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DYNAMIC AND STATIC PROPERTIES OF KENAF FIBRE REINFORCED WITH LOW-DENSITY POLYETYLENE COMPOSITES

Okele A.I., Ali S.M., Abdulsalam J.A., Agho O.B. and Zubair H.
Nigerian Institute of Leather and Science Technology, Zaria, Nigeria
Correspondence: walislove4real@yahoo.com

ABSTRACT

Kenaf fibre was compounded with low-density polyethylene on a two-roll mill to produce a composite for various applications. The kenaf fibre was sourced, socked in water for two weeks by ratting method to separate fibre from cellulosic content which was washed, treated with sodium hydroxide, for five minutes each and sun dried under room temperature, also with the aid of the oven to dry at 100 ^{o}C for 2 hours. It was then reduced to a particulate size of 2mm. The low-density polyethylene/kenaf fibre was varied into samples such as 100/0, 95/5, 90/10, 85/15, 80/20, 75/25 and 70/30g respectively which was compounded on the two-roll mill and compressed with a compression moulding machine and the result of the composite were characterized on the bases of mechanical analysis (hardness, tensile strength, water absorption and dynamic mechanical analysis). The results were obtained in the course of this research, as filler loading increased, the hardness of the sample increased, while the percentage water adsorption increases with increase in filler loading. The storage modulus, loss modulus, damping, inflation and glass transition temperature to determine the dynamic and static properties on polyethylene/kenaf fibre and its application.

KEYWORDS
Kenaf fibre, LDPE, composite, tensile strength, mechanical properties

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INTRDUCTION

Composite are manufactured by combining two dissimilar materials into a new material which may be better suited for particular application than either of the original materials alone (Egwakhide *et al.,* 2017). Nowadays, modern technologies require material with unusual combination of properties that cannot met by the conventional material (Okele et al., 2016). A relatively new class of composite material is fibre reinforced polymer manufacture from fibred and polymer matrix. It is efficient economical for use in a variant of engineering application. Thermoplastic or thermoset reinforced polymer-based composite. Fibres of various types can be used as reinforcing agent (Okele et al., 2018). Thermoplastic resin achieved much interest due to their economic and mechanical advantage such as fabrication, intrinsic recyclability, unlimited self-life, high toughness, and increase moisture resistance. Fibres provide stiffness and strength to the composite and improve their mechanical characteristics (Okele et al., 2019).

Every year, billions of tons of agricultural crop residue are produced around the world. Among the large amount of residue are utilized as household fuel or fertilizer and the rest is the burned in the field as a result, it courses air population. Utilized agricultural crop reduces as reinforcement of polymer composite can help to protect the environment problem application of natural fibres as reinforcing agent to composites gained much interest due to increased environment awareness and consciousness throughout the world (Okele et al., 2019). Natural fibres are now considered as an alternative to synthetics fibres for used in various field such as building and construction, packaging, automobile and railway coach interiors and storage device, and various load bearing application, natural fibre reinforced composite are environmentally friendly, biodegradable, widely, renewable, cheap and have low density (Oboh et al., 2018). Recently, fibre reinforced composites have appealed huge consideration in the arena of engineering applications because of their excellent and unique combination of physical and mechanical properties. The bast fibres such as jute, flax, hemp, ramie, sisal, kenaf are presently used as reinforcement in polymer composite and many efforts have been made by researchers to establish natural biodegradable fibre as substitute to synthetic fibre which can be used effectively in the composite material. Several studies reported that incorporation of lingo-cellulosic fibre improves the physio-mechanical properties of polymer matrices in the composite material (Okele et al, 2015). Synthetic fibre reinforced thermoplastic composites are dominating over natural fibre reinforced composites due to their higher strength, stability and corrosion resistance properties. But synthetic fibres are not easily degradable and are causing ecological problem. Due to increasing environmental consciousness, composites made of lingo-cellulosic fibres as reinforcing material are exploring day by day (Torres *et al*., 2023).

Agro-waste is the green waste in agricultural field which sometimes create environmental problem when it is abundantly excreted. But introduction into a matrix can serve many productive purposes to minimize the pollution and help in waste management, and also considered as the key activity of clean technology. Therefore, it is thought to be the duty of present-day researchers to use those bio-mass for productive purposes. Keeping in view, the present study focused on extraction of fibre (El Nashar, *et al*., 2014).

MATERIALS AND METHODS

Materials

Low-density polyethylene was sourced from polymer workshop NILEST, Zaria, while Kenaf fibre were sourced from Graceland, Hanwa, Sabon Gari Local Government Area of Kaduna state and sodium hydroxide (NaOH) from Haddis Chemicals in Samaru, Zaria.

Methods

Fibre treatment

Alkali treatment with 5% NaOH concentration solution was carried out on the fibres. The fibre was soaked in a standard solution of NaOH for 1hour in order to remove impurities such as lignin, waxes, paraffin. The fibre was now removed from the NaOH solution and then wash thoroughly with a standard solution and followed by thorough washing with distilled water and then it was dried in an oven at 100 ^{o}C to remove moisture content from the fibre for 30 minutes.

Sample preparation

The treated fibre was weighed at different ratio loading of fibre and polyethylene pellet were also weight in percentages (%) to produce a natural composite. Kenaf fibre composites were produce using a two-roll mill, at set temperature of 135^{o}C. A homogenous mix was achieved by thoroughly dispersing the mixed fibre on the plasticized low-density polyethylene using a mixing knife. The samples produced were compressed by using the compression moulding machine at 135 ^{o}C for 5 minutes.

Table 1: Formulation Table

S/NO	SAMPLE (g)	LDPE LOADING (%)	KENAF FIBRE LOADIND (%)
1	LDPE	100	0
2	LDPE/KF	95	5
3	LDPE/KF	90	10
4	LDPE/KF	80	20
5	LDPE/KF	85	25
6	LDPE/KF	70	30

Physical and mechanical property determination

Tensile strength test was carried out using the tensometer according to ASTM standard. The stress-strain curve was generated and tensile properties were determined. The flex meter was used to carry out flexural test according to ASTM Standard and modulus of elasticity (MDE) of the composite samples. Hardness test was done using a durometer shore according to ASTM at three different points and a mean value recorded. The dynamic mechanical analysis was carried out on the three best samples produced to determine the effect of thermal degradation according to ASTM standard.

Physical properties

Water absorption of composite:

A water bath was used for the water-immersion tests. These samples were immersed in water at a temperature of 100 ^{o}C. (the samples were periodically removed at 24 hrs interval) from the water bath and surface water was wiped off. The moisture absorption was determined by weighing the samples on a balance with a precision of 0.1mg. The moisture absorption at any time was calculated by

% water absorption = $\frac{Wi-Wo}{Wo} \times 100$ …………………… equation 1

Where, Wi and Wo refer to the weight of the dry samples and weight samples, respectively, the samples will be immersed in the water for a period of 96 hours.

Tests for Mechanical Properties

Hardness test:

The hardness testing of plastics is most often measured by the Rockwell hardness test or shore (Durometer) hardness test. Both methods measure the resistance of the plastic toward permanent indentation. The hardness test was carried out according to International standard organization.

Tensile strength:

The ability to resist breaking under tensile stress is one of the most important and widely measured properties of materials used in structural applications. The force per unit area (MPa or Psi) required to break a material in such a manner is the ultimate tensile strength or tensile strength at break. The rate at which a sample is pulled apart in the test can range for 0.2-20mm per unit time and will influence the results. The method used was according to ASTM D882 or ISO1184. The tensile testing machine pulls the sample from both ends and measures the force required to pull the specimen apart and how the sample stretches before breaking.

Dynamic mechanical analysis

Dynamic mechanical analysis is a technique used to study and characterize materials. It is most useful for studying the viscoelastic behaviour of polymers. A sinusoidal stress is applied and a strain in the material is measured, allowing one to determine elastic modulus (or storage modulus, G'), viscous modulus (or loss modulus, G') and damping coefficient (Tan**σ**) as a function of temperature, frequency or time, this approach can be used to locate the glass transition temperature of the material, as well as to identify transitions corresponding to other molecular motions. DMA was carried out according ASTM D4065.

RESULTS AND DISCUSSION

Results

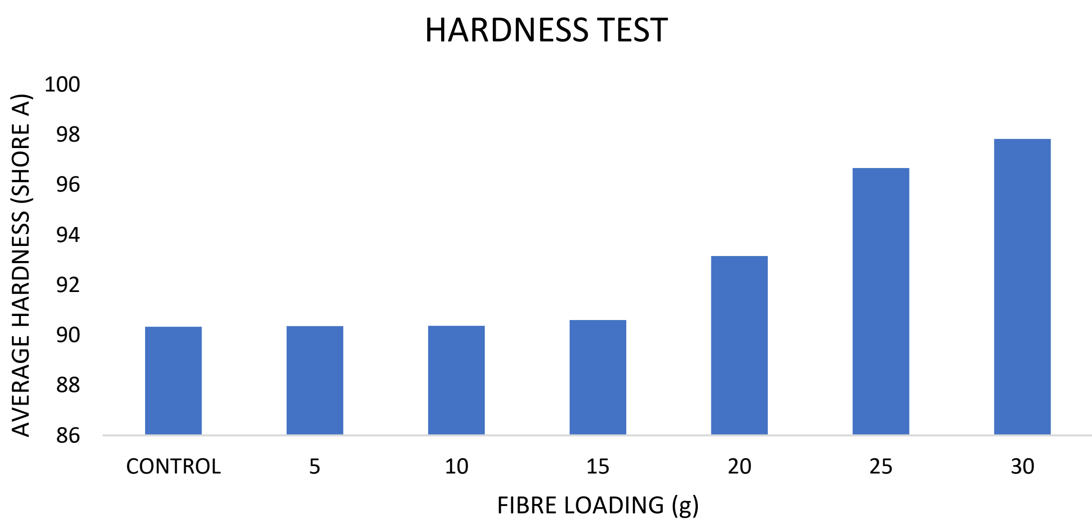

Figure 1: Effect of hardness on fibre loading

From figure 1 shows the hardness test carried out for various samples in their ratio, 100/0, 95/5, 90/10, 85/15, 80/20, 75/25, 70/30, respectively. Sample 70/30 shows a significant hardness in filler loading compared to the control sample and sample 75/25 had a decreasing hardness which could be as a result of poor interaction between the filler and low-density polyethylene and also surface treatment.

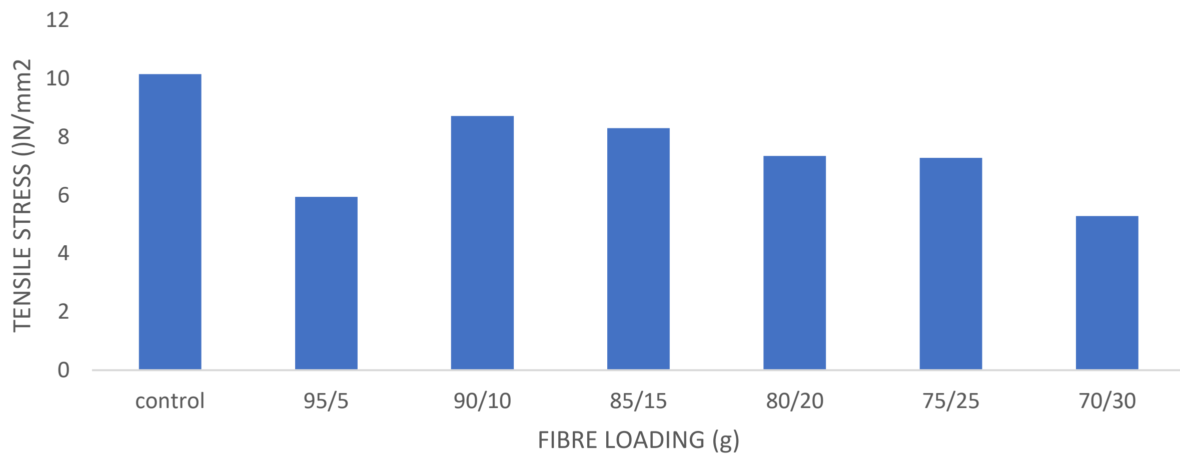

Figure 2: Effect of tensile stress on fibre loading

Figure 2 shows the tensile strength of the composite at different loading of kenaf fibre, it could be deduced that tensile strength increased as volume fraction increase from 10g, but decreased as the volume fraction decreased beyond 10g. however the tensile stress was low at 5g and 30g filler loading, but the control sample had the highest tensile stress which shows that kenaf fibre incorporated into the matrix weakens the interfacial bond and therefore decreases the tensile stress from 15,20,25, and 30g. The lower tensile stress of the composites at higher fibre loading could be due to a number of reasons such as weak interfacial bonding at kenaf fibre and low-density polyethylene matrix interface, agglomeration of kenaf fibre, process-related defects such as porosity (Okele et al, 2020).

Table 2: Dynamic Mechanical Analysis

Sample (g)	SM/Freq (MPa/Hz)	LM/Freq (MPa/Hz)	Tan **σ**	Onset Temp (^{O}C)	Inflection (^{O}C)	Peak (^{O}C)	Tg (^{O}C)
90/10	595	54.2	0.089	35.8	77.7	23.9	94.4
80/20	403	55.2	0.136	45.0	51.4	33.2	94.3
70/30	626	68.0	0.140	47.2	57.8	40.3	39.7

Discussion

Table 2 shows the effect of temperature on the dynamic modulus of the low-density polyethylene composites with different fibre content. Variation in modulus occurs due to the effect of the incorporated fibres.

The values obtained for the different systems at frequency 10 Hz are given in the table above. In this case the lowest E' value has been obtained for 20% fibre loading at 10Hz and the highest value for control and 5% fibre loading. It is important to mention that modulus in the glassy state is determined primarily by the strength of the intermolecular forces and the way the polymer chain is packed.

It also shows that at low temperature, E' values of matrix and composite are found to be close to each other emphasizing that at low temperatures fibres do not contribute much to imparting stiffness to the material. At higher temperature, any water molecules adhering on to the fibre will be evaporated making the fibres stiffer. This ultimately contributes to the improved modulus of the composite at high temperatures. However, the table shows a decrease in E', this could imply that the composite at higher fibre loading might not be able to store more energy.

The loss modulus can be seen from the above table such loss modulus peak values increase with increase in fibre content at temperatures below the glass transition. This implies that, as the temperature is increasing, the loss energy also increases relating it to the fibre/matrix variation due the lignocellulos nature of the fibre which will not allow the fibre to retain more energy than the low-density polyethylene.

Tan**σ** is a damping term that can be related to the impact resistance of a material. Since the damping peak occurs in the region of the glass transition where the material changes from a rigid to a more elastic state, it is associated with the movement of small groups and chains of molecules within the polymer structure, all of which are initially frozen in a composite system, damping is affected through the incorporation of fibres. This is due to mainly shear stress concentrations as the fibre ends in association with the additional viscoelastic energy dissipation in the matrix material, another reason could be the elastic nature of the fibre (Okele et al,.2018).

Addition of fibre lowers the tan**σ** peak height, which again points to the improved fibre/matrix adhesion. The glass transition temperature is shifted positively on the addition of fibre. Oboh et al. (2018) concluded based on his studies that a composite with poor interface bonding tends to dissipate more energy than that with good interface bonding.

Incorporation of fibres reduces the tan**σ**peak height by restricting the movement of the polymer molecules. Magnitude of the tan d peak is indicative of the nature of the polymer system. In an unfilled system, the chain segments are free from restraint. Also, it delineates the effect of temperature on tan **σ**. Improvement in interfacial bonding in composites occurs as observed by the lowering in tan d values. The higher the damping at the interfaces, the poorer the interface adhesion.

The table above also shows addition of fibre increases the Tg value at low fibre loading, showing that the addition of fibre below 20% has only a plasticizing effect. However, at 10% fibre loading, the Tg values show a positive shift, stressing the effectiveness of the fibre as a reinforcing agent i.e. the high polymer- filler interaction. The shifting of Tg to higher temperatures can be associated with the decreased mobility of the chains by the addition of fibres.

CONCLUSION

Kenaf fibre reinforced with low density polyethylene to produce a composite having different filler loading of 5, 10, 15, 20, 25 and 30g respectively. Dynamic mechanical properties such as dynamic mechanical analysis (DMA)" loss modulus, storage modulus, inflation and damping", hardness test and tensile strength test were carried out and results were obtained for various samples. This signifies that kenaf fibre could be to produce composite with high degradability due to its hydrophilic nature of the filler Kenaf fibre reinforce with low density polyethylene increases hardness of the composite. The dynamic modulus shows an increase with incorporation of fibre below the glass transition temperature and has a negative effect on the temperatures below Tg. Therefore, these composites can be used for product packaging and also as vibration isolating materials,

This research reveals that certain properties of the filler 'kenaf fibre', in order to modify and establish this finding the following recommendation have been forwarded:

1. Particle size variation of the filler should be used to ascertain the best particles for the composite to be produced
2. Further work should be done on SEM and FTIR to view some essential properties of the filler as the equipment are available.
3. Kenaf fibre when obtained should be treated with acetic acid to get better and improved properties.

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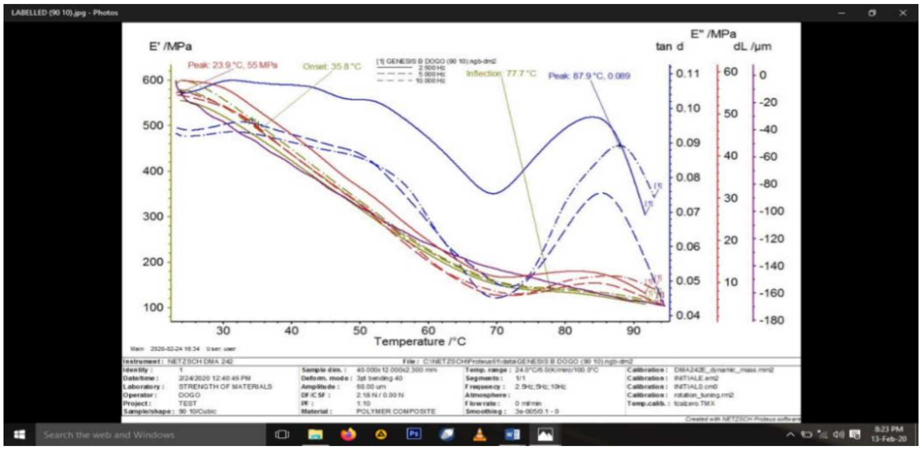
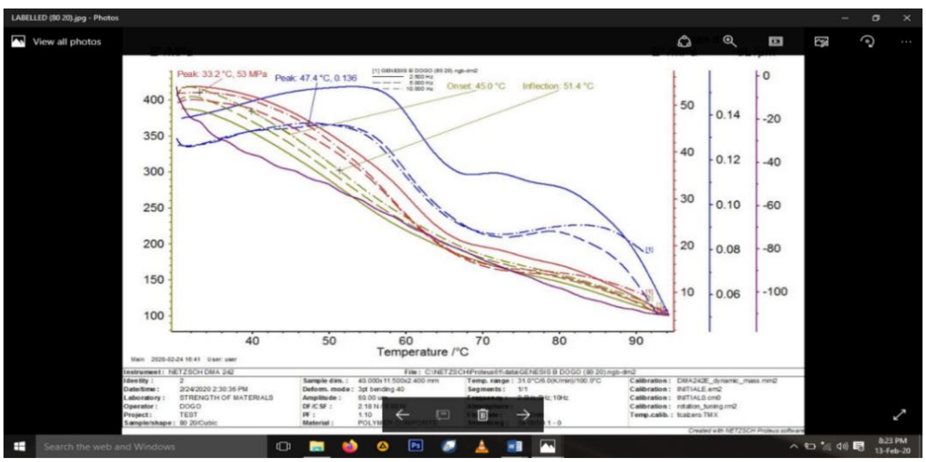
Appendix 1: 10/90 SAMPLE



Appendix 2: 20/80 SAMPLE



Appendix 3: 30/70 SAMPLE