

# Influence of Particle Size and Fibre Content on the Dimensional Stability and Mechanical Behaviour of composites produced from *Cordiamillenii* and Recycled Polyethylene

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**Abstract**— The degradation of the environment by wood and plastic wastes has continued to attract serious attention. Utilisation of these wastes without additives and pre-treatment for the production of wood plastic composites will give credence to the fundamentals of compatibility and performance of the composites and also for economic reasons. Therefore, this study was designed to investigate the dimensional stability and strength properties of wood plastics composites produced from wastes of *Cordiamillenii* and recycled polyethylene at a target density of 920kg/m<sup>3</sup>. Three levels of wood particle size ( $0.0 < 0.25$ ,  $0.25 \leq 1.0$  and  $1.0 < 2.0$ ), three levels of wood/plastics ratio (30:70, 40:60 and 50:50) and three types of recycled polyethylene (LDPE, HDPE and LDPE/HDPE) were applied. The dimensional stability (Water Absorption (WA), thickness swelling (TS) and Linear Expansion (LE)) and strength properties (Modulus of Elasticity (MOE) and Modulus of Rupture (MOR)) were examined. The mean range of results obtained for the sorption properties (WA; 1.6-10.2%, TS; 0.14-2.07% and LE; 0.11-0.37%) indicated the composites are dimensionally stable. The mean strength properties values (MOE; 0.24-1.81GPa and MOR; 6.55-15.87MPa) compared favourably with those reported in literature. The composites produced with HDPE at 30% wood content had higher strength and lower sorption properties than other formations. Particle sizes, plastics types and mixing ratio had significant effect the dimensional stability and mechanical behaviour of the composites at  $\alpha_{0.05}$  significance level. Acceptable WPCs were produced from *Cordiamillenii* wastes and recycled polyethylene for non-structural applications.

**Keywords**— *Cordiamillenii*, Dimensional stability, Modulus of elasticity, Recycled polyethylene, Wood plastic composites.

## I. INTRODUCTION

There has been a huge demand for wood for man's use which has led to destructive exploitation of trees especially in Nigeria despite the availability of large number of diverse tree species. Wood has been used since time immemorial for medicinal, fuel, cultural, construction, agricultural, and animal fodder putting pressure on the forest and resulting in extreme deforestation. Aina [1] observed that one of the factors that have contributed greatly to the spontaneous depletion of the country's timber resources is the large accumulation of wastes generated during log harvesting and processing. Waste wood is usually composed of sawdust, wood offcuts, wood chips, wood barks, and plain shavings. 1.8million tons out of the 5.2million wood wastes generated in Nigeria are

sawdust [2]. The wood wastes are used as landfill, sometimes disposed causing environmental pollution, or burnt which releases greenhouse gases into the atmosphere causing health issues. If wood wastes are maximally utilized and recycled, the number of trees cut yearly for lumber production and the negative effects on the environment would be reduced.

The environmental accumulation of plastic products wastes in form of pollution adversely affect wildlife habitat, aquatic habitat, humans and cause the degradation of the environments [3]. The popularity of plastic pollution correlates with plastics being cheap and durable, which makes it available to humans for use at high volumes. However, it degrades at a slow rate. Plastic wastes include Sachet water plastic, plastic containers (for food, water,

and, some other liquids) etc. These are found in large quantities littering the environment, water bodies and dumpsites across Nigeria.

Koranteng [4] reported that researchers across the world have focused attention on wood plastic composites (WPC) to curb the environmental impact of plastic wastes and over-consumption of forest wood. Wood-plastic composites (WPC) are composite materials consisting of wood fibre/ wood flour and thermoplastics; Low Density Polyethylene (LDPE), High Density Polyethylene (HDPE), Polypropylene (PP), Poly Vinyl Chloride (PVC), etc. [3, 5]. Stark [6], also reported that researchers are combining wood fibres with thermoplastic resin resulting in wood-plastic composites (WPCs) in order to increase the value of low-value wood resources to high-value products. The most common type of WPCs panels widely used in USA are produced by mixing wood flour and plastics to produce materials that can be processed to perfect plastic based products [7-10]. Due to the large benefits the WPCs materials exhibit, the use of the materials made of thermoplastics resins loaded with fillers rich in lingo-cellulosic fibres had increased over the years.

The geometry of wood particle as well as the ratio influenced the strength properties of WPCs from *Laran Species* [11]. The properties of WPCs were observed to have been affected by the particle size and fibre contents ([12 – 15]. This study was aimed at evaluating the influence of the particle sizes, fibre contents and polymer types (LDPE, HDPE and Mixture of LDPE and HDPE) on the dimensional stability and mechanical properties of WPCs produced from *Cordiamillenii*, without additives and pre-treatment, by extrusion and hot press processes.

## II. MATERIALS AND METHODS

### 2.1 Material collection and preparation

#### 2.1.1 Wood residue

*Cordiamillenii* (Omo) was used in this experiment because it is widely used for constructional purposes and the residues from the wood are available in abundance [16]. The wood waste was collected from a local plant market at Sango, Ibadan, Nigeria as shown in Plate 1.



Plate 1. Sawdust of *Cordiamillenii* (Omo)

#### 2.1.2 Recycled Polyethylene

Recycled plastic containers, grocery bags, water sachets and flexible bottles were collected from discarded municipal and commercial waste outlets and were graded as Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE).

#### 2.1.3 Materials preparation

The wood wastes were milled and screened by sieving to three particle sizes of  $0.0 < 0.25$ ,  $0.25 \leq 1.0$  and  $1.0 < 2.0$  by using mesh numbers 60, 18 and 10, respectively. The sieved particles were first sundried for one week and later oven-dried at  $103 \pm 3^\circ\text{C}$  to a moisture content of 4.0% (Plate 2). The recycled LDPE and HDPE were thoroughly washed with detergent, well rinsed, and dried in convection oven at  $60^\circ\text{C}$  for 12 hours. The dried samples were shredded and hammer milled (Plate 3) to granules of 0.2-0.5 $\mu\text{m}$  in diameter (Plate 4a: LDPE, and 4b: HDPE).



Plate 2: Saw-dust of *Cordiamillenii*



Plate 3: Milling of recycled Polyethylene



Plate 4a: Milled recycled Polyethylene (LDPE)



Plate 4b. Milled recycled Polyethylene (HDPE)

#### 2.1.4 Composite Processing

The amount of wood flour was varied from 30, 40 to 50 wt% on the total weight of plastics wastes. The nomenclature and formulation of samples are shown in Table 1.0. The wood flour and the polymer matrix were blended using a laboratory scale mixer for 10 minutes. The blends were compounded in a single screw extruder (Plate 5). The temperatures of the extruder were controlled at mixing (120°C), melting and mixing (160 – 170°C) and metering (170°C), the screw speed was 40rpm. The extruded strand was cooled and subsequently hot pressed to sheet of a nominal thickness of 10mm and 20 by 30 cm nominal dimensions using a laboratory hot press at 170°C for 2minutes at a pressure of 3.5MPa (Plate 6). After hot

pressing, boards were kept in a cold press for 5min. The boards were later kept at room conditions for seven days before samples were cut for physical and mechanical tests.



Plate 5: Single Screw extruder



Plate 6: Hot Press

#### 2.2 Tests for Physical Properties

Dimensional stability of samples was investigated by WA, TS and LE properties of the samples. The tests were carried out according to ASTM D570: [17] and British Standard 373 [18]. Measurements of mass (g), thickness (mm) and length (mm) of the samples were taken prior to treatment as initial parameters while the final measurements were taken after immersion in water for 24 hrs using electronic weighing balance, digital caliper and meter rule, respectively. The properties were estimated using equations (1), (2) and (3):

Water Absorption (WA (%)):

$$WA (\%) = \frac{W_2 - W_1}{W_1} \times 100 \quad (1)$$

Thickness Swelling (TS (%)):



$$TS (\%) = \frac{T_2 - T_1}{T_1} \times 100 \quad (2)$$

Linear Expansion (LE (%)):

$$LE (\%) = \frac{L_2 - L_1}{L_1} \times 100 \quad (3)$$

Where:  $W_1$ ,  $T_1$ ,  $L_1$  are initial mass (g), thickness (mm), and length (mm) before treatment and  $W_2$ ,  $T_2$ ,  $L_2$  are final mass (g), thickness (mm) and length (mm) after treatment, respectively.

### 2.3 Tests of Mechanical Properties

The mechanical properties were assessed through bending and static flexural tests and were determined according to ASTM D 7031-04 [19] and ASTM D638-99 [20] specifications using an INSTRON testing machine (Plate 7). Nominal sizes of the samples produced were  $200 \times 30 \times 10$  mm. with a speed loading of 10mm/min. MOR and MOE were calculated, three samples of each treatments were tested. All tests were carried out at room temperature ( $25 \pm 2^\circ\text{C}$ ) and constant relative humidity (65%). The specimens were conditioned at constant room temperature ( $25 \pm 2^\circ\text{C}$ ) and relative humidity (65%) prior to testing.



Plate 7: Flexural Test of WPC

### Statistics Analysis

Data were analysed using descriptive statistics and Analysis of variance at 5% probability level to estimate the level of significance among the various parameters tested. The experiments were laid in  $3 \times 3 \times 3$  factorial in completely randomized design as shown in Table 1. Three replications were produced for each composite formulation resulting into the production of 81 specimens

Table 1.0: Formulations of Samples (Research Design)

Factor A Size of Wood Particles (mm)	Factor B (Type of Plastics)	Factor C Wood/Plastic Ratios (w/w)
$0.0 < 0.25$ (Fine)	LDPE	30:70
$0.25 \leq 1.0$ (moderate)	HDPE	40:60
$1.0 < 2.0$ (Oversize)	Mixture	50:50

## III. RESULTS AND DISCUSSION

Plate 8 shows the samples of composites produced. The **dimensional** stability properties investigated were the WA, TS and LE, and the mechanical strength properties investigated were the MOE and MOR of the WPCs at the target density of  $920\text{kg/m}^3$  for all the specimens considered. The results are shown in Table 2.0.



Plate 8: Samples of Composites Produced

Table 2. Physical and mechanical properties of WPC as influenced by wood particle size, plastics type and wood-plastics mixing ratio

Particle size	Plastic Type	Wood plastic ratio (w/w)	TS (%)	WA (%)	LE (%)	MOE (GPa)	MOR (MPa)
<b>Fine</b>	LDPE	30W70P	$0.35 \pm 0.03$	$3.8 \pm 0.14$	$0.11 \pm 0.01$	$0.95 \pm 0.05$	$10.87 \pm 0.05$
<b>moderate</b>	LDPE	30W70P	$0.39 \pm 0.05$	$5.5 \pm 0.09$	$0.13 \pm 0.01$	$0.68 \pm 0.03$	$10.12 \pm 0.04$
<b>Oversize</b>	LDPE	30W70P	$0.60 \pm 0.02$	$6.1 \pm 0.14$	$0.18 \pm 0.02$	$0.45 \pm 0.06$	$9.15 \pm 0.03$
<b>Fine</b>	LDPE	40W60P	$0.76 \pm 0.08$	$4.6 \pm 0.19$	$0.16 \pm 0.04$	$0.83 \pm 0.04$	$8.77 \pm 0.07$
<b>moderate</b>	LDPE	40W60P	$1.41 \pm 0.11$	$7.6 \pm 0.18$	$0.22 \pm 0.01$	$0.61 \pm 0.03$	$7.79 \pm 0.02$

<b>Oversize</b>	LDPE	40W60P	1.96±0.09	8.0±0.26	0.29±0.03	0.41±0.07	7.74±0.08
<b>Fine</b>	LDPE	50W50P	0.89±0.01	6.5±0.14	0.24±0.02	0.67±0.04	8.25±0.12
<b>moderate</b>	LDPE	50W50P	1.82±0.07	8.9±0.09	0.3±0.01	0.53±0.07	6.91±0.08
<b>Oversize</b>	LDPE	50W50P	2.07±0.09	10.2±0.9	0.37±0.03	0.32±0.05	6.55±0.08
<b>Fine</b>	HDPE	30W70P	0.14±0.01	1.6±0.04	0.11±0.02	1.81±0.02	15.87±0.44
<b>moderate</b>	HDPE	30W70P	0.18±0.02	1.9±0.07	0.12±0.01	1.49±0.09	14.08±0.21
<b>Oversize</b>	HDPE	30W70P	0.46±0.06	2.3±0.08	0.17±0.06	0.93±0.03	10.1±0.15
<b>Fine</b>	HDPE	40W60P	0.55±0.03	2.2±0.04	0.12±0.01	1.46±0.08	12.43±0.09
<b>moderate</b>	HDPE	40W60P	1.20±0.07	2.8±0.03	0.14±0.03	1.03±0.04	10.45±0.05
<b>Oversize</b>	HDPE	40W60P	1.51±0.13	3.6±0.07	0.21±0.03	0.69±0.03	9.62±0.64
<b>Fine</b>	HDPE	50W50P	0.72±0.6	2.7±0.06	0.18±0.04	1.25±0.01	10.25±0.36
<b>moderate</b>	HDPE	50W50P	1.29±0.2	4.4±0.32	0.21±0.01	0.71±0.16	9.25±0.91
<b>Oversize</b>	HDPE	50W50P	1.67±0.4	6.5±0.99	0.28±0.02	0.48±0.02	8.99±0.25
<b>Fine</b>	MIXTURE	30W70P	0.29±0.02	2.9±0.17	0.11±0.02	1.18±0.07	13.01±0.73
<b>moderate</b>	MIXTURE	30W70P	0.35±0.03	3.5±0.21	0.13±0.01	1.0±0.06	12.33±0.22
<b>Oversize</b>	MIXTURE	30W70P	0.58±0.09	4.0±0.15	0.19±0.02	0.54±0.09	9.21±0.97
<b>Fine</b>	MIXTURE	40W60P	0.68±0.07	3.3±0.9	0.14±0.01	1.01±0.05	11.11±0.28
<b>moderate</b>	MIXTURE	40W60P	1.31±0.13	4.6±0.65	0.17±0.03	0.64±0.08	8.89±0.43
<b>Oversize</b>	MIXTURE	40W60P	1.87±0.08	5.8±0.21	0.2±0.01	0.47±0.08	8.47±0.88
<b>Fine</b>	MIXTURE	50W50P	0.79±0.01	4.9±0.07	0.21±0.01	0.79±0.03	9.31±0.71
<b>moderate</b>	MIXTURE	50W50P	1.36±0.06	6.0±0.12	0.24±0.03	0.51±0.04	7.74±0.23
<b>Oversize</b>	MIXTURE	50W50P	1.80±0.04	7.7±0.09	0.32±0.01	0.24±0.01	7.52±0.78

Values are average of three replicates and values after '±' are the standard deviations; While:

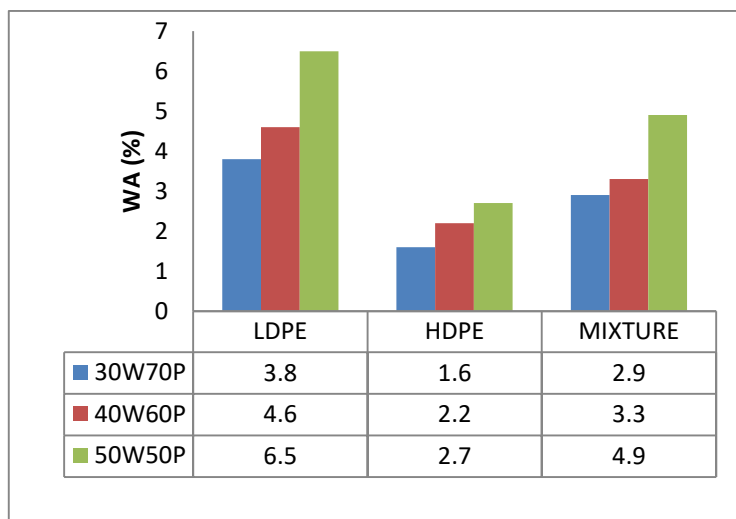
TS = Thickness Swelling; LE = Linear Expansion; WA = Water Absorption; MOE = Modulus of Elasticity; MOR = Modulus of Rupture; 30W70P = Wood: Plastics = 30:70; 40W60P = Wood: Plastics = 40:60 and 50W50P = Wood : Plastics = 50:50

### 3.1 Water Absorption

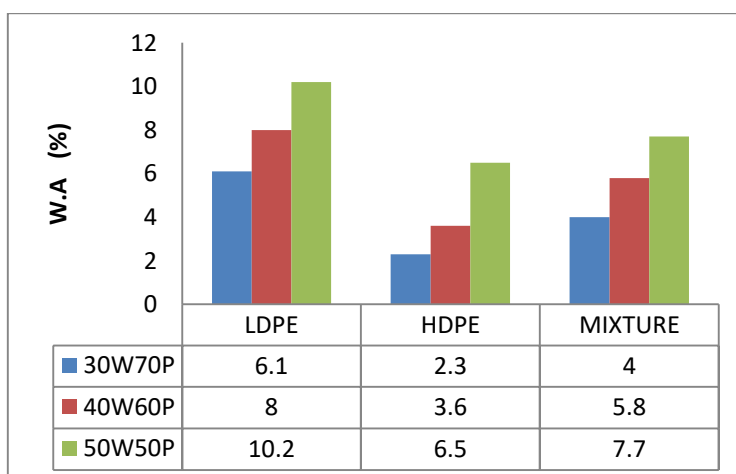
The mean water absorption ranged from 1.6±0.04 to 10.2±0.9 (Table 2.0). The lowest value was observed for fine particle size  $0.0 < 0.25$ , high density polyethylene and wood plastics ratio of 30:70 as shown in Fig. 1a., while the highest value was observed in oversized particle ( $1.0 < 2.0$ ), low density polyethylene, and wood plastics ratio of 50:50 (Fig. 1b). The ANOVA test (Table 3) indicated that all the production variables (particle size, plastic type and wood plastic ratio) have significant effects on WA of the WPC produced. Also the interactions between the production variables except for particle size and mixing ratios have significant effect on WA of the WPC produced. The result indicated that water absorption increased with increase in particle size and increased with increase in proportion of wood content in wood/plastics ratio. This is in agreement

with the report of Rahman *et al* [21]. This could be due to the fact that wood is hydrophilic which exhibit poor resistance to moisture leading to high water absorption as the proportion of wood in WPC is increased. This is also in accordance with the reports of Goszdecki and Wilcysynski, [22]; Azeez, [23]; Oluyee *et al* [24]. Also wood contain natural substances such as pectin, lignin and waxes which interfere with wood adhesion with the polymer matrices. The fine particle sizes are easily dispersed in the polymer matrix and are fully encapsulated by the plastics at lower wood content hence they have low water absorption. The HDPE plastic type practically shows negligible water absorption, If well processed in WPC, the water absorbed is least compared with Nylon which attract water due to the presence of the polar groups (CO-NH), therefore water absorption by Nylon was relatively high, hence the highest water absorption was sample with oversized sample, LDPE

with wood/plastic ratio of 50:50 while the least was fine sample, HDPE with wood/plastics ratio of 30:70.



1a



1b

Fig. 1: Influence of plastic type and mixing ratio on the WA of the WPC produced with fine and over-sized particle size

Table 3. Analysis of Variance for Water Absorption (%) at  $\alpha_{0.05}$

Source of Variation	SS	Df	MS	F	p-value	Sig.
Particle Size	26.41407	2	13.20704	110.4849	1.49E-06	Yes
Plastics Type	61.50296	2	30.75148	257.2548	5.5E-08	Yes
Mixing Ratio	38.49407	2	19.24704	161.0132	3.45E-07	Yes
Particle size x Plastics Type	2.257037	4	0.564259	4.720372	0.029883	Yes
Particle size x mixing ratio	3.365926	4	0.841481	7.039504	0.009861	Yes
Plastics Type x mixing ratio	0.623704	4	0.155926	1.304415	0.346093	No
Within	0.956296	8	0.119537			
Total	133.6141	26	5.139003			

Table 4: Analysis of Variance for Thickness Swelling (%) at  $\alpha_{0.05}$ 

Source of Variation	SS	df	MS	F ( $\alpha$ )	p-value (0.05)	Sig
Particle Size	3.017266667	2	1.5086333	246.419238	6.50982E-08	Yes
Plastics Type	0.355755556	2	0.1778778	29.0544465	0.000214447	Yes
Mixing Ratio	5.414022222	2	2.7070111	442.161525	6.46058E-09	Yes
particle size x Plastics Type	0.023111111	4	0.0057778	0.94373866	0.486304785	No
particle size x mixing ratio	0.708377778	4	0.1770944	28.9264973	8.29271E-05	Yes
Plastics Type x mixing ratio	0.053488889	4	0.0133722	2.18421053	0.161194507	No
Within	0.048977778	8	0.0061222			
Total	9.621	26	0.3700385			

Table 5: Analysis of Variance for Linear Expansion (%) at  $\alpha_{0.05}$ 

Source of variation	SS	Df	MS	F	p-value	Sig.
Particle Size	0.039622	2	0.019811	148.5833	4.72E-07	Yes
Plastics Type	0.012022	2	0.006011	45.08333	4.41E-05	Yes
Mixing Ratio	0.068889	2	0.034444	258.3333	5.41E-08	Yes
particle size x Plastics Type	0.000889	4	0.000222	1.666667	0.249461	No
particle size x mixing ratio	0.001489	4	0.000372	2.791667	0.101082	No
Plastics Type x mixing ratio	0.005289	4	0.001322	9.916667	0.003434	Yes
Within	0.001067	8	0.000133			
Total	0.129267	26	0.004972			

### 3.2 Thickness Swelling (TS)

Table 2 presents the results of the TS of the composites produced from different wood particles (*Cordiamillennii*) sizes and LDPE, HDPE and a mixture of both after 24h immersion in water. The mean TS ranged from  $0.14 \pm 0.01$  –  $2.07 \pm 0.09\%$ . Composites produced from large sized wood particles and LDPE at 50% wood contents showed the highest TS value of 2.07%, while those produced from fine wood particles and HDPE at 30% wood contents showed the lowest value of 0.14%. Figure 2 showed how the particle size, plastic types and mixing ratios influenced the TS properties of the composites. Generally an increase in wood particle size and wood contents increased the TS values. The ANOVA test (Table 4.0) carried out on the TS values at 5% ( $p < 0.05$ ) probability showed significant differences as regards the particle size, plastic type as well as the mixing ratio. The results showed that there was a significant difference regarding the interaction of particle size and mixing ratio while the interaction between the particle size and plastic types, and plastic types and mixing

ratio showed no significance differences on thickness swelling.

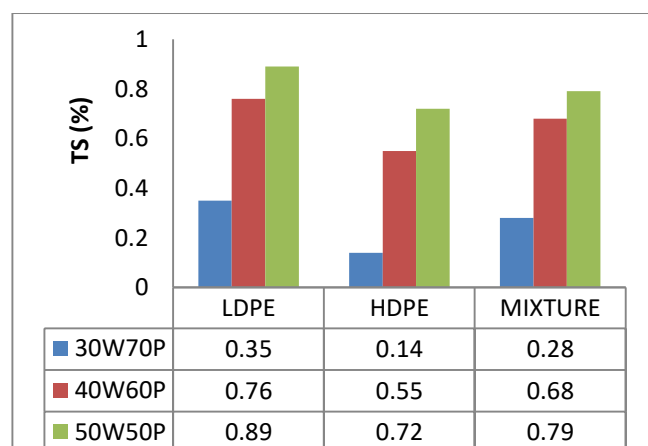


Fig. 2: Influence of plastic type and mixing ratio on the TS of the WPC produced with fine particles

### 3.3 Linear Expansion (LE)

The mean LE values for WPC produced from *Cordiamillennii* particles of different sizes with different plastic types at different wood/plastics proportions ranged

from  $0.11 \pm 0.02$  to  $0.37 \pm 0.03\%$  (Table 2). The least value (0.11%) of LE was observed for all the plastic types with fine particles ( $<0.25$ ) of 30% wood contents. The highest value (0.34%) was observed for the composites produced from oversized wood particles, LDPE plastics type at 50% wood contents. Generally, values of LE in WPCs produced with HDPE were lower compared to those produced with LDPE and a mixture of both. Figure 3 shows the influence of plastic types and mixing ratio of the best performing particle size (fine) on the LE properties of the WPC produced. The ANOVA test results (Table 5) for the LE of the composites produced showed significant effect of the particle size, plastic types and mixing ratio on the overall LE properties of the composites. However only the interaction of plastic types and mixing ratio had significant effects on the LE while other interactions, particle size and plastic type; particle size and mixing ratio, had no significant effect on LE of the WPC produced.

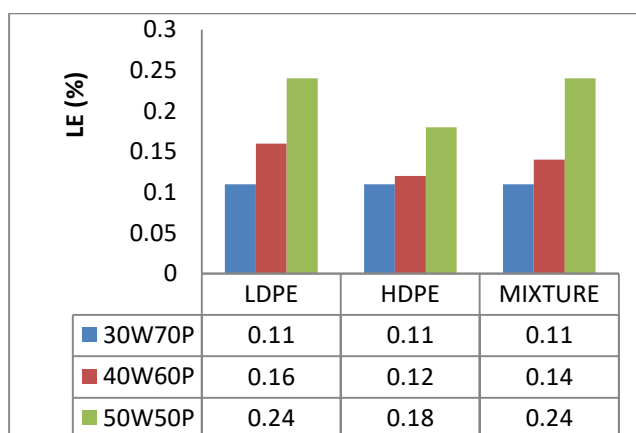


Fig.3: Influence of plastic types, and mixing ratio on the LE of the WPC produced with fine particles.

### 3.4 Modulus of Elasticity (MOE)

The mean values of modulus of elasticity (MOE) of the composites produced, as presented in Table 2, from the combination of wood (*Cordiamelanii*) particles of different sizes and plastics of different kinds at different wood and plastics proportion ranged from  $0.24 \pm 0.01$  to  $1.81 \pm 0.02$  GPa. These values compared favourably with those reported in literature (0.46 – 1.79 GPa) for WPCs produced from wood (*Ceibapentandra*) particles and different plastic materials by Oluyegbe *et al* [24], and those reported by Aina *et al* [25]. The values also compared well with the typical values revised by Chan *et al* [26]. The

values were less compared to the values reported by Adefisan and McDonald [27] for composites produced from mahogany and teak. This can be linked to the fact that coupling agent was used for the WPC whose MOE was reported. The lowest mean value of MOE (0.24 GPa) was observed for the composites produced from the combination of large size wood particles (50%) and a mixture of LDPE and HDPE plastics (50%), while the highest mean value of the MOE (1.81 GPa) was observed for the composites produced from the extrusion of fine wood particles at 30% and HDPE at 70%. Generally, as the wood particles' size increased the MOE values decrease, and similar trend was observed as the wood proportions increased. The MOE also reduced. However, an increase in the proportion of plastic in the mixing ratio increases the MOE of the composite produced. These findings may be due to the high elastic nature of plastic which is better than that of wood. Another variable which had effects on the MOE of the WPCs produced is the type of plastic used; composites produced from HDPE had the highest observed mean MOE values, then composites produced from a mixture of both plastic types and finally the LDPE produced composites. Figure 4 shows the relationship between the production variables for the best performed produced WPC in terms of MOE.



Fig. 4: Influence of plastic types, and mixing ratio on the MOE of the WPC produced with fine particles

The results (Table 6) of the ANOVA test carried out indicated that the particle size, plastic types and mixing ratio all had significant effect on the MOE of the composites produced. The interactions of the plastic types with the particle sizes and with the mixing ratio both had significant effects on the MOE, while the interaction of the particle size and mixing ratio had no significant effect on the overall values of the MOE of the composite produced.



Table 6: ANOVA for the MOE of Composites Produced at 0.05 Significant Levels

Source of Variation	SS	df	MS	F ( $\alpha$ )	p-value	Sig.
Particle Size	1.632141	2	0.81607	254.0663	5.77E-08	Yes
Plastics Type	1.19503	2	0.597515	186.0236	1.96E-07	Yes
Mixing Ratio	0.693252	2	0.346626	107.9147	1.63E-06	Yes
particle size x Plastics Type	0.113259	4	0.028315	8.815221	0.004982	Yes
particle size x mixing ratio	0.03317	4	0.008293	2.581724	0.118144	No
Plastics Type x mixing ratio	0.131015	4	0.032754	10.19717	0.00314	Yes
Within	0.025696	8	0.003212			
Total	3.823563	26	0.14706			

Table 7: ANOVA for the MOR of Composites Produced at 0.05 Significant Levels

Source of Variation	SS	Df	MS	F	p-value	Sig.
Particle Size	28.25669	2	14.12834	36.72429	9.31E-05	Yes
Plastics Type	34.49216	2	17.24608	44.82832	4.5E-05	Yes
Mixing Ratio	51.39007	2	25.69503	66.78998	1.02E-05	Yes
particle size x Plastics Type	2.661822	4	0.665456	1.729741	0.23606	No
particle size x mixing ratio	6.412911	4	1.603228	4.167325	0.040951	Yes
Plastics Type x mixing ratio	0.873444	4	0.218361	0.567594	0.693668	No
Within	3.077711	8	0.384714			
Total	127.1648	26	4.890954			

### 3.5 Modulus of Rigidity (MOR)

Presented in Table 2 are the mean values observed for the MOR of the composites produced from the extrusion, at different proportion, of *Cordiamillenii* particles of different geometry and plastic types. The results showed the MOR values ranged from  $6.55 \pm 0.08$  to  $15.87 \pm 0.44$  MPa. These values compared favourably with the 7.3 – 21.7 MPa reported by Adefisanet *et al* [28] and the 2.76 – 16.42 MPa reported by Olugyeet *et al* [24]. The highest mean MOR value (15.87 MPa) was observed for the composite produced from the extrusion of fine particles <0.25 mm at minima composition of 30% and HDPE while the least mean MOR value (6.55 MPa) was observed for the composite produced from the extrusion of over-sized wood particles 1 < 2.0 mm at 50% proportion with LDPE. The MOR values tend to increase with decrease in the particle sizes and proportion of wood in the composite. This may be due to poor interfacial adhesion, as described by Chan *et al* [26]. A significant change was observed as the plastic types were changed from LDPE to HDPE and LDPE + HDPE. The HDPE performed best of the plastic types. This may be due to the density difference in the plastic types

which will invariably translate to the composites each produced. Figure 5 illustrates the effects of plastic types and mixing ratios on the composites produced with fine particles which gave the best tensile strength for the composites.

The WPCs produces showed a decreasing trend as the wood contents increased this may be due to disruption of the continuity of polymer matrix resulting into creation of several stress concentration points and therefore reduction in MOR. Also the larger the particle sizes the more the reduction in MOR. It was also observed that samples with fine particle size exhibited greater MOR than the oversized ones this could be as a result of better interaction and dispersion of fine particle sizes in the polymer matrices. The gradual loss in mechanical property could probably be attributed to an increased probability of flaws and defects in the composite matrix interface with reinforcing large particles.

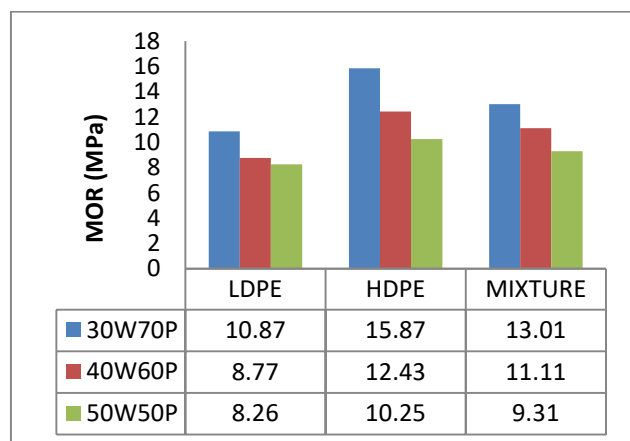


Fig. 5: Influence of plastic types, and mixing ratio on the MOR of WPC produced with fine particles

As presented in Table 7, the ANOVA test carried out indicated that the particle sizes, plastic types and mixing ratio all had significant effect on the MOR of the composites produced. The interactions of the plastic types with the particle sizes and with the mixing ratio both had no significant effects on the MOR, while the interaction of the particle size and mixing ratio had significant effect on the overall values of the MOR of the composite produced.

#### IV. CONCLUSIONS AND RECOMMENDATIONS

Wood plastics composite was produced from recycled polyethylene and *Cordiamillenii* wastes. The influence of wood particle size, plastic type and wood plastic mixing ratio on dimensional stability and strengths properties of wood composite boards was examined. The results obtained showed that:

- Moderate wood particle size produced acceptable non-structural wood plastics composite for internal and external application however further increase in *Cordiamillenii* particle sizes led to overall reduction in mechanical properties and stability probably due to dispersion and stress concentration problems.
- The higher the wood content in wood plastic composite the higher the water absorption, thickness swelling and linear expansion of the composite which will invariably affect the mechanical properties.
- The use of recycled Low density polyethylene, high density polyethylene and the mixture of the two produced acceptable wood plastic composite for internal and external applications within the specified parameters.

The mechanical and stability properties of the wood plastics composite can further be enhanced by pretreating the wood and by adding coupling agents

or compatibilizers to improve the compatibility. The use of recycled polyethylene and wood wastes may potentially reduce the pressure on the forest resources in the provision of furniture items and also reduce environmental pollution.

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