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MECHANICAL, BIODEGRADABILITY AND MORPHOLOGICAL STUDIES ON STEARIC ACID TREATED OKRA BAST FIBER - CASTOR OIL MODIFIED POLYESTER MATRIX COMPOSITE

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ABSTRACT

Plant based natural fibers are fast gaining attention worldwide in areas of composites application because of their lightweight, low cost, biodegradability, eco-friendly nature and sustainability properties. However, as the interests in fiber reinforced composites continue to grow, combined studies on physical, mechanical and biodegradability investigations of composites produced from natural okra bast fibers are sparse in literature. Therefore, this work aimed at the study of the physical, mechanical and biodegradability properties of Okra bast fiber-polyester composite. The okra bast fiber treated with stearic acid reinforced the castor oil modified matrix. Stearic acid was added to ethyl alcohol solution and treated with 10% by weight of fiber while castor oil was varied from 0% to 2% (at 0.5% interval) on the polyester resin. The composite was fabricated by a hand-layout of the okra bast fiber and the polyester matrix poured onto it and compressed in a mould. Physical and mechanical properties such as water absorption, hardness, elongation and modulus of elasticity were carried out on the produced composites samples. Bio-degradability studies coupled with infrared, thermogravimetric and morphological analyses were carried. Castor oil concentration of 1% had the highest modulus of elasticity, hardness and water resistance properties. Biodegradability was evident in the composite materials buried for 80 days while the thermal analysis revealed anti-

biodegradability property of castor oil on the composite. This double test method therefore establishes a potential in material development within physical, mechanical, thermal and biological environments.

Keywords: Biodegradation, fiber reinforced composite, castor oil, burial method, polyester.

1.0 INTRODUCTION

Natural fibers are composed of cellulose, lignin, pectin, hemicellulose. These constituents contribute positively to specific stiffness, strength, and biodegradability of polymeric matrices. The lignocellulosic nature of the fibers gives the fiber its hydrophilic properties [1]. This lignin content is responsible for their incompatibility with hydrophobic matrices in fiber reinforced composite applications [2]. Synthetic fibers, although processed to be hydrophobic and compatible with the common hydrophobic matrices are mostly from non-renewable petrochemical derivatives. These derivatives are not only non-renewable and expensive to produce but are also from processes which are not environmentally friendly [3]. These draw backs have led researchers towards the studies of natural fibers such as jute, hemp, banana, okra and flax as probable substitute to synthetic ones by methods of treatments or modifications. Natural fibers are abundant, they have low density and biodegradable [4, 5]. Treatments or modifications of natural fibres reduces the lignin content of the fiber thereby making them less hydrophilic. The fiber surface also becomes rougher resulting in increased fiber and matrix inter-micromechanical interactions [6, 7]. In some cases, adhesion promoters are introduced for improved compatibilities between the fibre and the matrix leading to enhanced physical, mechanical and morphological properties [8]. These improved properties make them applicable in automotive,

marine, civil engineering, medicine, agricultural industries [9]. Several methods have been used in the modification and treatments of naturals fibers. These includes mercerization (alkali treatment), acetylation, benzylation, esterification. Others include treatments with peroxides, stearic acid, toluene-2,4-diisocyanate (TDI), anhydrides, plasma and permanganates [10, 11]. Matrixes used in composite development are polyethylene, polypropylenes, natural rubber, polyesters etc. Most researches on natural fiber reinforced composite have focussed more on the fiber modifications than on promotion of the matrix. This study however focuses on mechanical, biodegradation and morphological studies of fiber surface modification as well as enhancing matrix adhesiveness. The use of Castor oil will serve as an adhesive promoter in the polyester matrix while Stearic acid as a pore modifier/treatment on the okra bast fiber surface.

2.0 MATERIALS AND METHODS

2.1 Treatment of Okra Bast Fibre

Okra bast fibre was obtained from Juneng Nigeria Limited, Nsukka (Enugu State). It was chopped to 2-10mm and treated with 15g of Stearic acid dissolved in 600ml of ethyl alcohol solution. The treatment was carried out by immersing the fiber into the prepared acid solution for 4 hours. The fibre was then removed and dried in an oven at 65oC for 20 minutes [11].

2.2 Preparation of Treated Okra Bast Fibre/Polymer Matrix Composite

A 21cm x 16cm by 4cm steel mold was thoroughly cleaned with wax, which was applied in the inner surface/walls to aid removal of the fabricated composite. 15g of dried treated fibre

was placed in the cavity of the mold while 200ml of polyester resin was measured in 250 ml beaker. Methyl Ethyl Ketone Peroxide (MEKP) catalyst (1% weight of polyester resin), was added to the polyester and stirred for 1 minute. Furthermore, Cobalt naphthalate of 1% weight of polyester was added to the mixture. Castor oil concentration was varied from 0% to 2% at an interval of 0.5% by volume of polyester resin was then mixed. This matrix mixture was then poured into the treated okra bast fiber in the mould. The fabricated composite as prepared according to varying castor concentration was allowed to cure at room temperature before demoulding for physical, mechanical, morphological and biodegradability studies [6]. The sample prepared is shown in Table 1 according to amount of castor oil used for modification.

Table 1: Fabricated samples showing amount of castor oil in the polyester matrix

Sample	Castor oil content in Polyester matrix
Sample A	Unmodified Polyester resin (Control)
Sample B	0.5% castor oil in polyester matrix
Sample C:	1.0% Castor oil in polyester matrix;
Sample D	1.5% castor oil in polyester matrix
Sample E	2.0% castor oil in polyester maatrix

2.3 Physical and Mechancal Property Determination

2.3.1 Water absorption test

This section presents physical and mechanical properties of the fabricated composite; Water absorption test was carried out according to ASTM D570. Equation 1 establishes the percent water absorbed.

$$\%\ Water\ absorption = \frac{W_f - W_i}{W_i} * 100 \qquad (1)$$

where, Wf = weight of sample after immersion, Wi = weight of sample before immersion

All results were taken as average of samples tested.

2.3.2 Hardness test

Hardness Test was conducted using Shore A Hardness Testing Machine with model No. 5019, 2007.

2.3.3. Tensile test

Tensile Test was carried out using the Hounsfield tensometer with the specimens cut in a dumb-bell shape according to ASTM D638M.

2.4. Biodegradability Studies of the Fabricated Composite

The extent of biodegradability was based on weight loss in a burial method. The changes in thermal, morphological and infra-red diagnostic analyses before and after 80 days burial was also monitored.

2.4.1 Soil sample analysis for sample burial

Soil sample was obtained from a refuse located at Hayin dogo, Zaria, Kaduna State of Nigeria. 10g of the soil sample was mixed with sterile normal saline in a conical flask. Serial dilution of 10-5 was prepared and 0.1ml of the dilution transferred into sterile nutrient agar plates. A bent glass rod was then used to spread the inoculant on the surface of the culture media. All the inoculated plates were then incubated at 37^0C for 24 hrs after which all the bacteria colonies were counted and recorded [12].

2.4.2 Composite sample burial method

5kg of the soil sample was weighed and transferred into three different plastic containers. Three of the okro fiber reinforced polyester samples 0% castor oil in matrix (0% C.O), 1% castor oil in matrix (1% C.O) and 2% castor oil in matrix (2% C.O) were then cut into rectangular shapes of 2 × 5mm and weighed. The samples were then buried at a depth of 5cm into the soil sample. The soil was watered every three days to ensure microbial activities. The percentage weight loss was recorded periodically every 20 days after which the samples are reburied and watered until the next period for analysis. The burial studies were carried out over a period of 80 days [13]. Thermal, morphological and Infra-red Spectroscopic studies were then carried on initial and the final (80 day) buried samples using differential scanning calorimeter (DSC), Scanning Electron Microscopy (SEM) and Fourier Transform Infra-red analysis (FTIR) respectively [14 - 16].

3.0 RESULTS AND DISCUSSION

The water absorption was noted to decrease from 2.75% to 1.98% as the composition of castor oil in the matrix increased from 0% to 1% as shown in Figure 1. This implies that the introduction of a desirable amount of castor oil between 0 to 1% by volume of polyester resin help improved the adhesiveness of the composite material thereby increasing the water resistance of the material. Increasing the composition of castor oil beyond Sample C (1%) resulted in the decrease in effectiveness of the matrix leading to increase of the amount of water absorbed. This can be attributed to the lowering of the polyester resin mix required for adequate adhesive/binding capabilities [17].

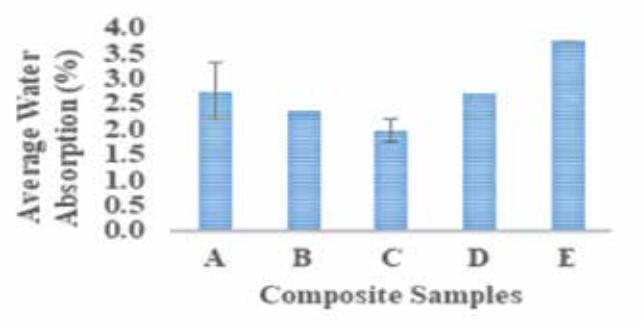


Figure 1: Effect of treatment concentration on water absorption capacity of the composite

In Figure 2, material hardness which is a measure of deformation, penetration, indentation and scratching properties was monitored with castor oil concentration. It was observed that hardness of 90 Durometer was highest for sample C (1% castor oil concentration) before further decreasing with increase in castor oil concentration. This trend can be linked to the deterioration of adhesion capabilities of the matrix with increase in castor oil content beyond 1% [18].

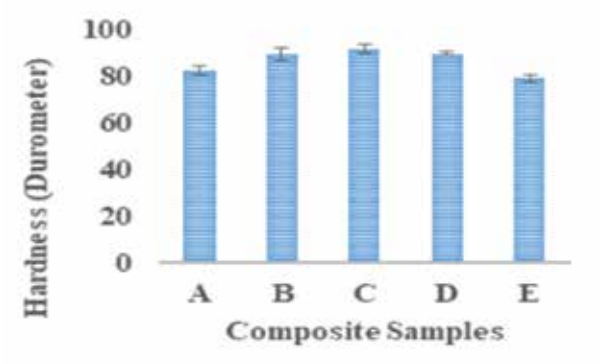


Figure 2: Effect of treatment concentration on hardness of the composite

The measure of resistance of the composites to elastic deformation (Modulus of Elasticity) was highest (266.87 MN/m2) for the sample C. Increasing the composition of castor oil in the composite above 1% by volume of the matrix decreased the modulus of elasticity (200.46 MN/m2 for sample D and 215.28 MN/m2 for sample E) as shown in Figure 3.

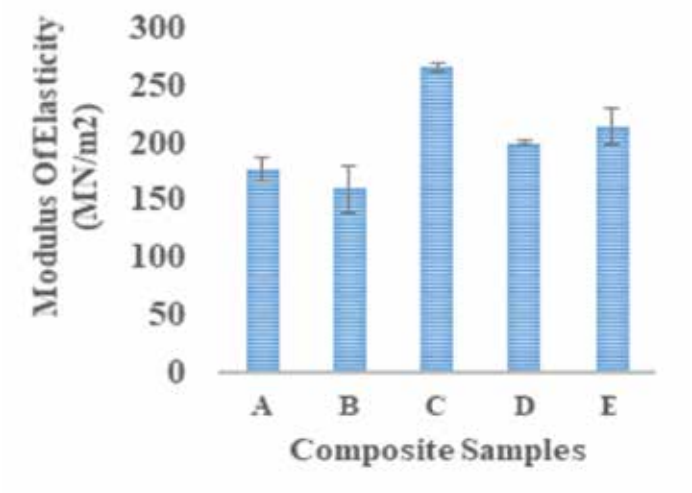


Figure 3: Effect of treatment concentration on the modulus of elasticity of the composite

Castor oil have been reported to favour resistance to elastic deformation of composite [19]. Figure 4 shows the percentage elongation with respect to castor oil improved polyester matrix. The Percentage elongation of sample A (unmodified matrix) was observed to be highest (9.17%) as compared to the other composites of Samples which implied that castor oil modification did not improve the election of the fabricated composite. 11% Polyalcohol blends such as with castor oil have been reported to have positive effect on the percentage elongation of up to 5% [20].

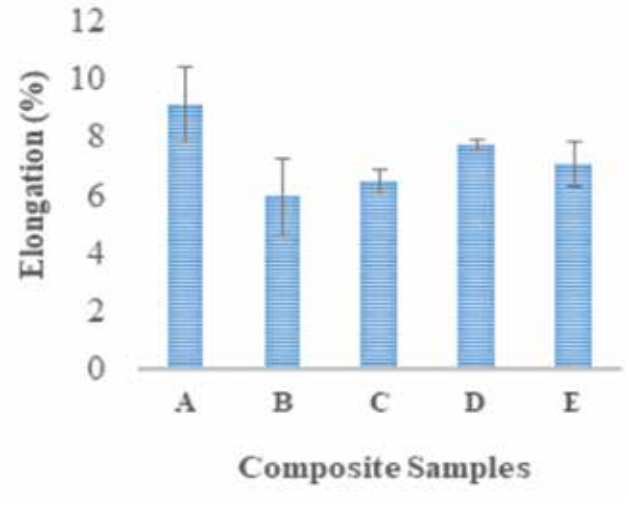


Figure 4: Effect of treatment concentration on water on the percentage elongation of the composite

Biodegradation studies carried out on three (3) of the samples, the 0%, 1% and 2% castor oil concentration in the matrix respectively is shown in Figure 5. No significant weight change occurred in the first 60 days. At day 80, a weight loss of 0.17%, 0.73% and 0.36% was recorded for the samples. This implies that while castor oil can aid biodegradation, excess in treatment concentration can protect fiber surface thereby protecting the composite from microbial attacks [21]. Similar trend where biodegradation until the 80 days was reported on Kenaf reinforced polyurethane composite signifying the start of the biodegradation process [22, 23].

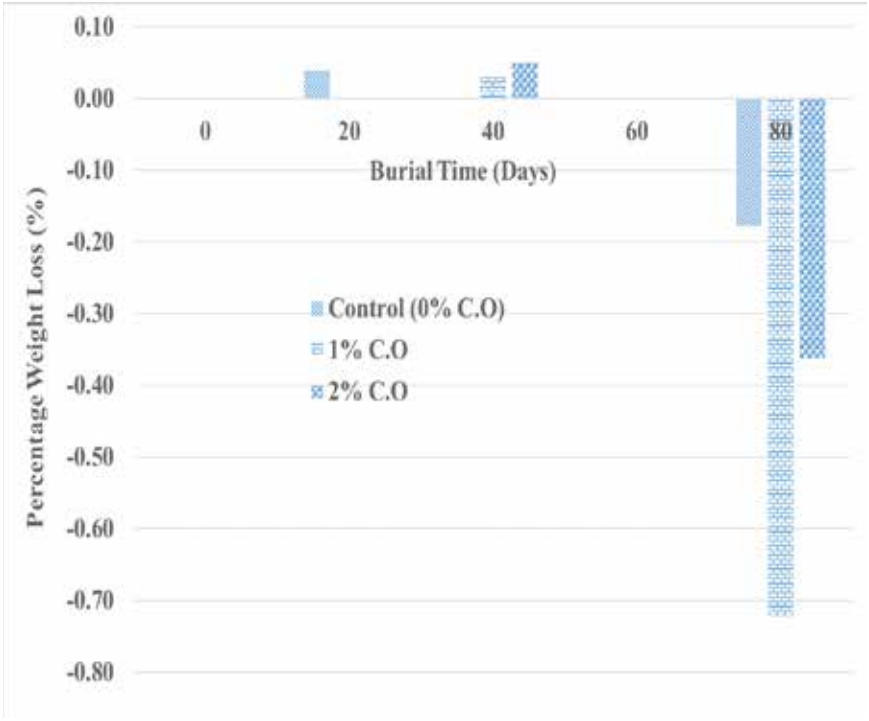


Figure 5: Weight of soil buried okra bast reinforced modified polyester composite

Degradation was further observed for the unburied and the buried composite after 80 days. FTIR studies for 0%, 1% and 2% castor oil modified polyester are shown from Figures 6 to 8. The major peaks are the C=0 stretch at 1720 cm^{-1}, C-H stretch at 3000 cm^{-1} and the -OH group corresponding to an cellulosic hydroxyl and aliphatic ketone functional groups of the composite [14]. The intensities of the peaks were found to reduce after 80 days burial which is an evidence of bio degradation of these functional groups present as well as the composite material [24].

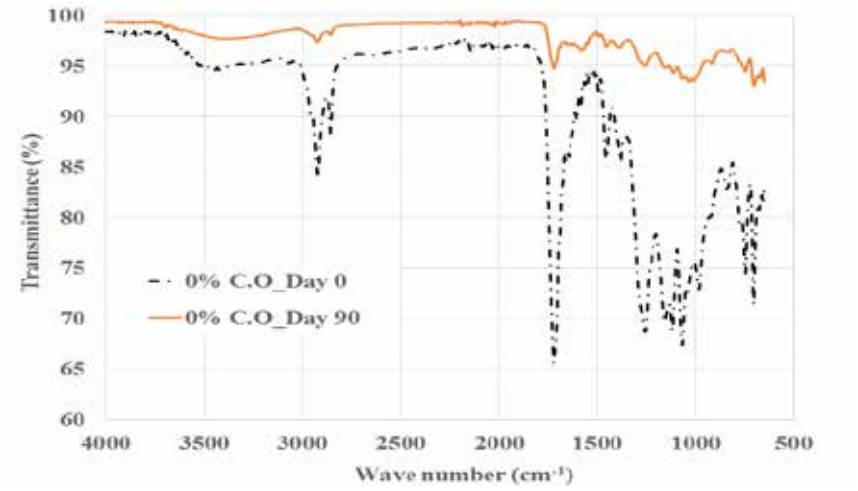


Figure 6: FTIR spectra of composite formed from 0% Castor oil modified polyester matrix

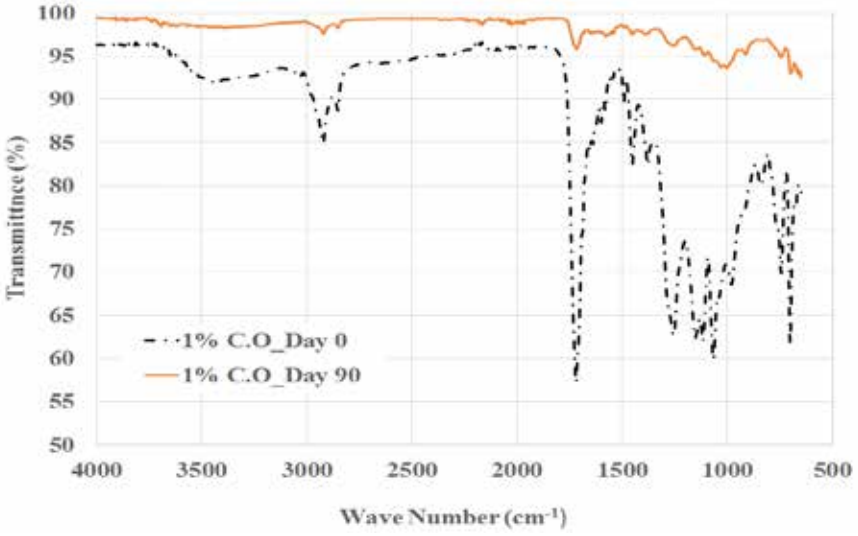


Figure 7: FTIR spectra of composite formed from 1% castor oil modified polyester matrix

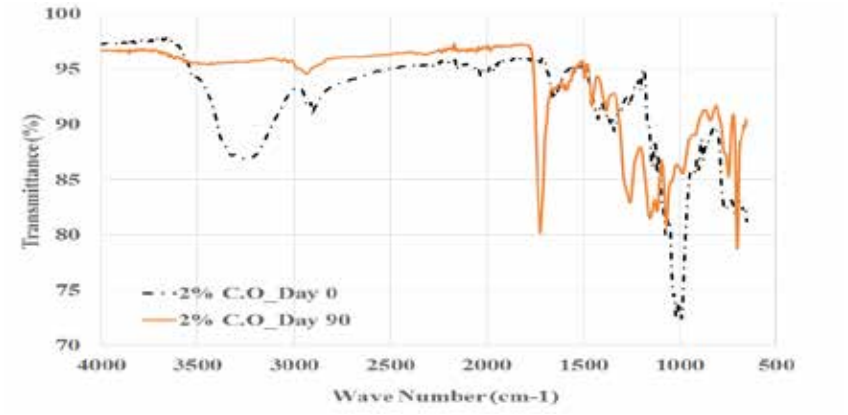


Figure 8: FTIR spectra of composite formed from 2% castor oil modified polyester matrix

Figure 9 shows the morphological image through the aid of scanning electron microscope set at 100 μm. Visible cracks were observed on the three samples after 80 days. This confirms the progress in degradation of the buried sample as at day 80 [12, 25]. 1% castor oil concentration in the matrix showed the most pronounced morphological degradation. This observation is in line with findings at weight loss analysis of the burial method

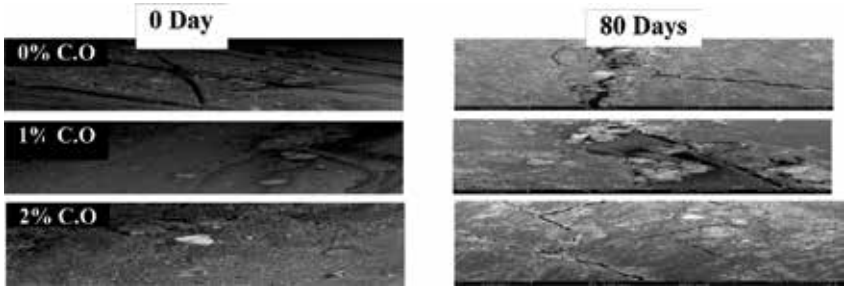


Figure 9: Morphological analysis of 0%, 1% and 2% castor oil modified castor oil in the buried and unburied okra bast fiber reinforced polyester composite

The thermal behaviours of the fabricated samples are shown the DSC thermograms of Figure 7. It was observed that the composites have glass transition temperature at 110°C as well as melting at 250°C. This property disappeared after 80 days except 2% castor oil concentration. This implies castor oil of 2% reduced the biodegradability of the composite [26, 27].

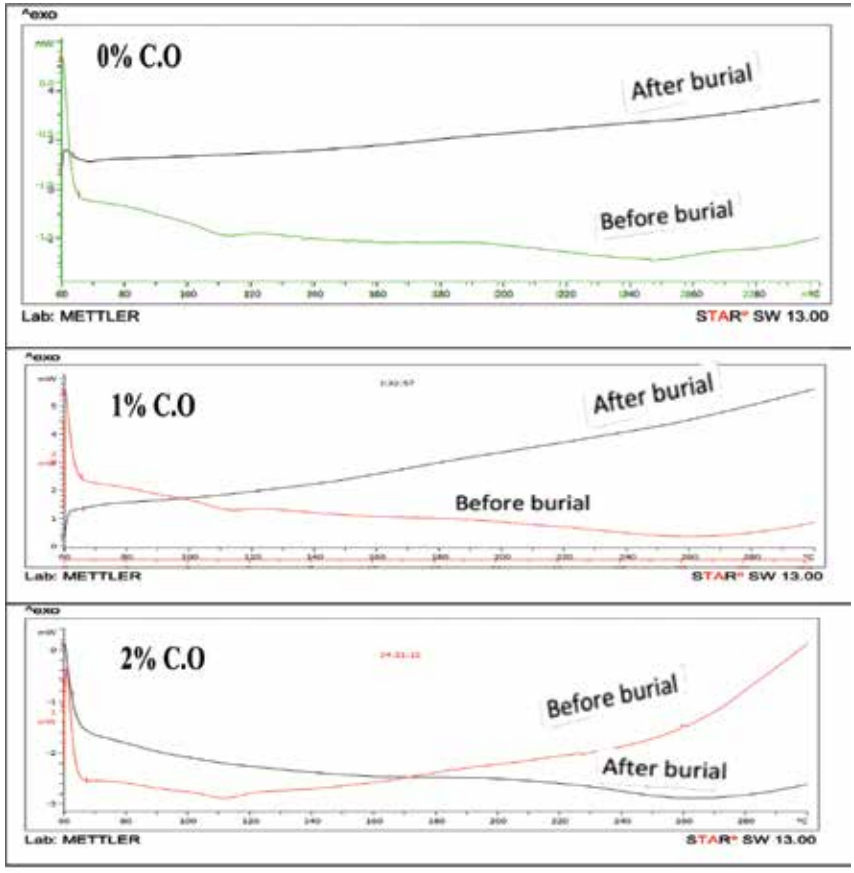


Figure 10: DSC thermograms of buried and unburied samples of okra bast fibre reinforced polyester composite.

4.0 CONCLUSION

Castor oil of 1% by weight of polyester resin improved the mechanical properties of okra bast fibre reinforced polyester composite recording the highest values for hardness (92 Durometer), and modulus of elasticity (266.87 MN/m2) and lowest water absorption (1.98). Thermal, morphological as well as FTIR analysis supported the biodegradation of the samples with 1% castor oil modification of matrix recording the maximum biodegradation. Castor oil concentration of 2% in the matrix reduced the biological activity on the composite in a compost.

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