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PRODUCTION OF WASTE LOW DENSITY POLYETHYLENE/CASTOR SHELL POWDER COMPOSITE AND INVESTIGATION OF ITS PHYSICO-MECHANICAL PROPERTIES

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ABSTRACT

The aim of this work is to produce a low-density polyethylene composite filled with castor shell powder. This involves collection, preparation and chemical treatment of castor seed shell. The composite samples were prepared by compounding the treated and untreated castor powder with LDPE on the two- roll mill, and then followed by compression with the compressing molding machine. tests on tensile strength, flexural strength, hardness test, and impact test and water absorption properties were carried out to determine the properties and optimum results were obtained.

KEYWORDS

Castor shell, LDPE, composite, tensile strength, impact strength

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INTRODUCTION

Bio composites development has been done by many scientific and engineering researchers as a way to reduce the utilization of petrol-derived thermoplastic for making plastic products, mainly as a result of environmental concern and threats of petroleum supply diminution in future times. Utilization of availably abundant natural fillers within our surrounding will produce environmentally friendly and low-cost products as well. However, the major challenge with biocomposites is the incompatibility between natural fillers and polymer matrices. This challenge has drawn many composite researchers to propose various ways to enhance the compatibility between the components of the biocomposite via the use of a coupling agent or compatibilizer. This is vital, as it will enhance the mechanical, thermal, and other related properties of the prepared biocomposites (Sudari *et al*., 2015).

Present day engineering utilizes materials with usual combination of properties that is difficult to be met by conventional alloys. Ceramics and polymer are potential materials that gives rise to emerging varieties of ecofriendly materials used in manufacturing of products across different applications. Although metals have been the determinant material for centuries, in the past few decade's plastics, ceramics and composite are majorly used in engineering applications. Composites in our present-day practice are developed to achieve better properties through combination of various engineering materials (Williams, 2008).

This work focuses on agriculturally based filler from castor seed shells as the reinforcement material and low density polyethylene (LDPE) as the matrix. The filler owing to their eco-friendly and biodegradable as well as relatively cheap. Synthetic polymers are generally non-degradable thereby polluting the environment.

MATERIALS AND METHODS

Materials	**Source**
Waste low density polyethylene (LDPE)	Samaru Environment
Castor seed shell	Enugu State, Nigeria

Equipment

Table 1: List of equipment used for this research

S/n	Equipment	Manufacturer	Model no.
1	Two-roll mill	Reliable rubber and Plastic machinery	5185
2	Compression Machine	Carver inc., Wabash, USA	3851-0
3	Impact Tester	Ceast	6957
4	Weighing Balance	A and D Instrument	HR-200-BC
5	Hardness Tester	Vickers	MV 1-PC
6	Tensiometer	Transcell Technology	BAB-200

Methods

Collection, preparation and chemical treatment of castor seed shell

The castor seed shells were collected from Enugu State, Nigeria. It was washed, so as to remove dirt and impurities. Two percent solution was prepared (2 mol solution) of sodium hydroxide. The castor seed shell was poured and stirred for 5 minutes and further allowed for 24 hours after which it was thoroughly washed with distilled water and dried at room temperature for two days. The castor seed shell that was utilized for the composite productions are the Alkaline Treated Castor Seed Shell (TCSS) and the Untreated Castor Seed Shell (UCSS).

Table 2: Formulation table for compounding of RLDPE/TCSS and /UCSS

S/n	Samples	RLDPE (g)	TCSS (g)	UCSS (g)
1	A	100	0	0
2	B	90	10	10
3	C	80	20	20
4	D	70	30	30
5	E	60	40	40
6	F	50	50	50

Compounding and compressing

The composite samples were prepared by mixing the castor seed shell (TCSS and UCSS) powder with the RLDPE. The mixing was done on the two-roll mill for 7 minutes at a temperature of 120 ^{o}C according to formulation. Further compression on the mixed samples was done using the compression molding machine for 10 minutes at temperature of 140 ^{o}C and each sample was subjected to various mechanical and physical property testing.

Water absorption test

The obtained samples were cut into the same dimensions of 10mm x 3mm sizes. All samples were immersed into water for 24 hours after weighing them. Afterwhich weight the samples were reweighed and differences taken. The water absorption was calculated using the following equation:

$$M = \frac{W_2 - W_1}{W_1} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (1)$$

Where:

M- Percentage water absorption

W_1- Initial Weight of sample before immersion

W_2- final weight sample after immersion

Tensile test

The tensile test was carried out using the Transcell Technology Tensometer (model BOB-200) CAP. 200 kg AT. 1.9951 MV/V according to ASTM D-638. A dumbbell shaped samples were subjected to a tensile force and tensile properties such as tensile strength, modulus for each sample were printed out and analyzed.

Impact test

The impact test was carried out according to the standard specified by ISO 179 ASTM D-156. The test samples were cut to (50 x 10) mm at 7 mm thickness from all the composites produced. The impact energy test was carried out using Izod Impact Tester (Resil impactor testing machine). The specimen was clamped vertically (IZOD) on the jaw of the machine and hammer of weight 1500 N was released from an inclined angle 150°. The impact energy for corresponding tested sample was taken and recorded. Impact strength was calculated and recorded accordingly. The Impact strength was determined using equation below:

$$Impact\ strength = \frac{impact\ energy}{thickness}\ (J/mm) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(2)$$

Hardness test

The hardness test was carried out using the Vickers Hardness tester with model MV1-PC, serial no. 07/2012-1329 on shore D scale in accordance with ASTM D785-08 standard for composites. The sample was placed on the mounting stage and the dial gauge adjusted to zero (0), the hand lever was used to raise the stage such that the sample come in contact with the dial point and exact pressure/force on the sample and the reading was taken. This was repeated three (3) times at different positions on the sample. Average hardness value was determined using the equation below:

$$\boldsymbol{Average\ Hardness} = \frac{\boldsymbol{1^{st} + 2^{nd} + 3^{rd} readings}}{\boldsymbol{3}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(\boldsymbol{3})$$

Flexural strength

The composite samples were die-cut (rectangular shape) and the thickness and width of each sample was taken. Each sample was then placed in the grips of the testing machine symmetrically in order for the tension to be distributed uniformly over the cross-sectional area. Force was exacted on the sample until it reaches its elastic limit According to the ASTM D790-10 standard.

$$flexural\ strength = \frac{3\rho l}{2bt^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(4)$$

Where, L=Length, b=Width, ρ=Load, t=Thickness of the composite samples.

RESULTS AND DISCUSSION

Results

Filler characterization

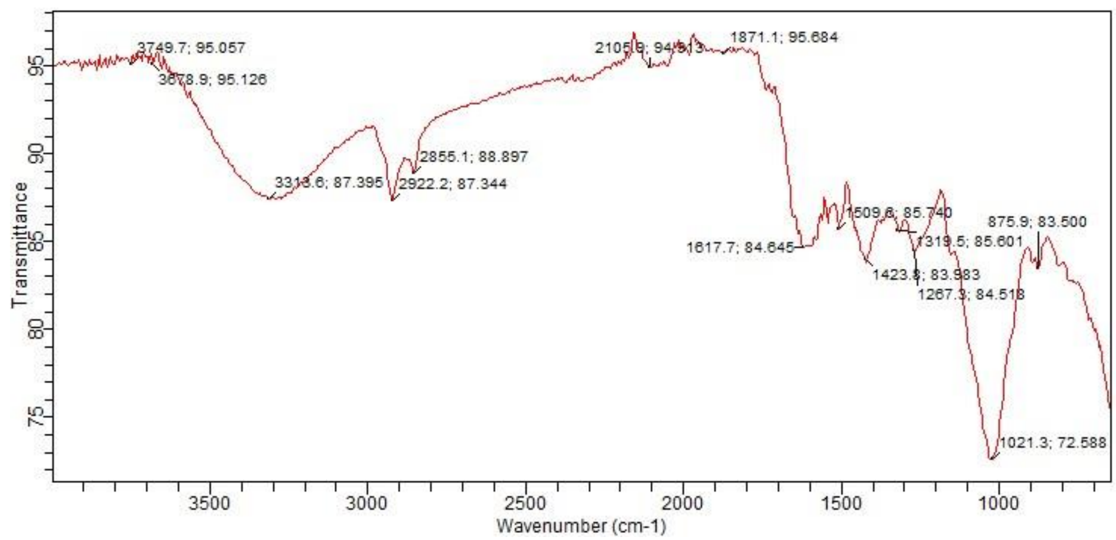


Figure 1: FTIR spectral of treated castor seed shell

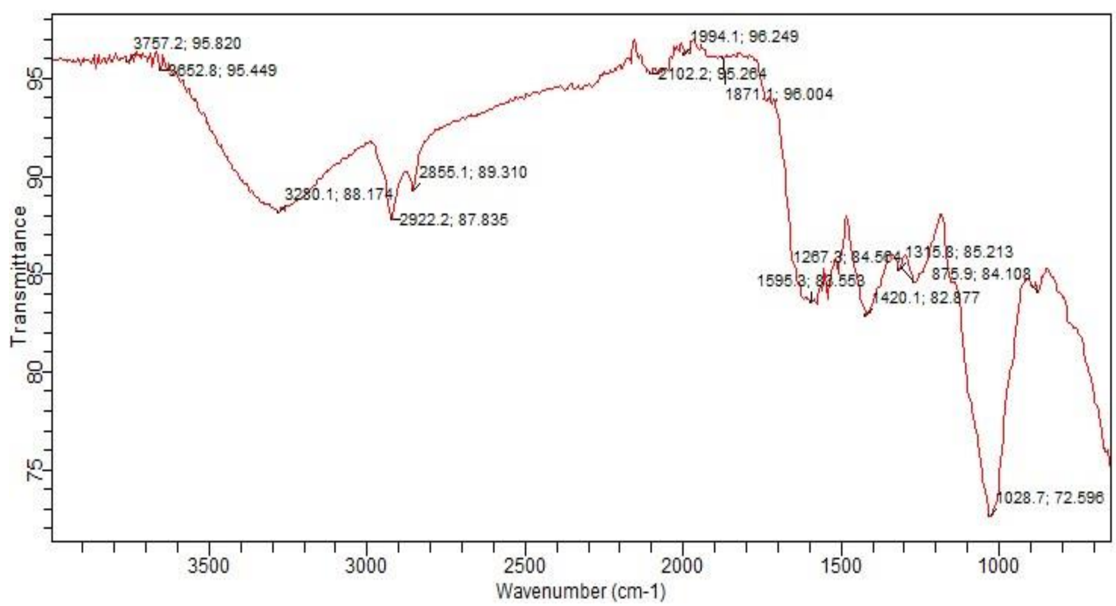


Figure 2: FTIR result of untreated castor seed shell

Water absorption of composites

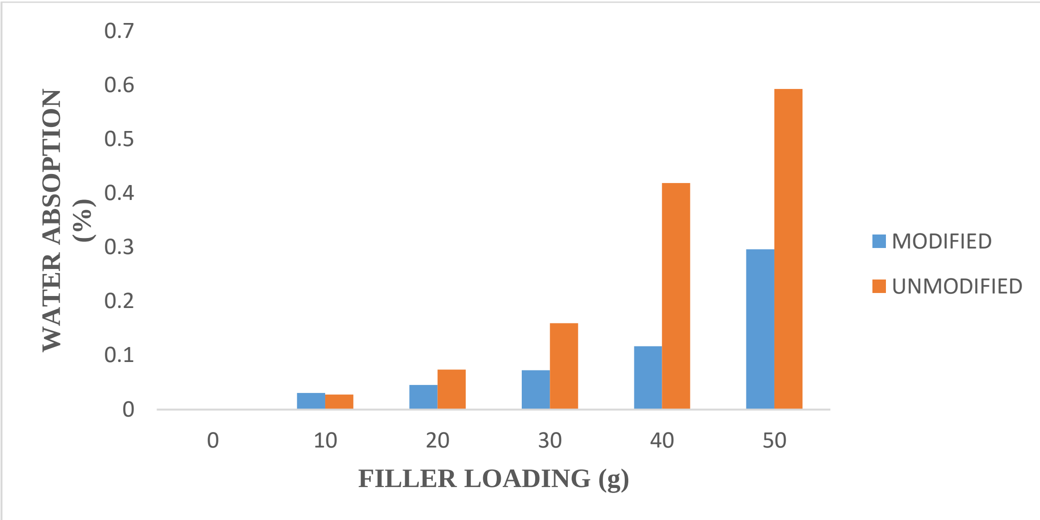
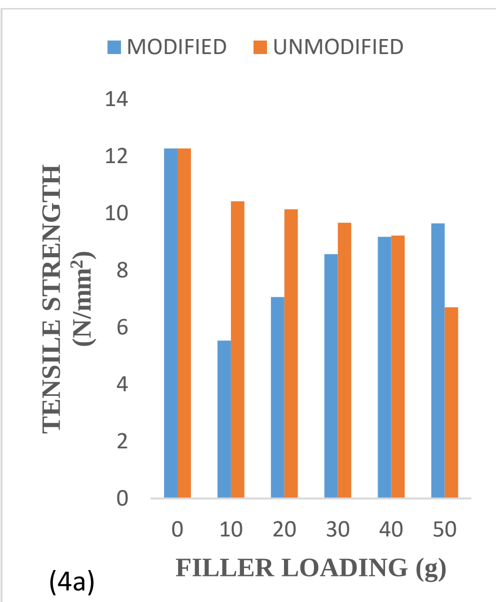


Figure 3: Water absorption property of UCSS and TCSS composites.

Tensile property



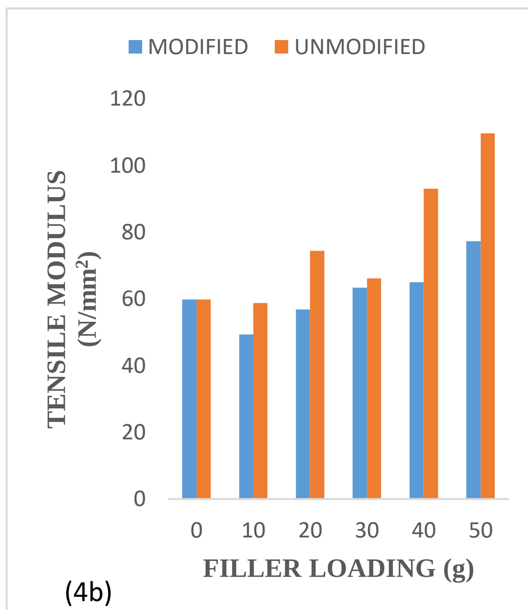


Figure 4 (a) & (b): Tensile strength and tensile modulus of UCSS and TCSS composites respectively.

Hardness test

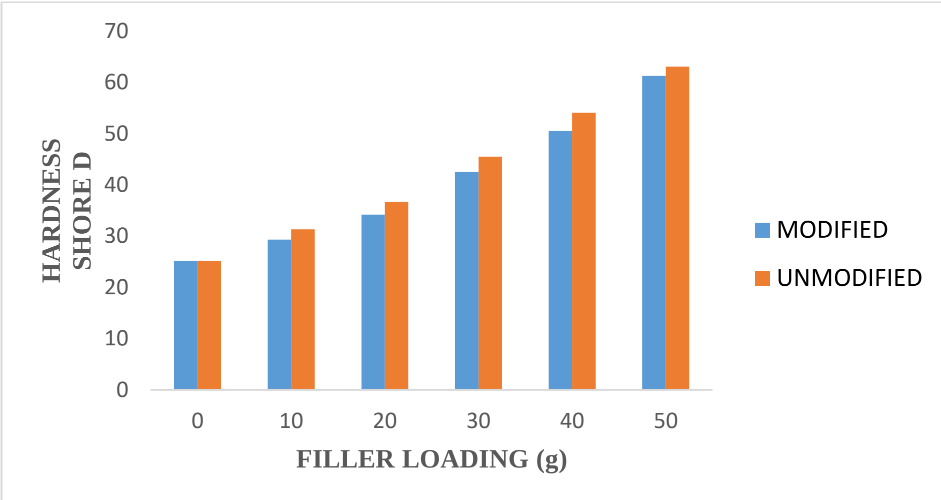


Figure 5: Hardness property of UCSS and TCSS composites.

Impact strength

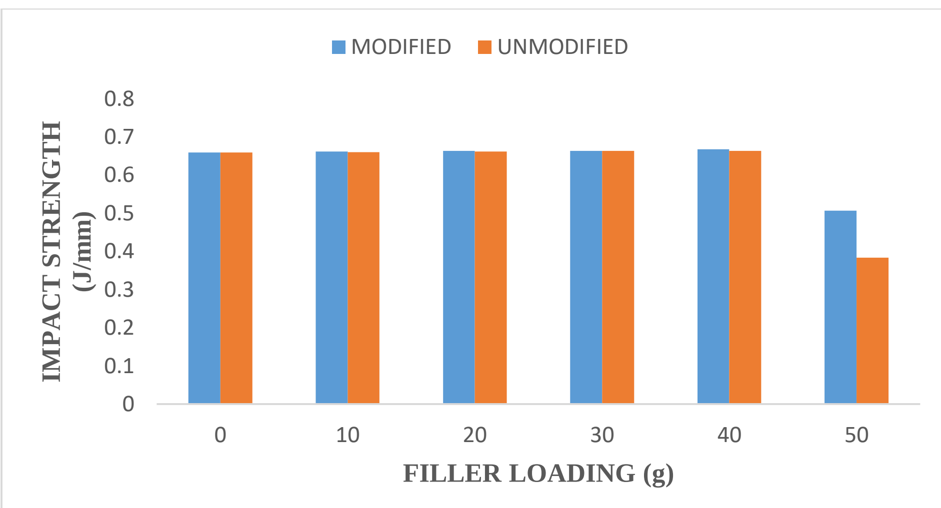


Figure 6: Impact strength property of UCSS and TCSS composites.

Flexural property

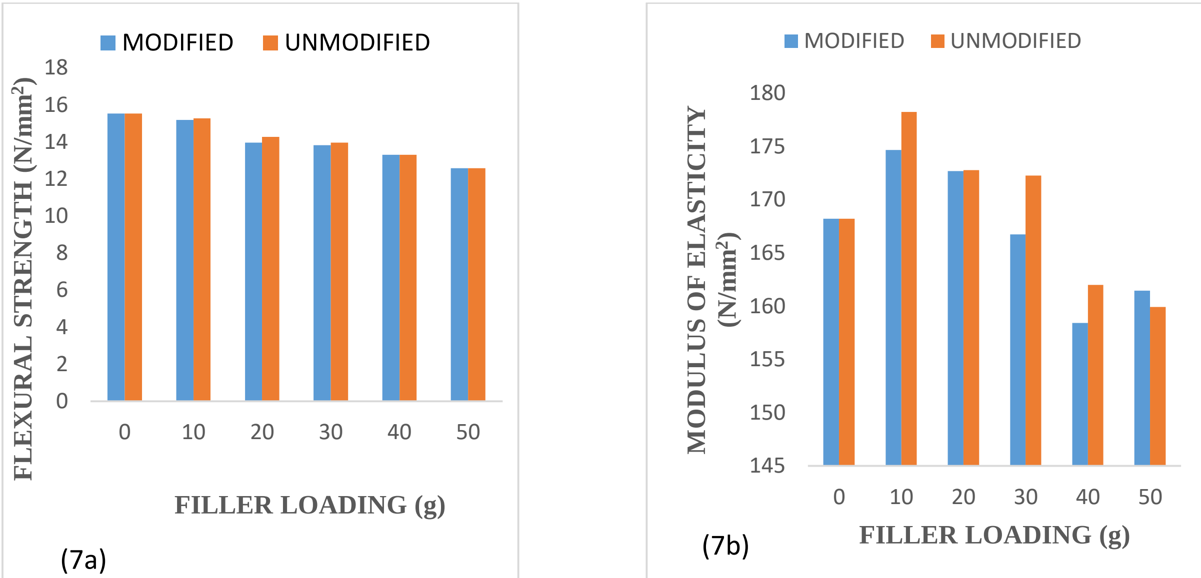


Figure 7 (a) & (b): Flexural strength and modulus of elasticity of UCSS and TCSS composites respectively.

DISCUSSION

Figure 3 represents the graph of percentage water absorption of the composite. Percentage water absorption is the amount of weight gain experienced in a polymer after immersion in water for a specific length of time under a controlled environment. The result obtained revealed that the water absorption increased with filler loading for both modified and unmodified composite for 24 hours. This trend is as result of the nature of the filler which is hydrophilic, and so it absorbs the water. The control sample absorbs water of 0 %, while the water absorption of the unmodified composite has higher percentage of water absorption compared to the modified composite. This influence could be as a result of the NaOH treatment of the modified composite, which could reduce the intake of moisture after passing through sufficient drying (Danjaji *et al.*, 2000). The general progressive increase in water absorption could be related to the fact that castor seed shell powder (modified and unmodified) is an agro-filler which is expected to have the possibility of moisture absorption property (hydrophilic) (Daniel *et al.*, 2019)

Figure 4 (a) represent the graph of tensile strength of the modified and unmodified composite. Tensile strength is the force or stress per unit of the original cross-sectional area at the point of rupture of the specimen. The result obtained shows that the tensile strength of the modified composite increased from 10 to 50 g loading, but the unmodified tensile strength reduces as the filler loading increased. The effect of the modified filler on the increase in tensile strength could be due to a better interfacial interaction of both the filler and matrix (Husna *et al.*, 2021). However, the treatment of the filler enhances good bonding and adhesion to the matrix. This trend is also observed in (Nwigbo *et al.*, 2013) research, where the tensile strength of the composites with modified filler increased.

Figure 4b shows the tensile modulus of the composite samples. Tensile modulus of the sample increased as the filler loading increased from 10 g to 50 g. Meanwhile, the unmodified filler is observed to have higher tensile modulus. The highest modulus of 109.704 N/mm^2 was obtained at 50 g filler loading. The tensile modulus was mainly influenced by the shape factor and particle size of both modified and unmodified (Fiore *et al.*, 2015). The increase in tensile modulus responses of composites might be attributed to the extent of dispersion of both modified and unmodified filler in the matrix phase; agglomeration and incorporation between particles and matrix may also be factor for the trend (Ismail *et al*., 2004; Piyush & Mohana, 2017).

Figure 5 represent the graph of hardness of the composite with both modified and unmodified filler. Hardness property of a material describes suitability to resist indentation (Cowie, 1991). The result obtained showed that the hardness property of the modified filler and unmodified filler composites increased with increasing filler loading. It can be observed that the rate of increment in the unmodified filler composite more is than in the modified filler composite. The increment in the hardness could be attributed to the rigid nature of the filler, which filled the core of the matrix and increasing the resistance to surface indentation. This trend was observed by Mersi *et al.* (2021) of which their hardness results increased as filler loading increases.

Figure 6 represent the graph of impact strength of the modified and unmodified filler composites. Impact strength is a property of a material that describes the amount of energy it can absorb before it fractures (Ikhlef *et al.*, 2012). The result obtained shows that the impact strength for both modified and unmodified filler composites decreased with increasing filler loading. However, it can be observed that the impact strength decreased drastically at 50 g loading, which could be as result of higher volume fraction of the filler. The decrease in impact strength of the composite could be attributed to poor filler-matrix molecular interaction.

Figure 4 represent the graph of flexural strength of the modified and unmodified filler composites. Flexural strength is a mechanical parameter of material which is defined as the material's ability to resist deformation under load (Tanvi & Kamal, 2022). The result obtained shows that flexural strength of the composites decreased with increasing filler loading. This trend could be traced to the nature of the filler (rigid) resisting the bending stress being applied.

Figure 8 represent the graph of flexural modulus of the modified and unmodified filler composites. Flexural modulus is a convenient measure of composite stiffness (Niu, 2005). The flexural modulus of the composite shows that the unmodified and modified filler composites decreased with increasing filler loading. This trend is similar to that flexural strength.

CONCLUSION

Modified and unmodified castor seed shell reinforced with recycled low density polyethylene composites were successfully prepared with different filler loadings of 0, 10, 20, 30, 40, and 50 g respectively. Water absorption, tensile, hardness, impact, flexural and properties of treated and untreated castor seed shell filler composites with different filler loading were determined. The composite samples showed great and significant properties, the water absorption of both composites increased with increasing filler loading, but the unmodified absorb moisture more, which could be traced to the hydrophilic nature of the filler while the modified composites absorbed less cause one of the major reasons for treatment was to reduce moisture absorption.

REFERENCES

Cowie, J. M. (1991). *Polymers, chemistry and physics of modern materials*. John Wiley and Sons.

Daniel, S., Vijay, G., Talwade, R., Dhake, J. D., & Pegoretti, A. (2019). Some studies on sugar palm fibers. International conference on Advances in Fibrous Materials, Nonwoven and Technical Textiles, 7-9 August,Coimbatore, India.

Danjaji, I. D., Ishiaku, U. S., Ismail, H., & Ishak, Z. A. M. (2000). Sago starch-filled linear low-density polyethylene (LLDPE) films: Their mechanical properties and water absorption. *Journal of Applied Polymer Science, 78*, 29-37.

Fiore, V., Di bella, G., & Valenza, A. (2015). The effect of alkaline treatment on mechanical properties of kenaf fibers and epoxy composites. *Composite Science Technology*, *68*, 14-21.

Husna, S., Kaith, B., & Kaur, I. (2021). *Pretreatment of natural fiber and their physico-mechanical properties. Reference module in materials science and materials engineering*. Elsevier.

Ikhlef, S., Nekkaa, S., Guessoum, M., & Haddaoui (2012). Effect of alkaline treatment on the mechanical and rheological properties of low density polyethylene/Junceum flour composites. *International Journal of Polymeric Materials* ID 965101.

Ismail, H., & Suryadiansyah, A. (2004). Effects of filler loading on properties of polypropylene-natural rubber-recycle rubber powder (PP-NR-RPP) composites. *Journal of Reinforced Plastics and Composites, 23*(6), 639-650.

Mersi, K., Ika, A. K., Farah, F., & Dede, J. (2014). Physical and mechanical properties of particle board from castor cake meal. www.researchgateblog.com.

Niu, L. (2005). Using the bending beam model to estimate the elasticity of diphenylamine nanotubes. *Langmuir Publishers*, 23(14), 7443-7446.

Nwigbo, S. C., Okafor, T. C., & Atuanya, C. U. (2013). The mechanical properties of castor seed shell-polyester matrix comppposites. *Journal of Applied Sciences, Engineering and Technology*, *5*(11), 3159-3164.

Piyush, M. M., & Mohana, R. K. (2017). Extraction and tensile properties of natural fibers: sugar palm fibre particulate, date and bamboo. *Composite Structures, 77*, 288-295.

Sudari, A. K., Shamsuri, A. A., Zainudin, E. S., & Tahir, P. M. (2015). Exploration of compatibilizing effect of non-ionic surfactants on mechanical, morphological and chemical properties of high density/low density polyethylene. *Journal of Thermoplastic Composite Materials, 30*(6), 855-884.

Tanvi, P., & Kamal, K. K. (2022). *Fly ash-reinforced polypropylene composites. Handbook of Fly Ash*. Retrieved on 12/01/2023.

Williams, D. C. (2008). Fundamentals of materials science and engineering: A polymer science and engineering. *The Shifting Research Frontier*.