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P2C-10: DEVELOPMENT AND CHARACTERIZATION OF LOW-DENSITY POLYETHYLENE REINFORCED PINEAPPLE LEAVES FIBRE COMPOSITES

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ABSTRACT

Pineapple leaves are agricultural wastes that are found in abundance in Nigeria but its potentials have not been fully harnessed. It is a natural fibre with high cellulose content and low lignin and hemicellulous composition which indicates its possession of high mechanical properties. This research was aimed at developing a biodegradable composite from pineapple leave fibre (PALF) by reinforcing it with low density polyethylene (LDPE) based plastic as matrix. Alkaline treatment based on NaOH was used to clean and modify the surface of fibre to promote enhanced fibre-polymer adhesion. The composite was developed using compression moulding process. Mechanical analysis of the composites was carried out to determine its range of usefulness and service life expected, and thermal analysis was also carried out to determine its response on application of heat. Finally burial test was conducted to determine the level of biodegradability at various loading. The composite formed was used to produce a poor panel that can be used as automotive parts. The maximum tensile strength reinforced composite was obtained at 30wt% of PALF loading of 14.09136 MPa while composite of ratio 50:50 of LDPE/PALF was found to have the lowest flexural strength of 4.2 MPa. Also the FTIR results after burial showed that there was the shift of band from the 1033cm^{-1} to 1021cm^{-1} and the peak changed from sharp to broad. Hence PALF is an efficient fibre for the production of biodegradable composites that can replace synthetic fibres, help to safe cost and other resources.

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Keywords: Pineapple, Composites, Natural fibres, Polyethylene, Environment.

1.0 Introduction

Nowadays, polyethylene based plastic materials are being extensively used for commercial and household purposes. However, these polyethylene-based plastics are substantially resistant to biodegradation. Thus, their increasing accumulation in the environment is proving to be an ecological threat to the world (Liu et al., 2013). Pineapple is a fruit crop that can grow in every part of Nigeria, fibres gotten from the leaves are found to contain high cellulose content enough to be used as reinforcement for polymers. Pineapple leaves can be used for fibre production (Dey et al., 2014). The comparative value of the chemical composition of pineapple leave fibres and other major plant fibres indicates that pineapple leave fibres has about the same Pentosen contents as wood fibre. Since pineapple leave fibres has less lignin and more cellulose than wood fibre. Pineapple leave fibres have only a small quantity of both lignin and pectin. It can be said that the unique features of pineapple leave fibres are its relatively large cellulose contents and extremely low contents of lignin and pectin which is the major inter-cellular components. This low content of lignin and pectin makes it very different from other fibres. Blending PAPF with LDPE will increase the mechanical properties of the composites as they have satisfactorily high specific strength and modulus light weight (Roshafima et al,.2017).It is therefore expected that pineapple leave fibres can be easily made into composite under mild treatment conditions giving good yield.

Table 1: **Chemical compositions of pineapple leave fibres**

Constituents	**Percentage**
Ash Content	4.5
Cellulose Content	66.2
Hollocellulose Content	85.7
Hemicellulose Content	19.5
Lignin Content	4.2
Moisture Content	81.6
Hot water soluble Content	32.5
1% NaOH Solubility Content	

(Faruk et al., 2012)

Low density polyethylene has been used in hybrid composite formulations because it is the least expensive polyethylene. It was also reported that low density polyethylene has the ability to photodegrade in sunlight and photo-degradation is found to be important in biodegradation (Basu and Roy, 2007). Polymer matrix composite materials are formed into shape using different processing technologies such as extrusion, compression, rotational, and injection moulding techniques. Processing of natural short fibre reinforced polymer composites is based on mixing of short natural fibres and polymer matrix followed by subsequent moulding (Kim et al., 2014). Although composites reinforced with synthetic fibres possess superior mechanical properties, they have some severe drawbacks that include high cost, poor recyclability and non-biodegradability (Mohammed et al., 2015).

Surface treatment of fibres is used to reduce their tendency for moisture absorption and thereby facilitates greater compatibility with the polymer matrix (Kabir et al., 2014). Mercerization is an economical and effective method used for improving the interfacial incompatibility between the matrix and the fibre. It has also proven to reduce water uptake of fibres. It improves the adhesive characteristics of the fibre surface by removing natural waxy materials, hemicellulose and artificial impurities, and produce good surface topography (Jacob et al., 2014). However, mercerization of natural fibres by alkali is the most popular method nowadays to improve fibre/matrix interactions by reducing the hydrophilicity of the natural fibre (AbdulMotalib et al., 2018). To minimize this threat, there is need to improve the biodegradability properties of polyethylene. This study focuses on the production of polyethylene reinforced pineapple leaves fibres composites.

2.0 Materials and Methods

2.1. Materials

Ten (10) kg of pineapple leaves fibre were collected from Station market in Barnawa area of Kaduna state, Nigeria. Low density polyethylene (LDPE) was supplied by Nigeria Institute of Leather and Science Technology (NILEST) Samaru-Zaria, Kaduna state, Nigeria. Sodium hydroxide (NaOH) pellets (98% purity, analytical grade) and distilled water (100% purity) were supplied by a vendor. All chemicals were used as received.

2.2. Method

2.2.1. Extraction and pre-treatment of pineapple leaves fibres

Ripe and mature pineapples were bought from the market and the leaves were removed mechanically using a metal cutter. The leaves were washed in a running tap water to remove sand and other impurities and then allowed to dry for 24h. Pineapple fibres were then extracted through scrapping the pineapple leaf with a sauce plate.

2.2.1. Chemical treatment (Mercerization)

The extracted pineapple leaves fibres were subjected to alkaline treatment to clean and modify the surface and to promote enhanced fibre-polymer adhesion. Five (5) wt% of NaOH solution was prepared; pineapple leave fibres were soaked in the prepared 5 wt% of NaOH solution and heated at 40 ℃ for 20mins on a regulated hot plate under a continuous stirring to ensure even modification. These concentrations were chosen to preserve the cellulose part of the fibres but dissolving the hemicellulose and the lignin portions (Elanga et al., 2013). Distilled water was used to rinse the fibres until a neutral pH was achieved, and then the treated fibre was allowed to dry.

2.2.2 Size Reduction

The dried PALF fibres were subjected to size reduction by grinding using local milling machine. The ground fibres were sieved. Fibres with sizes of 2mm-4mm were taken for this study as the size was the highest amount from sieving

2.2.3. Formulation and production of Composites

The composites were produced through mixing the treated pineapple leaves fibres and low density polyethylene according to the composition: 10 wt%, 20 wt%, 30 wt%, 40 wt% and 50 wt% of pineapple leave fibres with the corresponding 90 wt%, 80 wt%, 70 wt%, 60 wt% and 50 wt% matrices of low density polyethylene. The mixing was achieved by a way of compounding using two-roll mill. The two-roll mill machine was heated to a temperature of 120℃ for 30 minutes, which is the melting temperature of low density polyethylene. At the end of this period, 50 wt% of LDPE was poured into the preheated two-roll mill to melt the LDPE for about 5 min, followed by gradual pouring of 50 wt% PALF into the melted LDPE until a complete mixing of the fibre with the matrix was achieved. Finally, the compounded PALF/LDPE was scraped from the mill to form a sheet. A total of five samples were made. After mixing, the samples were introduced to the extruding machine, where uniformly mixed extrudates were produced. The processing parameters used were: motor current = 6.5 A, melt pressure = 0.1 MPa, screw speed = 320 rpm and feeder speed = 25 rpm.

2.2.4. Characterization of polymer composites

The composites formed were characterized in order to have a complete understanding of their behaviours. Different mechanical and thermal were carried out. This includes tensile test, water absorption measurements and FTIR respectively to know the level of strength and functional group.

2.2.4.1 Tensile Test

The tensile test was conducted according to ASTM D638 using the Instron universal testing machine. The dimensions, gauge length and cross-head speeds are chosen according to the ASTM D638 standard. The test specimens were cut into dog-bone shape of dimension 150 mm × 20 mm × 3.2 mm using a hydraulic cutter. Five specimens were tested for each composite formulation with a load cell of 5 kN and crosshead speed of 5 mm/min.

2.2.4.2 Flexural Test

Flexural strength was measured under a three-point bending approach using a universal testing machine according to ASTM D790. The dimensions and gauge length were chosen according to the ASTM D790 standard. Samples measuring 127 mm × 12.7 mm × 3.2 mm were tested at a crosshead speed of 4 mm/min, which was determined using equation 2.1 (AbdulMotalib et al., 2018).

$$R = \frac{ZL2}{6d} \qquad 2.1$$

where;
Z which is a constant, is the rate of straining of the outer fibre, while
L is the support span, and
d is the thickness of the sample.

2.2.4.3 Impact Test

The impact test was conducted according to ASTM D256 using the charpy V-notch impact testing machine. The dimensions, gauge length and V-notch were chosen according to the standard. The specimen was placed between a special holder with the notch oriented vertically and towards the origin of impact. The specimen was struck by a "tup" attached to a swinging pendulum. The specimen breaks at its notched cross-section upon impact, and the upward swing of the pendulum was used to determine the amount of energy absorbed in the process.

2.2.4.4 Hardness Test

The hardness of the polyethylene reinforced baobab fibre composites were measured with the aid of Shore Duro-meter testing machine according to ASTM. The samples were indented following the various fibre compositions in the composites. The reading on the machine was noted and recorded.

2.5 Biodegradability behaviours of composites (Burying Process)

The masses of the PALF reinforced polyethylene composite samples were weighed using digital weighing balance before burying in the soil sample collected from the dump site. 4.4g, 5.0g and 4.51g for 100:0, 80:20 and 70:30 sample ratios of LDPE to PALF respectively were weighed before burial. The mean total bacteria count (TBC) of the soil sample is 8.0 x 10^7cfu/g (colony forming unit per gram) of soil. Also, the mean total fungal count (TFC) of the soil sample is 22 x 10^5cfu/g of soil. After two weeks, the samples were removed from the soil and then cleaned. They were then dried inside the oven for good three (3) hours at 50 °C for the removal of moisture contents from the samples after drying the samples were weighed again and their masses recorded. The same procedure was repeated for the next two weeks, and the interval of two weeks was continued up to the end of 90 days consecutively. The soil samples were kept moist always by addition of small amount of water to it, when they tend to dry.

2.6 Water Absorption Test

The samples were weighed and submerged in a 250-ml beaker containing water for 24 h. After the samples stayed for 24 h, they were then taken out of the water, dried and weighed according to ASTM D570-98. The percentage water absorbed was calculated using the Equation (2.2)

$$\frac{Wf - Wi}{Wi} \times 100 \qquad (2.2)$$

where,

W_f is the weight of the sample after immersion in water.
W_i is the weight of the sample before immersion in water.

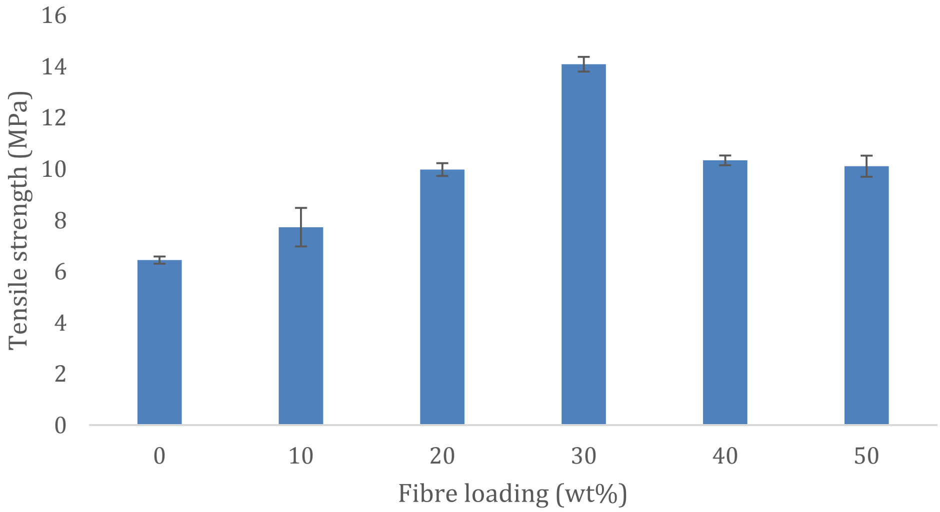


Figure 1: Tensile strength at varying fibre loading.

3.0 Results and discussion

3.1 Mechanical Properties of LDPE/PALF composite.

3.1.1 Tensile Strength

The maximum tensile strength reinforced composite was obtained at 30wt% of PALF loading as shown in Figure 1. While 10 wt% gave the lowest tensile strength of 7.73MPa on reinforcing with PALF. The tensile strength of the entire reinforced composite was higher than the un-reinforced LDPE as shown. The maximum tensile strength obtained at 30wt% might be due to proper binding between the fibre and matrix and the decrease in tensile strength as shown in Figure 3.1 after 30wt% might be due to agglomeration between the fibre and the matrix in the composite. The maximum tensile strength obtained at 30 wt% PALF loading is higher than 7.1 MPa obtained by Kuburi, (2017) for coir fibre-LDPE composite at 30 wt%.

3.1.2 Flexural Strength

The flexural strength of unreinforced LDPE composite gives the highest value of 13.69 MPa when compared to the other composites. The composite of ratio 50:50 of LDPE-PALF has the lowest flexural strength of 4.2 MPa. It was observed that on reinforcement, the flexural strength is reduced as the PALF loading was increased. The highest flexural strength of 13.69 MPa in the unreinforced LDPE is lower than 25 MPa obtained by Oluyemi et al., (2017) for unreinforced polyester. The nature of the two materials and their molecular structures may differ and this could lead to their differences in flexural strengths. The highest flexural strength of 11.84 MPa obtained on reinforcing with 10 wt% fibre content is low when compared with 17 MPa at 10 wt% obtained by Kuburi et al., (2017) for Coir fibre-polyethylene composite.

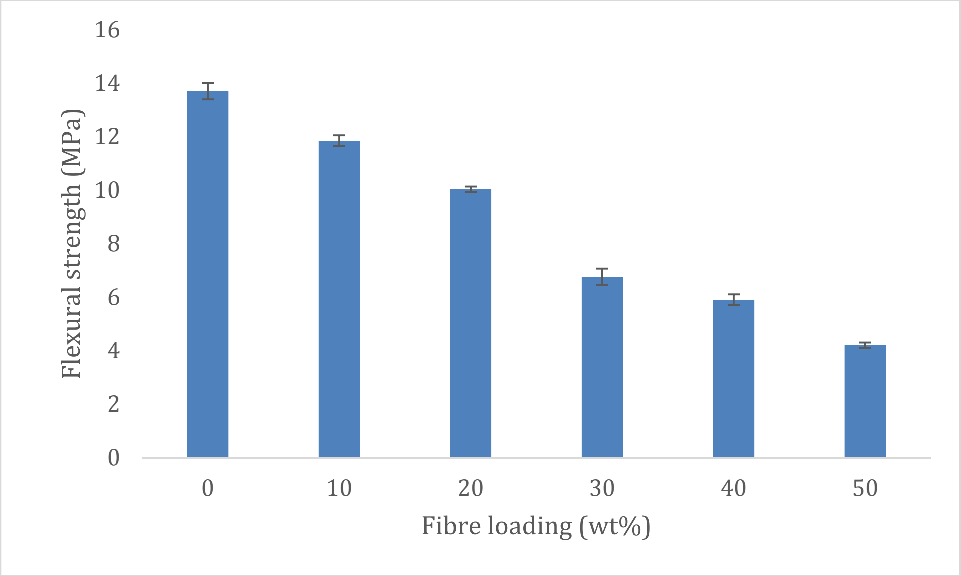


Figure 2: Flexural strength of composite at varying fibre loading

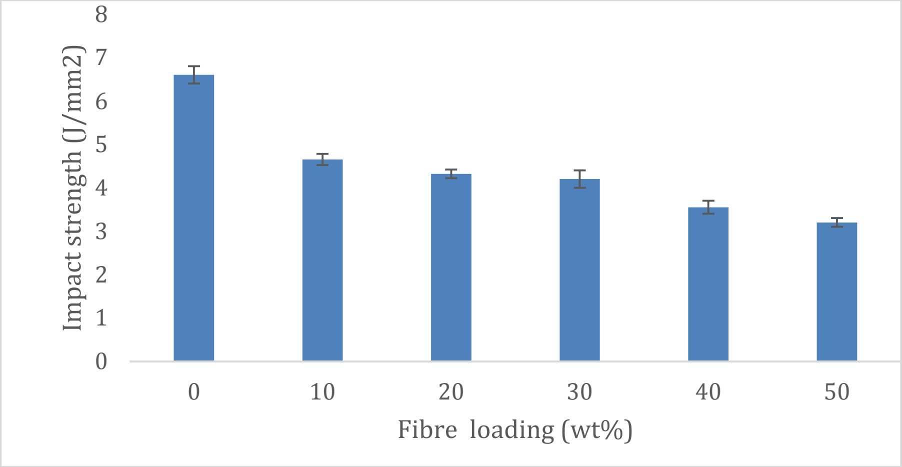


Figure 3: Impact strength of composite of varying PALF loading

3.1.3 Impact Test

The impact strength is higher on virgin LDPE than the reinforced composites. The impact strength of 4.65 J/mm^2 obtained at 10 wt% PALF loading is higher than 3.8 J/mm^{2}obtained by Shehu (2016) for untreated baobab fibre loading at 10 wt%. There is enhancement in mechanical properties of reinforced composite when the reinforcing fibre is being treated with alkali. The Figure 3 above reveals that the impact on composite decreases as the percentage of PALF increases. Impact properties decrease due to poor interfacial adhesion between the matrix and the fibre. The fibre loading increases the brittleness of the composite. The error bar overlapped between 20 wt% and 30 wt% fibre loading shows that there is no significant change in impact strength between the two composites.

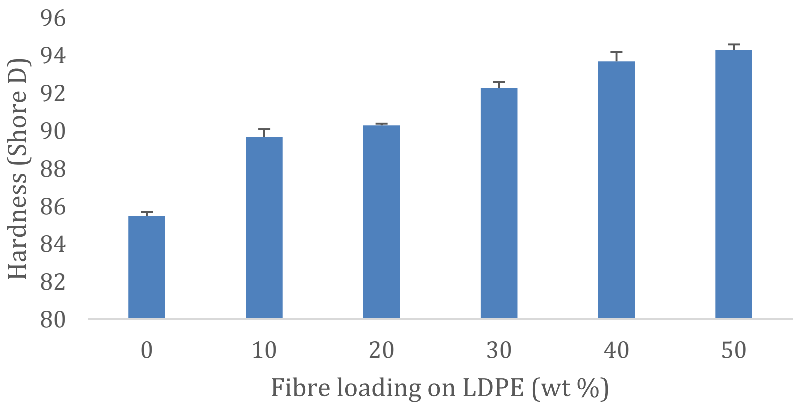


Figure 4: Hardness of composite of varying PALF loading

3.1.4 Hardness Test

Hardness is the resistance of a material to surface indentation. Figure 4 revealed the hardness of the PALF-LDPE composites. It was observed that the addition of fibre to polyethylene increases the hardness property. The lowest hardness strength of 85.5 shore D obtained at 10 wt% of PALF loading was lower than 86 shore D obtained by Kuburi et al, (2017) for Coir fibre loading-polyethylene composite. The overlapped in the error bars between 10 wt% and 20 wt% shows that there were no significant differences in the hardness strength between them and also between 40 wt% and 50 wt% baobab loading shows no significant differences in the hardness strength between the two.

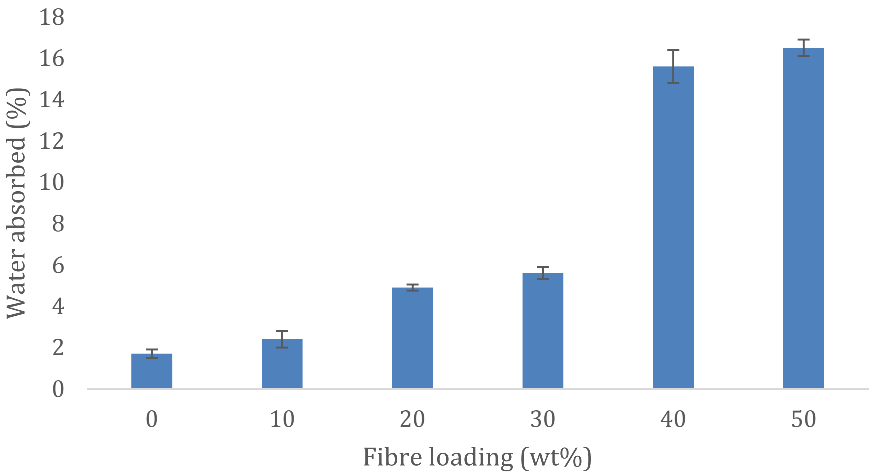
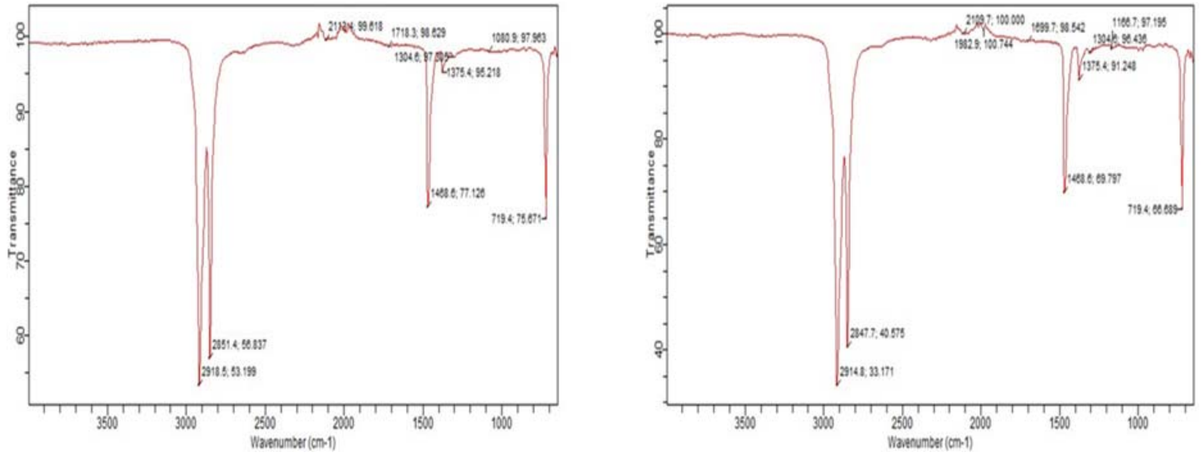


Figure 3: Water absorption on different loading for LDPE/PALF composite.

3.2 Water absorption analysis of LDPE/PALF composites.

The water absorption on virgin low density polyethylene is very low due to the hydrophobic characteristic. While on the reinforced composite of ratio 50:50 of low density polyethylene to pineapple leave fibres shows the highest water absorption than the remaining composites, this is due to the presence of higher percentage of pineapple leave fibres in the composite than the rest. This is a clear indication that water absorption increases with the increase in percentage fibre loading in the composite, the increase is due to the hydrophilic behaviours of the pineapple leave fibres.

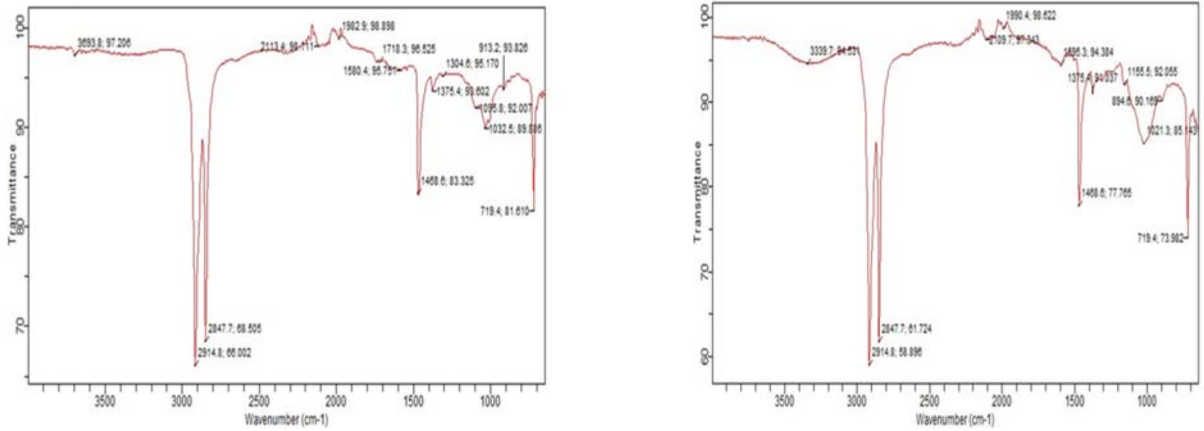


(a) (b)

Figure 4: FT-IR spectra of 100% LDPE (a) Before and (b) After burial

3.3 FT-IR Analysis for LDPE/PALF composites

It was observed from the Figure 4. which shows the FTIR spectra of 100% LDPE (a) Before burial and (b) After burial, that the peaks 1469 cm^{-1}, 1375 cm^{-1} and719 cm^{-1}, which were attributed to the stretching vibration of C=C, bending of -C-H and C-H respectively were appeared at both (a) before the burial and (b) after the burial, this shows no significant degradation has taken place throughout the period of 90 days of burial.



(a) (b)

Figure 5: FT-IR spectra of LDPE/PALF of ratio 70:30 (a) Before and (b) After burial

It was observed from Figure 5.which shows the FT-IR spectra of low density polyethylene to pineapple leave fibres of ratio 70:30 (a) Before burial and (b) After burial: that before burying sample 70:30 the peak at the band of 1033 cm^{-1}with stretching vibration of C-O was sharp. But, after burying the sample there was the shift of band from the 1033cm^{-1} to 1021cm^{-1}and the peak changed from sharp to broad. And the band at 1718cm^{-1} with stretching vibration of C=O in Figure 5(a) disappeared after the burial. The changes that occurred from 1033cm^{-1}to 1021cm^{-1} before and after the burial, and also the disappearance of the 1718cm^{-1} in 5(b) showed that degradation occurred.

4.0 Conclusion

Production of biodegradable composites from Pineapple leaves fibres was carried out using compression moulding and the following conclusions were drawn. The 30wt% and10wt% pineapple fibres loading exhibited the high tensile and low tensile strength of 14.09MPa and 7.73MPa respectively. Also, it was observed that the composite with the highest percentage of pineapple leaves fibres has the highest level of water absorption. Consequently, from the FTIR result it was concluded that significant biodegradation has occurred after burial for LDPE/PALF of ratio 70:30. Consequently, it can be concluded that pineapple leave fibre is an effective fibre that can be used as reinforcement for low density polyethylene to increase its biodegradability.

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