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Dynamic Vulcanization and Voids Content of Low-Density Polyethene/Natural Rubber Filled Coir Fibre Composites

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ABSTRACT
The study was aimed to determine the effect of dynamic vulcanization on density and voids content of low density polyethene/natural rubber filled with coir fibre (CF) at different percentage loadings. The voids contents were determined from the values of theoretical and experimental densities of non vulcanized LDPE/NR composites and their corresponding vulcanizates. The dynamically vulcanized composites have recorded higher densities than the non-vulcanized ones. This could be due to the cross linkage formed during vulcanization resulted into high compactness of the materials. Generally, higher percentage voids contents were recorded with increase in fibre content, with the exception of composite loaded with 40% CF. The decline signifies better interaction and interfacial adhesion between CF and the matrix at the respective fibre loading as supported by SEM.
Keywords: Coir fibre, composites, natural rubber, dynamic vulcanization, density, voids

INTRODUCTION
In recent years thermoplastic rubber composites filled with natural fibres have received special attention from researchers and manufacturers due to their lightness, low cost, ease of processing, and recyclability (Egwaikhide *et al.,* 2017). Voids also refer as pores are regions unfilled with matrices and fillers within a composite. They are considered a defect and also inevitable in the final product. It was established that voids are caused due to different manufacturing processes resulting into damaging to the reliability of the general properties of the composites. In this study, thermoplastic natural rubber (TPNR) composites filled with coir fibre were dynamically vulcanized using sulphur as a crosslinking agent to arrive at the products that are slightly dense and more compact as compared to the non-vulcanized ones. The experimental and theoretical densities were used to determine the voids content of the composites.

Hence, dynamic vulcanization found to improve the level of porosity of the TPNR composites to the bearable limits.

MATERIALS AND METHODS

Materials

Coir fibre (CF): The coir fibres were extracted by means of water retting process. The coir pods obtained as waste were allowed to soak in water for two weeks and extracted mechanically using a wooden mallet. Fine golden brown fibres were obtained and subsequently, washed in cleaned water and dried. Natural rubber (NR) was obtained from National Rubber Institute, Benin. Low-density polyethylene (LDPE) obtained as commercial grade.

Equipment

Two rolls mill, Model: 5183 North Bergen U.S.A. A Compression Moulding Machine, Model: 0557 and Digital analytical weighing balance.

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Methods

Preparation of the composites

Table: Formulation for LDPE/NR Blend and their Vulcanizates

S/N	Sample code	LDPE (%)	Natural Rubber (%)	Coir fibre (%)	Vulcanizing agents (Phr)				
					ZnO	MBTS	Stearic Acid	TMQ	Sulphur
1.	$P_{90}R_{10}$	90	10	0	-	-	-	-	-
2.	$P_{90}R_{10}C_{10}$	90	10	10	-	-	-	-	-
3.	$P_{90}R_{10}C_{20}$	90	10	20	-	-	-	-	-
4.	$P_{90}R_{10}C_{30}$	90	10	30	-	-	-	-	-
5.	$P_{90}R_{10}C_{40}$	90	10	40	-	-	-	-	-
6.	$P_{90}R_{10}C_{50}$	90	10	50	-	-	-	-	-
7.	$VP_{90}R_{10}$	90	10	0	5	2	2.5	1.5	2.5
8.	$VP_{90}R_{10}C_{10}$	90	10	10	5	2	2.5	1.5	2.5
9.	$VP_{90}R_{10}C_{20}$	90	10	20	5	2	2.5	1.5	2.5
10.	$VP_{90}R_{10}C_{30}$	90	10	30	5	2	2.5	1.5	2.5
11.	$VP_{90}R_{10}C_{40}$	90	10	40	5	2	2.5	1.5	2.5
12.	$VP_{90}R_{10}C_{50}$	90	10	50	5	2	2.5	1.5	2.5

(Baba, 2022)

Determination of Experimental Density

Density is one of the most important parameter used in determining the area of a composite. The procedure is based on the specific gravity measurement ASTM specification D792-86. Weights of the composites nearest to 0.001g were determined using an electronic top pan weighing balance, and also their volumes calculated from the dimensions. The densities were then calculated using equation (1)

$$\text{Density } (\rho) = \frac{\text{Mass}}{\text{Volume}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 1$$

Determination of Theoretical Density

Theoretical densities of Non-vulcanized LDPE/NR and dynamically vulcanized LDPE/NR filled coir fibre composites at different percentage loading of (0-50) were determined in accordance with ASTM 2734, using equation 2.

$$\rho_{theoretical} = \left[\left(\frac{w_f}{\rho_f}\right) + \left(\frac{w_m}{\rho_m}\right)\right]^{-1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 2$$

Where:

w_f, w_m, ρ_f, and ρ_f, are fibre weight fraction, matrix weight fraction, density of fibre and density of the matrix, respectively.

Percentage Voids Content of a Composite

The voids contents were determined from the values of theoretical and experimental densities of non vulcanized LDPE/NR composites and their corresponding vulcanizates using equation 3.

$$Voids\ content = \frac{\rho_{theoretical} - \rho_{experimental}}{\rho_{experimental}} \quad \ldots\ldots\ldots\ldots\ldots \quad 3$$

The values of theoretical densities of the composites produced were computed using equation 2, while experimental densities were determined using experimental procedures. The voids content is normally expressed in percentage as represented graphically in figure 4.

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RESULTS AND DISCUSSIONS

Experimental Density

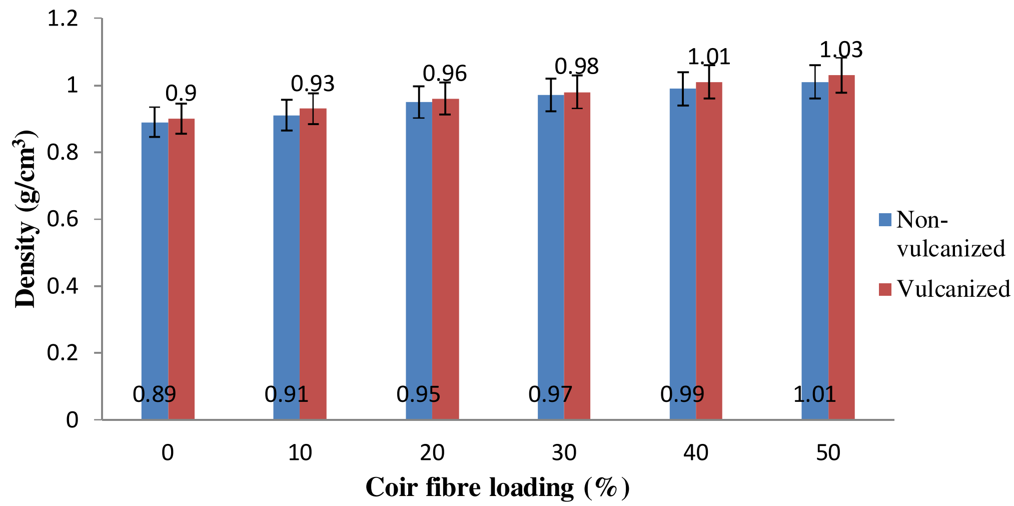

Figure 1: Effect of fibre loading on the density of LDPE/NR filled CF composites

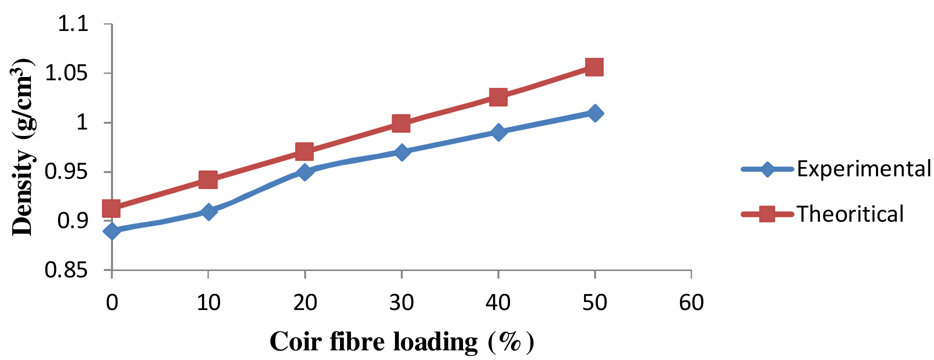

Figure 2: Experimental and theoretical densities of non-vulcanized low-density polyethene/natural rubber composites filled with (10-50)% coir fibre

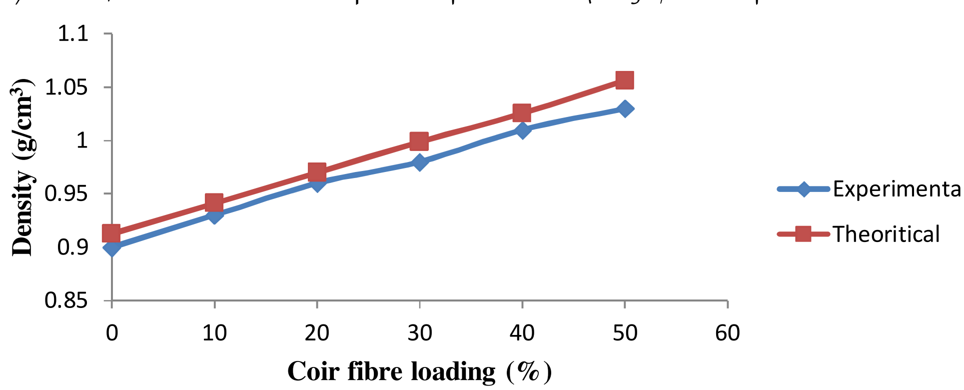

Figure 3: Experimental and theoretical densities of dynamically vulcanized low-density polyethene/natural rubber composites filled with (10-50)% coir fibre

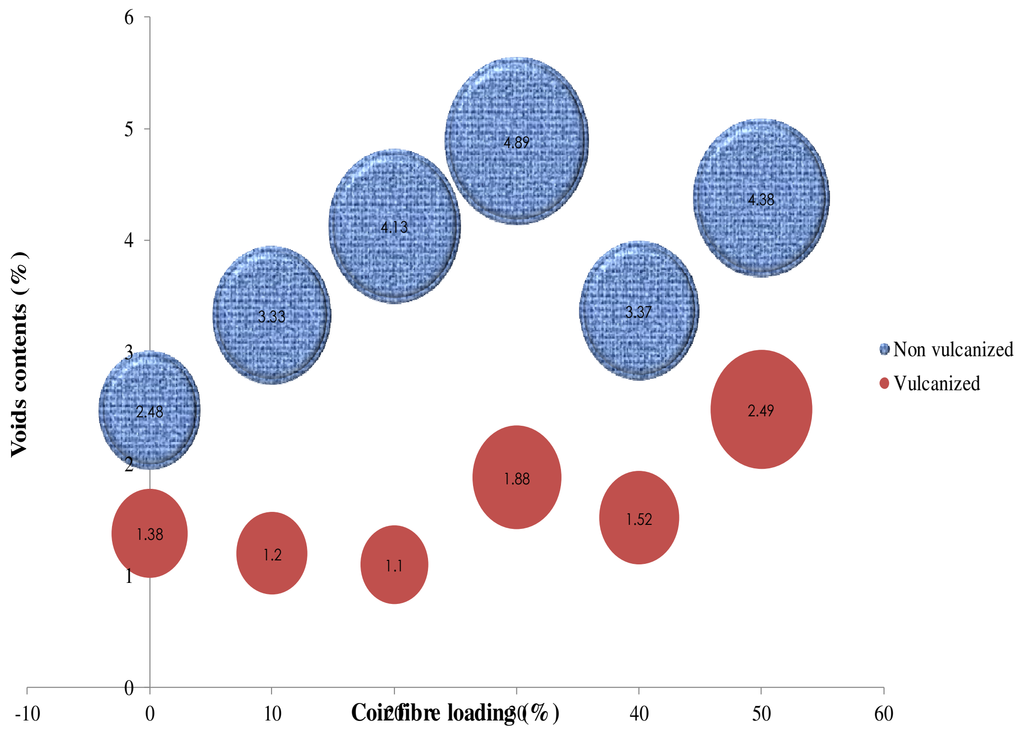

Figure 4: Voids contents of non vulcanized and dynamically vulcanized low-density polyethene/natural rubber composites filled with (10-50)% coir fibre

Figure 2 showed the experimental and theoretical densities of non-vulcanized LDPE/NR composites filled with coir fibre at different loadings from (0-50) %. It was generally observed that the densities of the composites increases with an increase in coir fibre, this could be attributed to the higher density associated with the coir fibre as compared with the matrix. The experimental density of the matrix ($P_{90}R_{10}$) was found to be 0.89g/cm^3, however, with the incorporation of coir fibre at 10, 20, 30, 40 and 50 percents, densities of the composites have shifted to 0.91, 0.95, 0.97, 0.99 and 1.01, respectively. The experimental densities of the non-vulcanized composites were compared with the theoretical values calculated from the rule of mixtures using equation (2). It was generally observed that the values of the theoretical densities are slightly higher than the experimental densities. The slight difference in densities could be as a result of voids created during processes of compounding and compression moulding of the composites. The difference in density could also be as a result of interspatial spaces created by the fibres incorporated into the matrix as reinforcement/fillers (Mario *et al.,* 2018). As shown in Figure 4, void contents increased with increase fibre content with the exception of $P_{90}R_{10}C_{40}$, the composite filled with 40% coir fibre, signified better interaction and interfacial adhesion between CF and the matrix at the respective fibre loading. In Figure 3, similar trend was observed for the respective vulcanizates, with similar coir fibre of (10-50) % loadings. The theoretical densities are slightly higher than the experimental densities of the composites produced.

In comparison, the dynamically vulcanized composites have recorded higher densities than the non-vulcanized ones. This could be due to the cross linkage formed during vulcanization resulted into high compactness of the material (Ansarifar *et al.,* 2019). Additionally, the voids contents of the composites were also deduced from the differences of theoretical and experimental densities in which were supported by SEM and water absorptions (Baba, 2022)

Plate 1: SEM of fractured surface from tensile measurement sample of $P_{90}R_{10}$

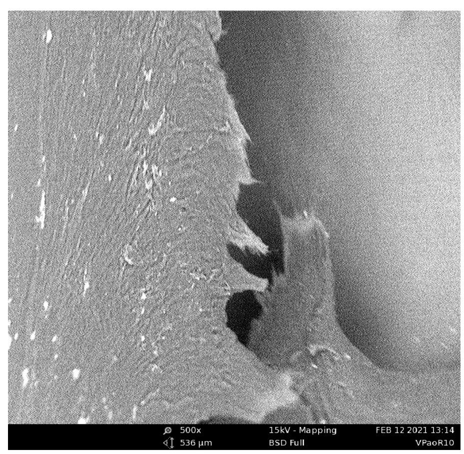

Plate 2: SEM of fractured surface from tensile measurement sample of $VP_{90}R_{10}$

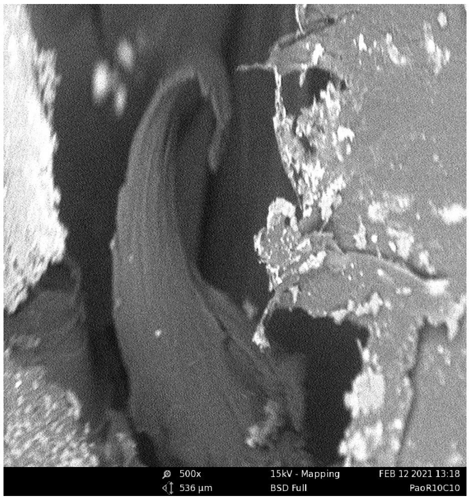

Plate 3: SEM of fractured surface from tensile measurement sample of $P_{90}R_{10}C_{10}$ *(filled with 10% CF)*

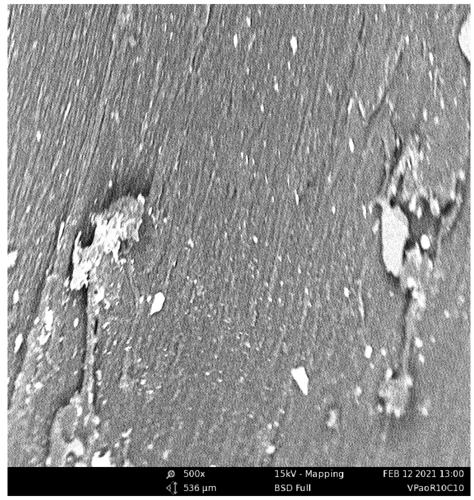

Plate 4: SEM of fractured surface from tensile measurement sample of $VP_{90}R_{10}C_{10}$ *(filled with 10% CF and vulcanized)*

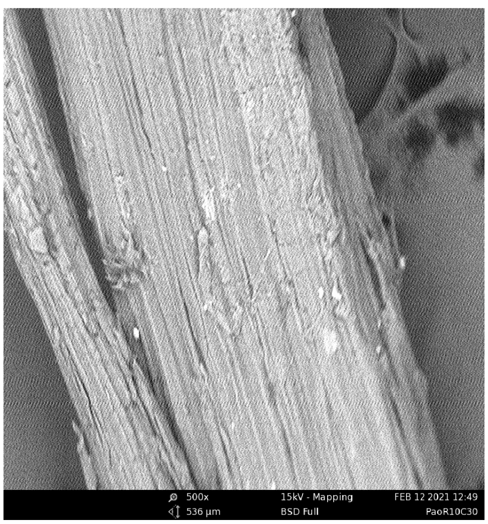

Plate 5: SEM of fractured surface from tensile measurement sample of $P_{90}R_{10}C_{30}$ *(filled with 30% CF)*

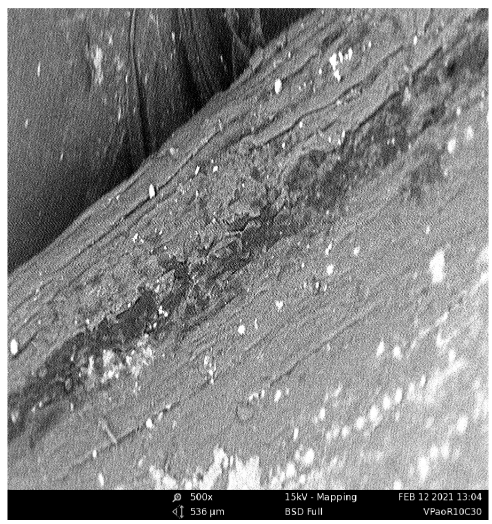

Plate 6: SEM of fractured surface from tensile measurement sample of $VP_{90}R_{10}C_{30}$ *(filled with 30% CF and vulcanized)*

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Plate 7: SEM of fractured surface from tensile measurement sample of *$P_{90}R_{10}C_{40}$ (filled with 40% CF)*

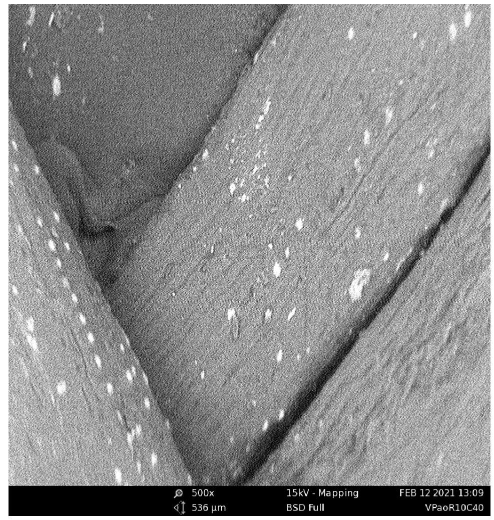

Plate 8: SEM of fractured surface from tensile measurement sample of *$VP_{90}R_{10}C_{40}$ (filled with 40% CF and vulcanized)*

Plate 9: SEM of fractured surface from tensile measurement sample of *$P_{90}R_{10}C_{50}$ (filled with 50% CF)*

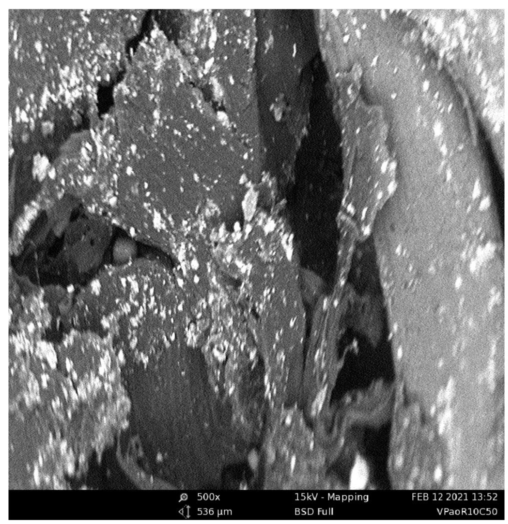

Plate 10: SEM of fractured surface from tensile measurement sample of *$VP_{90}R_{10}C_{50}$ (filled with 50% CF and vulcanized)*

CONCLUSION

The density of the composites increases with an increase in filler loading. The dynamically vulcanized LDPE/NR-filled coir fibre composites recorded higher densities against the corresponding non-vulcanizates. It also observed an increase in voids content with an increasing filler loading of up to 30%. The maximum percentage voids for the non-vulcanized composites and the dynamically vulcanized composites were 4.89% and 2.49% at 30% and 50% filler loadings, respectively. The general low percentage voids exhibited by the composites with less than 5% signifies that two rolls mill/compression moulding would be a suitable method for the production of LDPE/NR filled coir fibre composites and their vulcanizates.

REFERENCES

Anour, S., Abdalah, K., Rabea, E., Shalh, A., Hassan, E., & Wael, E. (2018). The Influence of LDPE Content on the Mechanical Properties of HDPE/LDPE Blends, *C Material Science* CRIMSON PUBLISHERS. Volume-7 Issue-5. ISSN: 2576-8840. p 791-797.

Ansarifar, A., Noulta, K., Weaver, G. W. and Wijayantha, K. G. U. (2019). An alternative method for the vulcanization of rubber articles. *International Journal for Polymer Industry.* Volume 14, 184-188.

Baba, M. A. (2022). Thermo-Mechanical Properties of Low-density Polyethylene/Natural Rubber Vulcanizate Blends filled Coir Fibre Composites. Ahmadu Bello University, Zaria *(PhD thesis unpublished)*

Egwaikhide, P. Akporhonor, E and Okiemen, F. (2007). Effect of Coconut Fibre Filler on the Cure Characteristics, Physico-mechanical and Swelling Properties of Natural Rubber Vulcanizates, *International Journal of Physical Sciences* 2(2): 039-046

Mario, F. M., Miguel A. H. and Jose H. M. (2018). Effect of Content and Surface Modification of Fique Fibers on the Properties of a Low-Density Polyethylene (LDPE)-Al/Fique Composite. *Polymers,* 10(10), 1050; doi: 10.3390/polym10101050