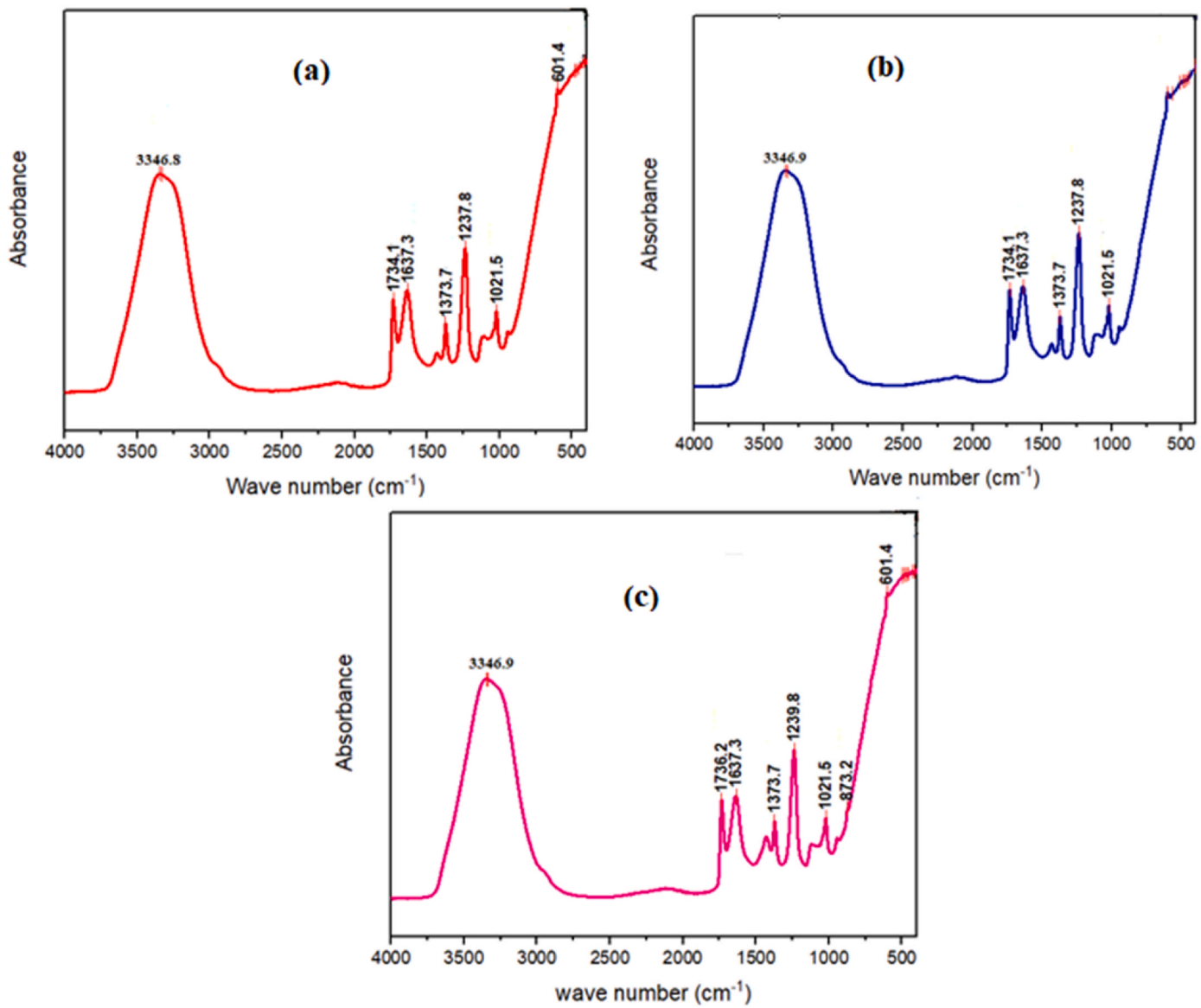

Fig. 3. FTIR spectra for (a) adhesive-FV, (b) adhesive -PA and (c) adhesive-WF.

significant component (see Table 3). A high calcium content is desired as it enhances the gelling ability of the other components in the adhesive. Calcium based compounds also reduce average cost of production, deter curing shrinkage and increase compression strength and hardness [33] justifying its high contribution in adhesives. Adhesive FV had a higher concentration of potassium and silicon compared to adhesives- PA and WF, suggesting that potassium silicate could be one of its production compounds.

3.2. Density

As can be seen in Fig. 5, the density of particleboards increased with proportion of sawdust, except for boards made by blending 10 wt% sawdust and 40 wt% rice husk, using either adhesives FV or WF. Adhesive WF resulted in composite particleboards with the lowest density (520 kgm^{-3}). The highest density (612 kgm^{-3}) was attained when 40 wt % sawdust was blended with 10 wt% rice husk, using adhesive FV. This range of density is close to the values reported in literature [34,35] for particleboards made from rice husks and sawdust. The increase in density with proportions of sawdust may be attributed to sawdust particles filling the voids created by the husks, which enhances bonding and compressibility of the particles. Consequently, this makes the particleboards more compact, and hence the increased density. On the other hand, the decrease in density as proportions of sawdust increased from 0 to 10 wt% in both adhesive FV and WF bonded particleboards may be due to distortion of the bonding structure, which subsequently weakens the bonding between the rice husk and sawdust particles.

The influence of adhesive type on density of particleboards varied with the proportion of sawdust. For instance, when the proportion of sawdust amounted to either 25 wt% or 40 wt%, the density of particleboards varied with adhesive type in the order FV > PA > WF. The trend was different when the adhesives were employed to mixtures incorporating either 10 wt% sawdust or entirely rice husks, suggesting that biomass proportions together with adhesive type influence the density of particleboards. Similar findings were reported by Zheng [36]. Since the maximum density reported from the samples is less than 640 kgm^{-3}, the prepared boards can be graded as low density particleboards [37], and their use can be limited to specific applications, such as sound –proofing [16,36].

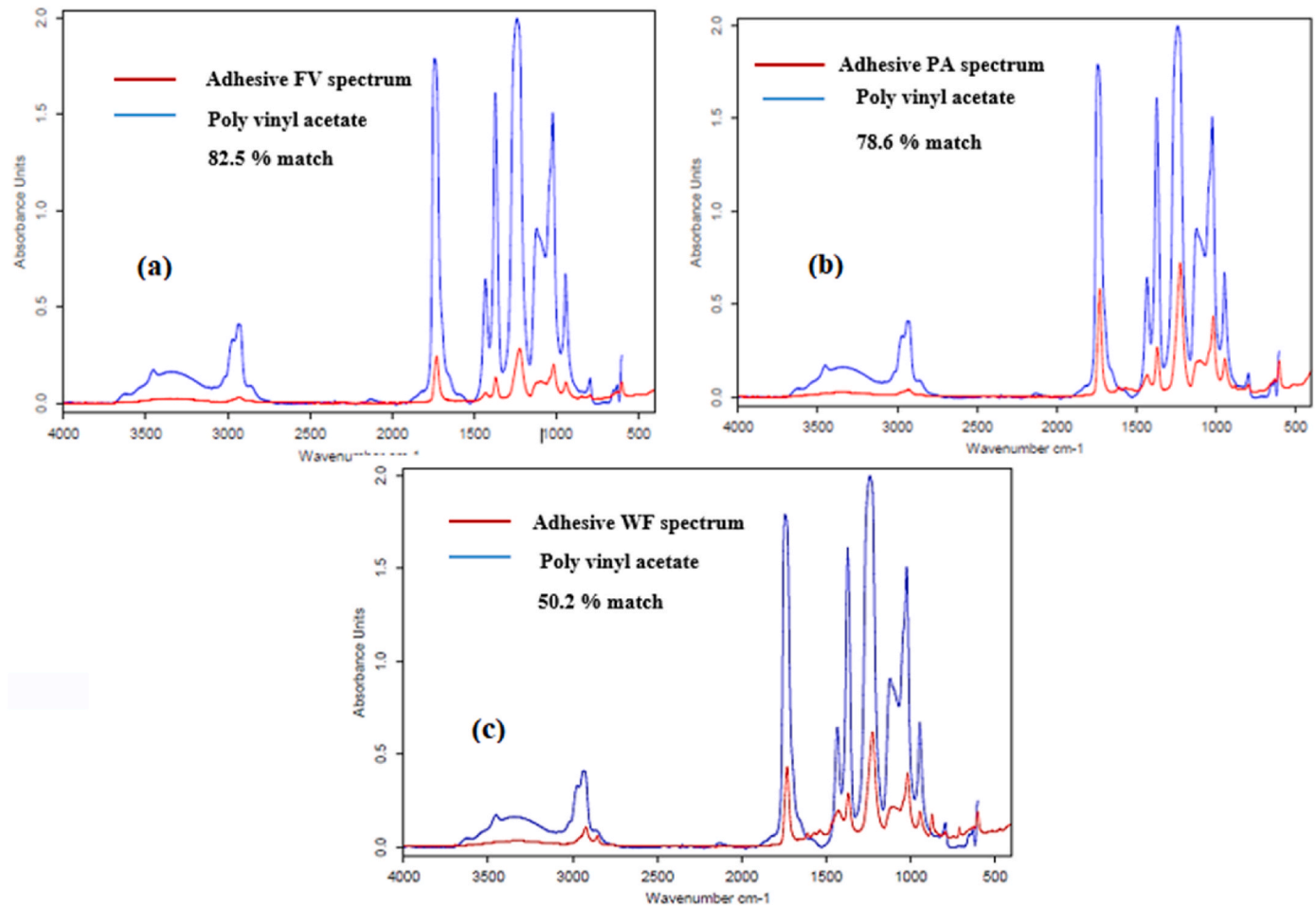

Fig. 4. Matching of poly vinyl acetate with (a) adhesive FV, (b) adhesive PA, (c) adhesive WF.

Table 2
Carbon, Nitrogen, Sulphur and Oxygen Contents of the Adhesives.

	Carbon (%)	Nitrogen (%)	Sulphur (%)	Oxygen[a] (%)
PA	41.62	7.48	15.10	35.80
WF	44.00	5.10	16.24	34.66
FV	43.72	5.38	16.35	34.55

[a] As difference.

3.3. Linear expansion

Fig. 6 shows the effects of adhesive type and proportions of rice husk and sawdust on the LE of composite particleboards after 24 h of soaking. With the exception of adhesive WF bonded particleboards, LE values of adhesives FV and PA bonded particleboards initially increased with proportion of sawdust amounting up to 10 wt%. This increase can be attributed to the higher concentrations of poly vinyl acetate thermoplastic [38]. Increasing the proportion of sawdust beyond this limit, led to a decrease in the LE values for FV and PA bonded particleboards. In the case of WF bonded particleboards, LE values steadily decreased with increase in the proportion of sawdust, suggesting that adhesive WF is a better binder when higher proportions of sawdust are incorporated in the particleboard. A reduction in LE values of adhesive WF-, FV- and PA-bonded particleboards, with increasing proportion of sawdust may be attributed to the increased compactness of the biomass particles, which enhances interaction between particles and adhesives, forming stronger crosslinks [36].

Irrespective of the adhesive type and proportion of biomass employed in particleboard production, the LE values obtained in this study ranged from 3.15 to 6.80%. Therefore, since the maximum acceptable LE value required of low density particleboards is 0.35% [39], the particleboards obtained in this study did not conform to the standards required of low density particleboards.

3.4. Water absorption (WA)

Fig. 7 shows the effects of adhesive type, and proportions of rice husk and sawdust on WA of particleboards after 24 h of soaking. As opposed to WF bonded particleboards, WA of FV and PA bonded particleboards initially increased with proportion of sawdust amounting up to 10 wt%.

Table 3
Chemical composition of adhesives FV, PA and WF.

Adhesives	Chemical composition										
	Si	P	Cl	K	Ca	Sn	Te	Ti	Fe	Er	Mn
FV	5.01	0.37	5.4	35.64	53.51	0.01	0.01	–	–	–	–
PA	2.45	0.05	1.19	–	87.18	–	–	0.02	3.65	5.46	0.15
WF	–	–	1.13	0.35	98.02	–	–	0.01	0.35	–	–

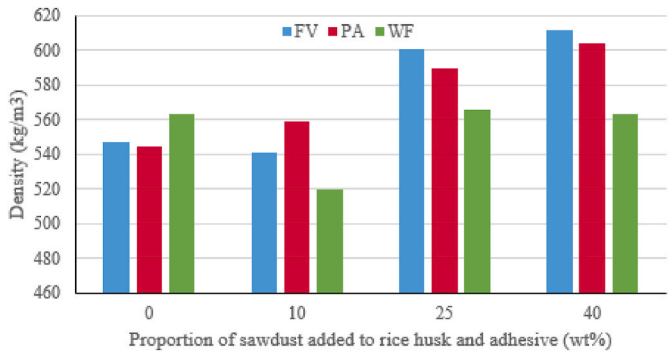

Fig. 5. Effect of adhesive type and proportions of rice husk and sawdust on the density of particleboard.

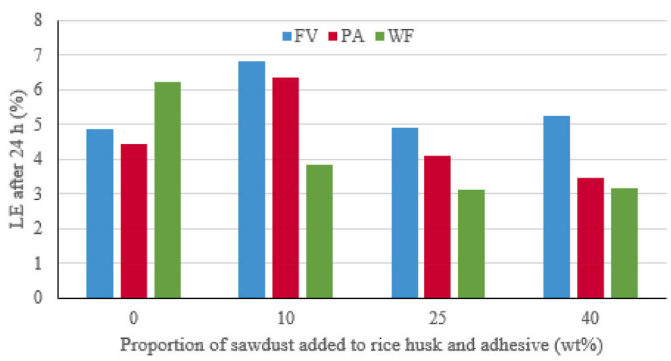

Fig. 6. Effect of adhesive type, and proportions of rice husk and sawdust on LE of particleboards after 24 h of soaking.

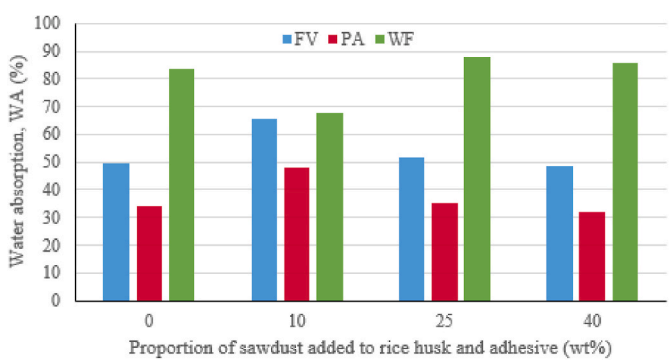

Fig. 7. Effect of adhesive type, proportions of rice husk and sawdust on WA of particleboards after 24 h of soaking.

A further increase in the proportion of sawdust led to a decrease in WA of adhesive FV and PA bonded particleboards. This decrease in WA may be attributed to a reduction in voids, which otherwise allow penetration of water into the particleboards [40].

With the exception of PA bonded 100 wt% rice husk particleboard and those with 10 wt% rice husk and 40 wt% sawdust, the rest of the particleboards exhibited higher WA values (40.71–97.58%), than the range (34.21–48.19%) reported by Kang et al. [38]. This difference in WA values may be attributed to differences in the adhesive type employed in particleboard production. Since the WA values of PA bonded 100 wt% rice husk particleboard and those with 10 wt% and 40 wt% rice husk are less than 60%, then the resulting particleboard could be employed in the manufacture of furniture boards [39].

3.5. Thickness swelling (TS)

Fig. 8 shows the effect of adhesive type, and proportions of rice husk and sawdust on TS of particleboards after 24 h of soaking. The TS of FV and PA bonded particleboards initially increased with proportion of sawdust amounting up to 10 wt%. Beyond this limit, increase in the proportion of sawdust led to a decrease in TS of both FV and PA bonded particleboards. On the other hand, TS of WF bonded particleboards steadily decreased with increase in proportion of sawdust, possibly due to the greater spring back of compacted particles in boards as the density decreased [38].

Irrespective of the adhesive type and proportion of biomass employed in particleboard production, TS values obtained in this study ranged from 9 to 31%, and were relatively lower than the range 44–50% reported by Melo et al. [40]. This variation from literature values may be attributed to differences in the quality of adhesives employed in the studies. For load bearing and heavy-duty load bearing applications, the TS values should not exceed 14% after 24 h of soaking [41]. Consequently, FV bonded particleboards constituting either 25 wt% or 40 wt% sawdust, and PA bonded particleboards constituting either 0 wt% or 40 wt% sawdust could comply with these requirements.

3.6. Modulus of elasticity (MOE) and modulus of rapture (MOR)

Fig. 9 shows the effect of adhesive type, and proportions of rice husk and sawdust on MOE and MOR of particleboards. The MOE of FV and WF bonded particleboards initially decreased with an increase in proportion of sawdust amounting up to 10 wt% **(see** Fig. 9a**).** Beyond this limit, increase in the proportion of sawdust led to an increase in MOE. On the other hand, the MOE of PA bonded particleboards steadily increased with increase in proportion of sawdust. The MOE of particleboards ranged from 13 to 26 MPa, and were close/or within the range of 15–40 MPa reported by Kariuki et al. [41]. Based on the American National Standards Institute (ANSI) ANSI A208.1–1999 standard, the particleboards generated in this study did not conform to the standards expected of low-density particleboards, since their MOE values were below 550 MPa.

MOR of FV and WF bonded particleboards reduced with increase in proportion of sawdust up to 10%, while a further increase in proportion of sawdust resulted in an increase in MOR (Fig. 9b). However, in the case of WF bonded particleboards, this increase was valid for proportions of sawdust amounting up to 25 wt%. On the other hand, the MOR of WF bonded particleboards decreased with increase in proportion of sawdust up to 10 wt%. Beyond this limit to 25 wt%, the MOR of particleboards increased. The increase in MOE and MOR of particleboards with increase in proportion of sawdust may be attributed to the increase in compactness or density of the particleboards [42]. However, as can be seen in Fig. 9, in some instances, MOE and MOR reduced with increase in proportion of sawdust. This could have been influenced by other factors

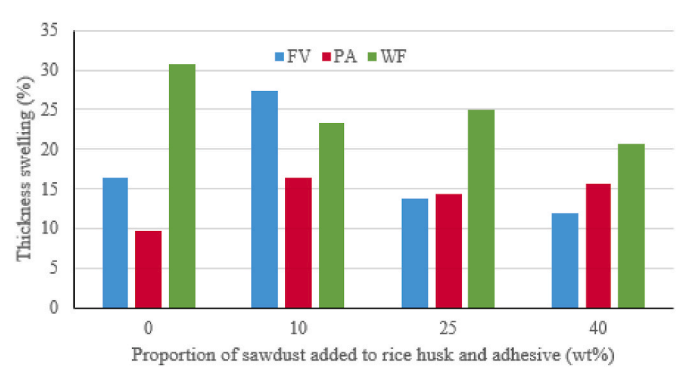

Fig. 8. Effect of adhesive type, and proportions of rice husk and sawdust on TS of particleboards after 24 h of soaking.

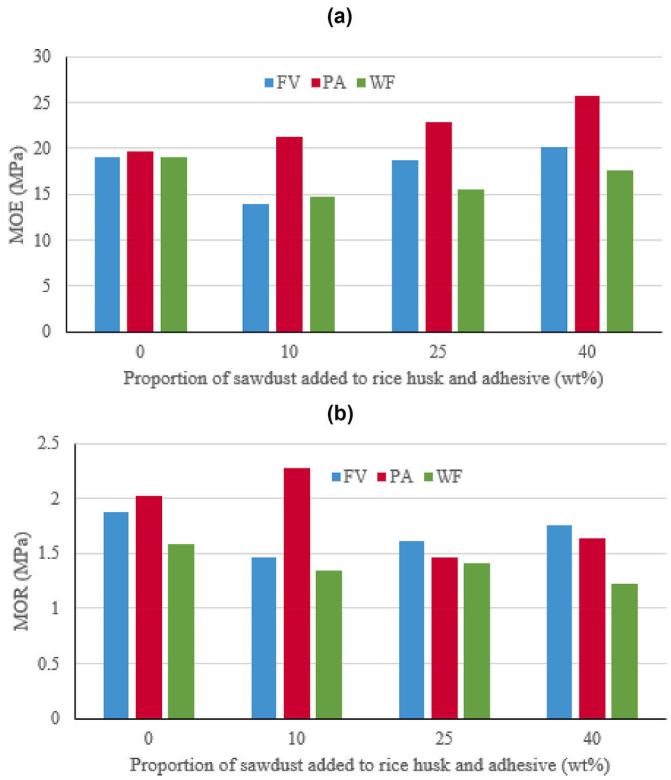

Fig. 9. (a) Effect of adhesive type, and proportions of rice husk and sawdust on MOE of particleboards, (b): Effect of adhesive type, and proportions of rice husk and sawdust on MOR of particleboards.

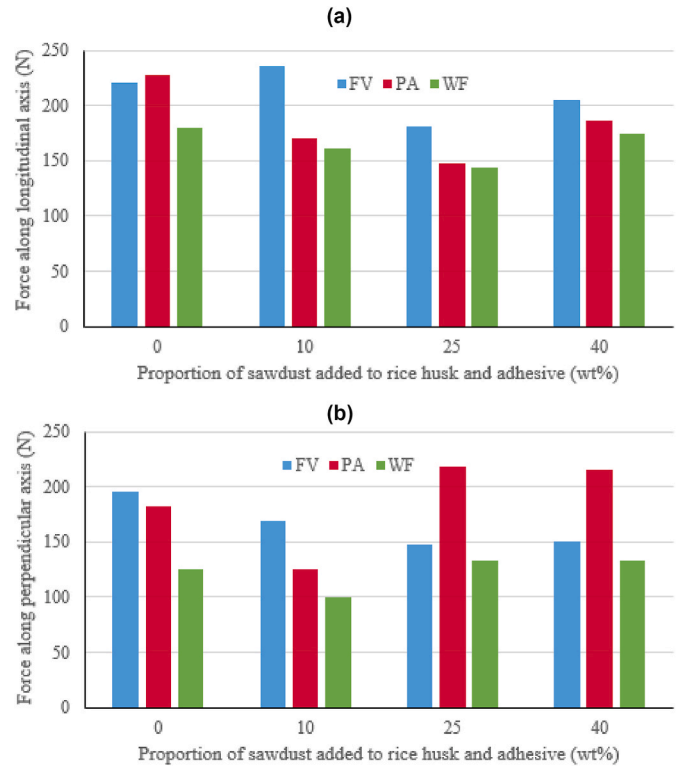

Fig. 10. (a) Effect of adhesive type, and proportions of rice husk and sawdust on screw holding capacity of particleboards along the longitudinal axis, (b): Effect of adhesive type, and proportions of rice husk and sawdust on screw holding capacity of particleboards along the perpendicular axis.

such as insufficient adhesive content and distribution, poor compatibility between substrate and adhesive, and adhesive properties [42].

MOR values of particleboards obtained in this study are lower than the range 4.69–6.74 MPa reported by Melo et al. [43], but within/or close to the range reported by Ndazi et al. [44]. Moreover, the MOR values obtained in this study were even higher than the range of 0.32–1.50 MPa for composite particleboards made from corn cob and sawdust [45], suggesting good potential for rice husks to be employed as a particleboard raw material. However, similarly to studies conducted elsewhere [44], the MOR of particleboards obtained in this study did not conform to the acceptable minimum standard of 11.5 Nmm^{-2} for general purpose particleboards [46]. Consequently, there is need to improve the MOR values by either increasing the density of the boards or optimizing process conditions including adhesive properties, particle size, and amount of adhesive among others.

3.7. Screw holding capacity

Fig. 10 shows the effect of adhesive type, and proportions of rice husk and sawdust on screw holding capacity of particleboards along the longitudinal and perpendicular and axes. Along the longitudinal axis (Fig. 10a), the screw holding force of PA and WF bonded particleboards initially decreased with increase in proportion of sawdust up to 25 wt%, a phenomenon which could be attributed to low concentration of potassium binder (see Table .2). A further increase in the proportion of sawdust to 40 wt% resulted in an increase in screw holding force. On the other hand, the screw holding force of adhesive FV bonded particleboard initially increased with increase in proportion of sawdust amounting up to 10 wt%. A further increase in the proportion of sawdust to 25 wt% and 40 wt% resulted in a decrease and increase in the screw holding force respectively.

Along the perpendicular axis (Fig. 10b), the screw holding force of PA and WF bonded particleboards decreased with increase in proportion of sawdust up to 10%. Beyond this limit, increase in the proportion of sawdust up to 25 wt%, led to an increase in the screw holding force. For adhesive FV bonded particleboard, the screw holding force decreased with increase in proportion of sawdust amounting up to 25 wt%, and thereafter, a further increase in proportion of sawdust resulted in a slight increase in the screw holding force. Increase in the screw holding capacity with proportion of sawdust may be attributed to improved bonding and interactions between particles, which subsequently increase the ability of the particleboards to hold the screws [47]. Generally, the blends that yielded particleboards with relatively low mechanical properties could be utilized in several ways including use as insulating material in buildings, since such materials may possibly not be subjected to any mechanical stress.

4. Conclusion

This study set out to investigate the effect of adhesive type and different proportions of rice husk and sawdust on the properties of composite particleboards. The findings reveal that:

1. Addition of different proportions of sawdust impacts positively on the density of rice husk particleboards.
2. Depending on the adhesive type, addition of sawdust can improve dimensional stability of the particleboards. This is evidenced through reduced levels of water absorption, linear expansion and thickness swelling of rice husk particleboards as the proportion of sawdust increased.
3. The addition of different proportions of sawdust yields similar effect in particleboards for all adhesives investigated.
4. The strength properties and screw holding capacity of the boards are lowered by addition of proportions of sawdust less than 10%. In majority of the particleboards, these properties improve with

increasing proportions of sawdust. The high density and interactions between board particles and adhesives are responsible for this trend.

5. Of all the adhesives, FV and PA bonded particleboards exhibited relatively high stability and strength due to the relatively higher levels of thermoplastic polymer in form of polyvinyl acetate. More specifically, blending 40 wt% sawdust, 10 wt% rice husk and using 50 wt% of either adhesive FV and PA yielded the most promising results in terms of dimensional stability and strength of the resulting particleboards.
6. The density and linear expansionwere found to be below the required minimum values for application of the developed boards as low density particle boards, however they are sufficient for their application in furniture boards and sound insulation
7. It should be noted that other factors like pressing pressure, time, curing/drying method and pretreatment of rice husks that could affect the properties of particleboards were not investigated in this research. Moreover, since these factors may have a differing impact on the boards' properties with different adhesives, further work is anticipated to optimize the conditions for producing particleboards using the adhesives investigated in this study.

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Author contributions

PWO developed the concept of the research, designed the work, supervised the experimental works, interpreted the findings and drafted the manuscript. EM, JW did the analysis of the experimental data and participated in drafting the manuscript. FL and LS participated in collecting the sample materials and executing experimental works in the Laboratory. BN participated in the drafting and writing of the manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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List of abbreviations

AD	Adhesive
ANSI	American National Standards Institute
ASTM	American Society for Testing and Material
h	hour
LE	Linear Expansion
min	minute
mm	millimeter
MOE	Modulus of Elasticity
MOR	Modulus of Rupture
MPa	Mega Pascal
NARO	National Agricultural Research Organization
RH	Rice husks
SD	Sawdust
TS	Thickness swelling
WA	Water absorption
wt%	Weight percentage

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