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INVESTIGATION OF PROPERTIES OF PAPER-PLASTIC COMPOSITE MADE FROM KRAFT PAPER AND PLASTIC WASTES

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Abstract:
In this study, we investigated the compatibility of kraft paper and plastic wastes. Also, the physical and mechanical properties of the paper-plastic composite were determined. Pulverized kraft paper wastes and fine sachet water particles were weighed and mixed together using different mixing ratios (50% of paper & 50% of plastic (1:1), 33% of paper & 67% of plastic (1:2) and 25% of paper & 75% of plastic (1:3)). The method of composite production employed was extrusion method. The results of water absorption (WA) conducted on the paper-plastic composite material ranged between 0.03% – 0.16% and 0.03% – 0.20% for 2 and 24 hours respectively. The average values obtained for thickness swell (TS) ranged between 0.00% – 0.23% and 0.00% – 0.33% for 2 and 24 hours respectively. The average values obtained for tensile modulus ranged between 0.11GPa to 0.33GPa and the average values obtained for tensile strength ranged between 9.99MPa to 15.12MPa. The result obtained from this study shows that kraft paper wastes and water sachet wastes can be utilized as a composite material as they were compatible. In addition, 25% of paper & 75% of plastic waste (1:3) gives the best mixing ratio as indicated by the result with the most dimensionally stable and high strength properties.

Key words: *pulverized kraft paper wastes; sachet water particles; Paper Plastic Composites.*

INTRODUCTION

In recent time, man has increasingly improved the technologies adopted in wood processing to achieve better conveniences in terms of utilizing forest products for several applications including constructions, domestic appliances, technological design and products manufacturing (Hetemäki *et al*. 2005). The forest has always been the main resource for major raw materials needed for these uses, because of its ability to naturally regenerate and for the durability, workability and adaptability properties of wood for different conditions and uses. However, the influence of humankind dependence on the forest has over the years caused an immense collective effect of in-balance in the environment (Brundtland *et al*. 2012). This unabated phenomenon is evident in the present day in terms of global warming, environmental degradation, earthquakes, urban flooding and other environmental problems. Moreover, another major environmental concern is related to the plastic and paper wastes. These plastic wastes are not only generated in a large amount but they are also non-biodegradable, posing great environmental problems. Lots of attempts have been made globally especially by the developed countries to use these types of wastes as alternative materials to virgin ones (Winandy *et al*. 2004). These attempts intended to produce new materials from recycled ones, close the loop and imitate the natural ecosystem which is on the concept of a cradle to cradle approach (McDonough 2002). The result is to minimize the waste content, where all costs, energy, and depletion of virgin materials are reduced. Moreover, this fact assures the sustainability over the coming years for future generations' use (Youngquist 1992).

The use of both paper and plastic wastes for the production of paper-plastic composite will help to reduce the pressure on the forest, reduce environmental pollution and hazards and reduce emission from burning these wastes, which leads to global warming. Paper-plastic composite (PPC) is a product that could be obtained from plastic and paper wastes. PPC is a composite with a rapid growth usage consisting of a mixture of paper and polymeric material (Soury *et al*. 2009). Paper-plastic composites which can also be referred to as fibre-reinforced plastic composites where plastic acts as the matrix, or binders, and fibers act as the reinforcement (Tuaka 2005). The combination of the matrix phase with a reinforced phase produces a new material system, analogous to steel reinforced concrete (Bank 2006). The interest in using plastic as a

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binder in the composite board is attributed to its inherent properties including, inter alia, high dimensional stability and resistance to insect attack (Falk *et al*. 2000).

OBJECTIVE

The general objective of this study is to investigate the properties of paper plastic composites made from Kraft paper and plastic wastes.

Specific Objectives is to:

1. Investigate the suitability/compatibility of kraft paper and plastic wastes for the production of paper plastic composites.
2. Determine the tensile strength, tensile modulus, thickness swelling and water absorption properties of the paper-plastic composites.

Determine the effect of different mixing ratio on the physical and mechanical properties of the paper-plastic composites.

METHODS

The kraft paper wastes were collected from Walex Paper Enterprise, Akure. It was soaked for three weeks. Then, it was sun-dried for two weeks, re-milled, and transformed into powder form and finally packed in a sealed nylon bag to reduce the changes in the moisture content. The water sachet wastes (LDPE plastic) were collected from the refuse dumping site at MTN sponsored waste recycling company at Alesinloye market, Ibadan, Oyo state. These sachet wastes were thoroughly washed, sun dried and later pulverized. Sachet wastes were sieved with 0.5mm sieve mesh to get fine particles. Paper and Plastics wastes were weighed using different mixing ratios: 50% paper & 50% plastic (1:1), 33% paper & 67% plastic (1:2) and 25% paper & 75% plastic (1:3). The pulverized paper and plastic wastes were thoroughly mixed and introduced into the hopper of the extruding moulding machine. The temperature of the hot plates was set between 180^{o}C and 200^{o}C. After manufacturing the composite, the following tests were carried out: tensile strength, tensile modulus, water absorption and thickness swelling.

Determination of dimensional stability (Thickness swelling and water absorption)

Three specimens with sizes of 50mm×20mm×5mm were used to determine the thickness swelling and water absorption properties of the composite. The thickness of the test specimens was measured with a vernier calliper and the weight of the specimens was taken using electronic sensitive weighing balance. The test specimens were then immersed in cold water for 2 hours and 24 hours. The specimens were later removed and drained with clean tissue paper to remove excess surface water. Thereafter, specimens were weighed and thickness was measured. Water absorption was calculated from the increase in weight of the specimens as follows

$$WA(\%) = \left(\frac{W_2 - W_1}{W_1}\right) X100$$

where: WA = Water absorption (%);
W_2 = Final weight after soaking (g);
W_1 = Initial weight before soaking (g).

The thickness swelling is expressed as a percentage increase of the original thickness. It is calculated as follows:

$$TS(\%) = \left(\frac{T_2 - T_1}{T_1}\right) X100$$

where: TS = Thickness swelling (%);
T_2 = Final thickness after immersion (mm);
T_1 = Initial thickness before immersion (mm).

Determination of mechanical properties

The mechanical test was carried out at the Research and Development Department, Engineering Material Development Institute (EMDI), Akure. Three samples from each of the mixing ratios were used, making a total of nine samples. The samples were machined to fit the accessories of Instron universal testing machine, a machine manufactured by the Illinois Tool Works (ITW) company, Norwood, Massachusetts.

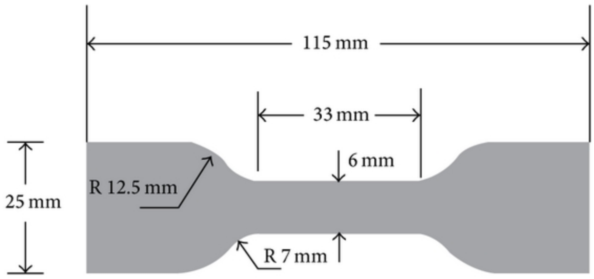

Fig. 1.
Test sample for Tensile test and tensile modulus (Surangsrirat et al. 2016).

The mechanical properties results (tensile strength and tensile modulus) were generated automatically by the universal testing machine computer software.

RESULTS AND DISCUSSION
Dimensional Stability Tests

Table 1

Effect of Mixing Ratios on % Water Absorption and thickness swelling

Mixing Ratio	Hrs	% WA ± SE[1]	% TS ± SE
1:1	2	0.13 ± 0.04	0.07 ± 0.11
	24	0.15 ± 0.06	0.19 ± 0.20
1:2	2	0.09 ± 0.04	0.05 ± 0.09
	24	0.09 ± 0.04	0.06 ± 0.08
1:3	2	0.04 ± 0.02	0.04 ± 0.05
	24	0.04 ± 0.02	0.05 ± 0.06

[1]SE represents standard error

The results of the physical tests (water absorption and thickness swelling) conducted on the paper-plastic composite samples after 2 and 24 hours immersion in water are presented in Table 1. The average values obtained for water absorption (WA) test for 2 hours and 24 hours ranged between 0.03% to 0.16% and between 0.03% to 0.20%, respectively. Also, the average values of the nine samples obtained for thickness swelling (TS) test for 2 hours and 24 hours ranged between 0.00% to 0.23% and between 0.00% to 0.33%, respectively as shown in Table 1. This result agreed with the findings of Ajayi and Aina (2010) and Omorege (2009) with percentage water absorption and percentage thickness swelling that ranged between 0.06%-0.40% and 0.09%-0.28% respectively. The results revealed that the samples with the (3:1) plastic to paper mixing ratio has the lowest mean value of 0.04% and 0.04 for water absorption and thickness swelling respectively. The reason for the low values could probably be because of the reduction in pores spaces, good internal bond formation and a decrease in cellulosic component (paper waste) which absorbs water.

Table 2

Analysis of Variance for percentage Water Absorption

SV	df	SS	MS	F	Sig
Treatment	2	0.01	0.01	4.45	0.07 ^{ns}
Error	6	0.01	0.00		
Total	8	0.02			

Not Significant ^{ns} *(P > 0.05)*

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Table 3

Analysis of Variance for percentage Thickness Swell

SV	df	SS	MS	F	Sig
Treatment	2	0.07	0.03	1.64	0.27 ns
Error	6	0.12	0.02		
Total	8	0.18			

Not Significant ns (P > 0.05)

The analysis of variance conducted on the %WA and %TS of the PPC composite material after 24 hours of soaking in water are presented in Table 2 and 3, respectively. The results show that there is no significant difference between the three mixing ratios considered both for the water absorption and thickness swell test at 95% confidence level (p<0.05).

Mechanical Test

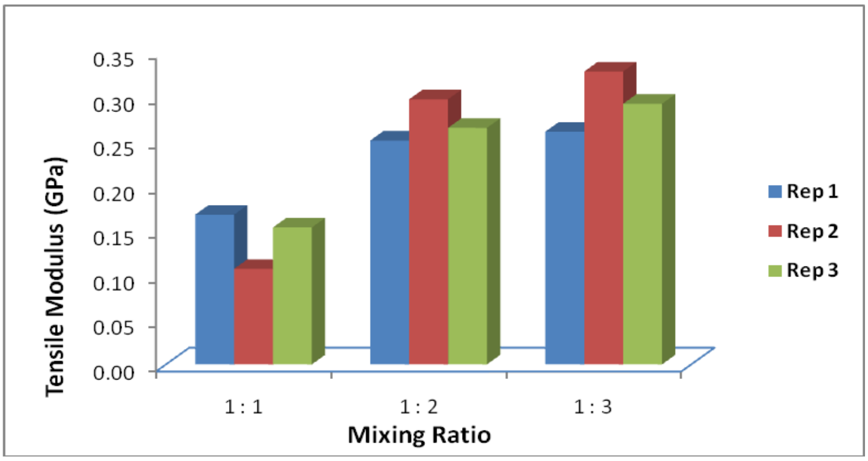

Fig. 1.
Effect of mixing ratio (paper: plastic) on tensile modulus of the PPC materials (Rep 1, 2 and 3 means Replicate 1, 2 and 3).

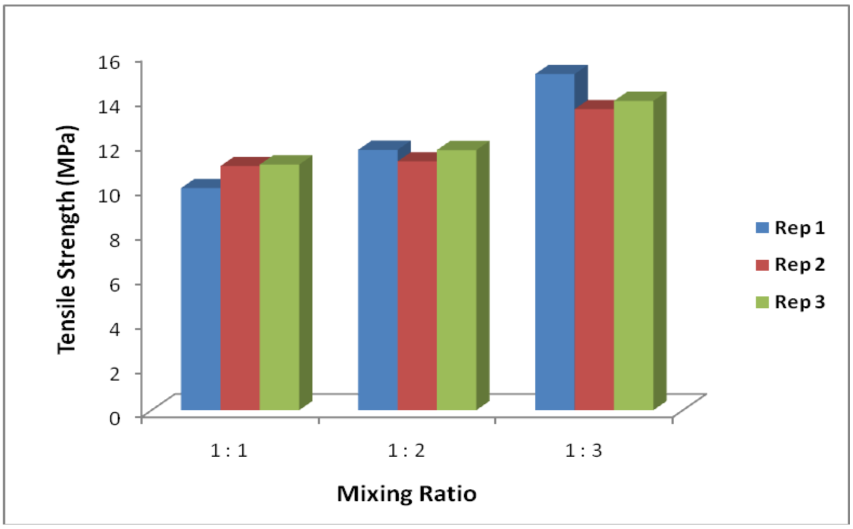

Fig. 2.
Effect of Mixing Ratio on the Tensile strength of the PPC materials (Rep 1, 2 and 3 means Replicate 1, 2 and 3).

The results of the mechanical tests are shown in Figs. 1 and 2. The average values obtained for tensile strength and tensile modulus are 12.56MPa and 0.22GPa respectively. These results followed the same trend with the previous reports of (Ajigbon and Fuwape 2005) for *Terminalia superba* with HDPE as a binder; (Aina and Fuwape 2008) for *Gmelina arborea* with HDPE as a binder. The tensile modulus result agreed with the report of Terry *et al*. (2000) with the average tensile modulus of 11.4MPa. Although, there was a deviation in the results of Song and Hwang (2001) with an average tensile modulus of 0.75GPa. The reason for this deviation could be because the components of the composite were wood fiber and recycled tire rubber. The paper-plastic composite material with 50% paper wastes and 50% plastic wastes by percentage (1:1) has the lowest mean values for tensile modulus and tensile while the paper-plastic composite material with 25% paper and 75% plastic by percentage (1:3) has the highest mean values for tensile modulus and tensile strength. This implies that the plastic component of the composite material will require more stress to either break or deform it because of its elasticity nature. That is, the plastic will accommodate more stretch or pull before breaking than the fiber.

Table 4

Analysis of Variance for Tensile Modulus

SV	df	SS	MS	F	Sig
Treatment	2	0.04	0.02	22.03	0.00 *
Error	6	0.01	0.00		
Total	8	0.05			

Significant (P < 0.05)*

Table 5

Analysis of Variance for Tensile strength

SV	df	SS	MS	F	Sig
Treatment	2	20.16	10.08	26.94	0.00 *
Error	6	2.25	0.37		
Total	8	22.41			

Significant (P < 0.05)*

The analysis of variance conducted on the tensile modulus and tensile strength properties of the paper-plastic composite materials is presented in Table 4 and 5 respectively. The results show that there is no significant difference between the different mixing ratio considered for tensile modulus and tensile strength at 95% confidence level (p<0.05).

Table 6

Result of the DMRT carried out at 0.05 level of significance, showing the effect of mixing ratio on the mechanical properties

	Modulus (GPa)	Tensile Strength (MPa)
1:1	0.14^a	10.67^a
1:2	0.27^b	11.53^a
1:3	0.29^b	14.19^b

Mean values followed by the same letter are not significantly different at P< 0.05 level of significance using DMRT

The result of the follow-up test as shown in Table 6 indicates that there is no significant difference between mixing ratio 1:1 and 1:2 while both mixing ratios are different significantly from 1:3 mixing ratio.

CONCLUSION

Paper and plastic wastes can be formed into a useful composite material, rather than polluting the environment. In order to understand the best mixing ratio and the properties of this composite material, a careful investigation was made, which includes comprehensive physical tests (water absorption and thickness swell) and mechanical tests (tensile modulus and tensile strength). From the results of the tests, combining plastic and paper wastes in ratio 3 to 1 respectively show the best physical and mechanical properties. It implies that this composite material has the potential to be used as a substitute for wood materials. However, more study needs to be carried out to ascertain the appropriate uses this composite material will best fit.

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