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PRODUCTION AND TESTING OF WOOD-PLASTIC COMPOSITES BOARDS FROM MIXED PARTICLES OF *GMELINA ARBOREA* AND *KHAYA IVORENSIS*

ADEFISAN, O.O.
Department of Agricultural and Environmental Engineering, University of Ibadan
femiadefisan@hotmail.com, oo.adefisan@mail.ui.edu.ng

ABSTRACT

A lot of wood waste is generated from wood species in the Nigerian wood mills which are hazardous to the mill, mill workers and the wood. These wastes can be incorporated into plastic composites to manufacture value added products for interior and exterior applications in housing construction. This work examined the production and testing of plastic composites from mixed sawdusts of *Gmelina arborea* and *Khaya ivorensis*. Mixed sawdusts of *G. arborea* and *K. ivorensis* collected from mills were screened, dried, milled to 0.4 mm particle sizes, blended with Polyvinylchloride (PVC) and chemical additives (calcium carbonate, talcum, calcium, magnesium and zinc stearate) in ratios 3: 16: 1; 5: 14: 1 and 7: 12: 1. The mixes were extruded at barrel and die temperatures of 140^0 C and 165^0 C, conditioned at temperature of 20^0C and relative humidity of 55%. Specimens were cut from the products and tested for flexural and sorption properties in comparison with those of locally sourced commercial 100% PVC. The moduli of rupture and elasticity of the plastic composites were between 13.2 to 22.9 N/mm^2 and 1254.0 to 3346.7 N/mm^2 respectively as against 2.4 N/mm^2 and 902.0 N/mm^2 for 100% PVC while the impact strength ranged between 5.0 to 7.9 N/mm^2 in comparison with 2.1 N/mm^2 for 100% PVC. The results obtained revealed that the flexural properties were superior to those of commercial 100% PVC and increased with increasing wood content. The plastic composites produced were dimensionally stable with low sorption rates and were suitable for moderately stressed interior and exterior purposes.

INTRODUCTION

Wood plastic composites (WPCs) are products made from mixtures of wood and thermoplastic polymers blended together under heat and pressure by extrusion, compression or injection processes. They are used in many countries such as United States of America, Canada, England, Spain, Taiwan, Switzerland, New Zealand etc. for cladding, siding, ceiling, railings, fencing, park benches, window and door frames, indoor furniture, structural construction support, etc. This is due their advantageous properties such as elegant wood grain texture, dimensional stability, pest, ultraviolet, and fade resistance, environmental friendliness, elegant and detailed shape design, ease of installation, workable using simple tools. They are also recyclable and less abrasive to processing equipment requiring low maintenance (San *et al.*, 2008).

The incorporation of wood to a thermoplastic matrix increases the mechanical and machining properties, thermal stability compared with solid thermoplastics. The thermoplastic component however, present moisture barriers to the wood elements, decreasing the water absorption and swelling characteristics when compared with wood and traditional wood composites (Woodhams *et al.*, 1993). In the production of WPCs, additives such as processing aids (lubricants, antioxidants, acid scavengers) to improve surface appearance and processing; property enhancers (biocides, coupling agents, inorganic fillers, fire retardants, UV stabilizers, colorants) to improve adhesion between the wood and plastic components are added in small amounts to enhance properties (Verhey and Laks, 2002).

In Nigeria, there is increasing demand for wood and wood products majorly for housing construction. This has culminated into over exploitation of wood in the forest resulting in dwindling timber supply and attendant depletion of Nigerian forest resources (Adefisan, 2010; Adewole, 2012). However, in the conversion of the dwindling wood resource to useful products, a lot of waste is generated in the mill due to inappropriate working practices and poor machinery (Adewole, 2012). These wastes constitute nuisance to the surrounding and are sources of hazards not only to the mill and mill workers but also to the wood products. A means of utilising these wastes is in the production of WPC which could serves as value added products for both interior and exterior purposes and augment small scale industrial enterprise especially the young Nigerian graduates seeking job opportunities. Also, characterisation of these products in terms of strength and sorption properties will be beneficial to the Nigerian populace who may seek to use these items as building components. This work therefore examined the production and testing of wood plastic composites made from mixed particles of *Gmelina arborea* (*Gmelina*) and *Khaya ivorensis* (Mahogany).

MATERIALS AND METHODS

Mixed sawdusts of *Gmelina aborea* and *Khaya ivorensis* were collected from saw mills in Akure environs. Polyvinyl chloride (PVC) was purchased from plastic company in Lagos while calcium carbonate, talcum, calcium, magnesium and zinc stearate were used as chemical additives. Foreign materials such as nails and stone were removed from the wood wastes which were later dried at temperature of 115°C.

Particle preparation and Blending

The dried particles were milled with a hammer mill with fitted sieve of 0.4 mm, blended with PVC and chemical additives in batch ratios 3: 16: 1; 5: 14: 1 and 7: 12: 1 and labelled P, Q and R respectively.

Board forming

The blended mix was transferred into a co-rotating twin-screw pelletizer to compound the mix into pellets at temperatures from 180^0 C to 190^0 C. Thereafter, the pellets were fed into an extruder at barrel and die temperatures of 140^0 C and 165^0 C. The extruded panels were conditioned in a chamber at temperature of 20^0C and relative humidity of 55% to prevent warping and cracking after which test samples measuring 150 mm x 60 mm and 50 mm x 20 mm were obtained for flexural and water resistance tests in accordance with ASTM D 790-07 (2008). Also, commercial PVC (100% PVC) used for ceiling applications were locally sourced, cut into samples sizes, tested and used as control.

Flexural Test

The flexural tests were conducted on a Universal Testing Machine at a cross – head speed of 1mm/min. The samples were loaded until failure occurred from which the Moduli of Rupture (MOR) and Elasticity (MOE) were evaluated. Impact test was based on repeated blows from increasing heights on the flat surface of the boards while noting the height of the ball that caused the failure impact.

Water Absorption (WA) and Thickness Swelling (TS) Test

The test samples were weighed and then immersed in distilled water at room temperature for 2 to 48 hours. At the end of 2 and 48 hours, each test samples were withdrawn from water and allowed to drain before the final weights and thicknesses were recorded. The water absorption and thickness swelling for each test piece was expressed as a percentage of the initial weights and thicknesses.

Results and Discussion

Flexural Strength

The results of the flexural tests are shown in Table 1. The MOR of the WPCs ranged between 13.2 N/mm^2 to 22.9 N/mm^2 as compared to 2.4 N/mm^2 obtained for 100% PVC. These values are low in comparison with those obtained by Migneault *et al*. (2008) and Schrip and Stender (2010) who recorded MOR values of 24 – 34 N/mm^2. As shown in Table 1, the MOR generally increased with increasing wood content. This observation is in line with the reports of San *et al*. (2008) that mechanical properties of plastic composites increase with increasing content of wood in the composites. While WPCs made with lower wood contents recorded low MOR and are not suitable for structural purposes but as insulating components as ceilings etc., products made with high wood recorded high strength values and suitable for moderately stressed applications.

The MOEs of the plastic composites were between 1254.6 N/mm^2 to 3346.7 N/mm^2 as against 902 N/mm^2 for 100% PVC. These values are similar to those reported by Migneault *et al*. (2008) and Schrip and Stender (2010) (3045 – 4582 N/mm^2). As shown in Table 1, composites made with higher plastic composites recorded low MOEs while products made with lower plastic component had high MOEs.

Table 1: Flexural Properties of Wood Plastic Composites

		N/mm^2	
Product Type	MOR	MOE	IMPACT STRENGTH
Control (100% PVC)	2.4^C (0.40)	902.0^D (9.5)	2.1^C (0.3)
P	14.3^B (0.15)	1510.2^B (120.8)	5.0^B (0.25)
Q	13.2^B (1.34)	1254^C (101.8)	5.0^B (0.45)
R	22.9^A (1.54)	3346.7^A (116.7)	7.9^A (0.25)

*Means with the same letters are not statistically different
*Standard deviation in parentheses

What this implies is that increasing plastic component during production significantly lowered the MOEs of the composites. The impact strength ranged between 5.0 to 7.9 N/mm^2 as against $2.1 N/mm^2$ for 100% PVC. The impact strength generally increased with increasing wood content in line with the report of Soroushian and Marikunte (1990).

Statistical analyses (Duncan's multiple test) revealed the product types significantly ($p \leq 0.05$) affected the MORs, MOEs and impact strength of the composites (Table 1). This may suggest that flexural properties of the plastic composites varied the product types.

Water Absorption (WA) and Thickness Swelling (TS)
The WA and TS of the WPCs are shown in Table 2. The respective WA and TS were between 0.3 to 2.7 % and 0.5 to 0.9 % after 2 h immersion in water and ranged between 0.8 to 18.4 % and 1.0 to 1.7% when soaked for 48 h in water. These values are comparable with those of San *et al.* (2008). Generally, the WPCs are dimensionally stable having low water absorption and thickness swelling rates. Hence they are suitable for both interior and exterior applications.

Table 2: Water Absorption and Thickness Swelling of Wood Plastic Composites

Soaking Time	WA (%)	TS (%)
100% PVC	-	-
P		
2 h	0.3^{F} (0.02)	0.5^{A} (0.19)
24 h	0.7^{F} (0.21)	0.7^{A} (0.13)
48 h	0.8^{F} (0.20)	1.0^{A} (0.22)
Q		
2 h	1.9^{EF} (0.44)	0.6^{A} (0.79)
24 h	3.9^{CD} (1.61)	1.3^{A} (1.29)
48 h	4.9^{C} (2.32)	1.6^{A} (1.81)
R		
2 h	2.7^{DE} (0.64)	0.9^{A} (0.09)
24 h	12.0^{B} (0.88)	1.3^{A} (0.25)
48 h	18.4^{A} (0.37)	1.7^{A} (0.24)

*Means with the same letters and within the same columns are not statistically different
*Standard deviation in parentheses

As shown in Table 2, boards with low wood components generally recorded the least water absorption and thickness swelling. This may be attributable to the fact that increase in wood content results in less encapsulation of wood by the matrix polymer and consequently absorbed more water (Stark, 2001).

Statistical analyses (Duncan's multiple test) revealed that while soaking time significantly ($p \leq 0.05$) influenced water absorption of the composites; the TS of the composites were not affected by the same (Table 2).

CONCLUSION

Wood plastic composites were produced from mixed particles of *Gmelina arborea* and *Khaya ivorensis*. The composites were dimensionally stable and possessed moderate strength applicable to both interior and exterior purposes. Increase in wood content during production significantly affected the strength and sorption properties of the composites.

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