



DEVELOPMENT OF CALABASH (LAGENARIA SICERARIA) – POLYVINYL CHLORIDE COMPOSITE FOR THERMAL INSULATION

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ABSTRACT

In this work of composite formulation, calabash fibre (Lagenaria siceraria) was used as the reinforcement and Polyvinyl Chloride (PVC) resin as the matrix. The fibre was divided into two (2) equal parts, Fibre part one(1) was treated with 10%w/v of NaOH (Alkali treatment) , part two (2) was left untreated (crude) . Both the matrix and binder were compounded using hand layup technique method. Samples of the treated and the untreated composites were subjected to tensile and flexural strength, Scanning Electron microscopy (SEM), water absorption, thermal conductivity , Specific heat capacity , thermal diffusivity and density tests. From the results obtained, 10% NaOH Alkali treatment for 24 hours was sufficient to remove impurities from the fibre, enhanced good interfacial fibre-matrix bonding. The treated sample of composition (D) has higher tensile strength of 1.41599 MPa ; the tensile and flexural strength of the treated samples increased with increase in fibre content loadings . The Thermal Conductivity result of the treated sample (D) of 40wt% composition has better thermal conductivity of 0.14W/m^ok. Differential Scanning Electron Microscopy machine was used to observe the fibre-matrix interfacial bonding. The density and water absorption values were evaluated. The newly developed composite has lower thermal conductivity than polyvinyl chloride and can be used for such thermal insulation applications as low temperature thermal insulation limits of 15 °C to -75 °C refrigeration and cold rooms' insulations and for hot water and steam condensate as in thermo-flask applications.

Keywords: Composite, Calabash fibre, Matrix, polymer, reinforcement, Thermal Conductivity, Thermal Insulation

1. INTRODUCTION

The name Calabash is applied to the fruits of a vine plant *Lagenaria siceraria* and to that of a calabash-tree *crescentia cujete*. Though, both are called by the same name, the calabash fruits from the calabash-tree (*crescentia cujete*) are not in the gourd family (*cucurbitaceae*), the calabash tree is a small ever green tree, it produces calabash fruits some up to 50cm in diameter, it yields twice in a year, Its fruit (calabash) are not eatable, the pulp inside the fruits are mainly used for trado- medicinal purposes (" The Calabash Tree", 2013). The calabash when dried is used as musical instruments, ornaments, containers for food and for fishing in many African nations such as Nigeria. The calabash from the tree are richer in carbohydrate content than the vine calabash, however due to its perennial, low Vitamins and non edible nature, farmers prefer planting the vine calabash also known as gourds (*lagenaria siceraria*) which have climbing vine stem, some are edible especially those species without bitter taste. They are also rich in carbohydrate and far richer in vitamins content than the tree calabash. Gourds yields up to 35 to 40 metric tonnes per hectare ("The Calabash Bottle Gourds", 2013). The fruits are harvested within 2 to 3 months. They have diverse shapes such as round, bottle-neck, or serpentine (Popularly known as shantu amongst the Hausa-Fulanis in northern Nigeria). The rounded shape types are called calabash gourd while the bottle neck types are called bottle gourd. Both are also used as musical instruments, ornaments, containers for food and for fishing in many African nations such as Nigeria. *Lagenaria Siceraria* also known as Gourds has long been believed to be indigenous to Africa (Erickson et al, 2005). Apparently native to Africa, Bottle Gourd had reached Asia and the Americas by 8000 to 10000 years ago ("The Calabash Bottle Gourds", 2013). Erickson et al (2005) suggested that this "utility specie" (along with another such specie, the Domestic Dog) were domesticated long before any food crops or livestock species and both were brought to the Americas by Paleo-Indian population as they colonized the new world.

According to Decker-Walters et al (2004) the Bottle Gourd is a diploid, self-compatible monoecious annual plant. Monoecious plants do not have separate male and female individuals. Two morphologically distinct subspecies of Bottle Gourd are recognized, *lagenaria siceraria* (the African and American/new world Gourds) and *lagenaria siceraria asiatica* (the Asian Gourd). Some species of *Lagenaria siceraria* fresh matured fruit with green shell may contain the chemical compounded Tetracyclic Triterpenoid cucurbitacin which taste bitter and can kill if consumed in large doses (" Bitter Lauki Juice can kill you", 2009). Calabash has long been used as containers for water and food (due to their good thermal insulator ability), musical instrument e.g. the Goge instrument used by the Fulani's in Northern Nigeria and central Africa, palm wine and Burukutu (local beer) in the southern and Northern part of Nigeria, respectively. Also in Kano (North western part of Nigeria), calabash was worn as crash helmet by bikers as a substitute to polymer helmet during the ban on biking without helmet in the city (" Nigerian Bikers Vegetable Helmet ", 2009). They are also used as fishing floats due to their buoyancy ability and light weight. They also find usage as soverniers during the Hausa Fulani marriages after been transformed as crafts of various designs and displays. It is hard and brittle, the inner foam part of the calabash is hydrophobic (absorbs and retain water). Idicula et al (2005) gave the etymology of the noun "composite" as been derived from the Latin verb "componere" which means to put together. Therefore, composites materials are considered as materials which are formed by the combination of two or more chemically distinct constituents on a macro scale ratio. Natural Fibre-Reinforced Composite (NFRC) are more and more frequently applied to building and the transportation industries (Kozlowski and Wladyka- Przybylak, 2008).

The major goal of natural fiber composites is to alleviate the need to use expensive glass fibre which has a relatively high density and is depending on non-renewable sources. The ancient use of Calabash gourds as food containers is due to its good thermal insulation property and low weight. It has the major advantage of being light weight, have high tensile strength under static loading, good particle orientation, good thermal insulator, and tri-annual cultivation. Hence, can be readily available and cheap.

However, it is disturbing that though this plant fibre has an ancient history and good unverified mechanical properties, it has no applications in modern industrial applications, even though there exist polymer matrixes to transform it into a viable precursor for industrial usage in composite material manufacturing. This work is an attempt to use the calabash fibre for green composite formulation following previous standard methods as embarked upon by various green composite researchers such as Mansour, Hocine and Nouredine (2011) on Fibre Reinforced Composite (FRC),

Its tensile and flexural strength, thermal conductivity, Specific Heat Capacity, Thermal diffusivity, Water absorption, Density and Scanning Electron Microscopy of the composite formulated shall be considered for possible thermal insulation applications.

2. Method/ Experimental Details

2.1 Preparation of the Calabash Samples

The specimen preparation for the fibre precursor part one (1) was as described in Mansour, Hocine and Nouredine (2011)[9] and Modibbo, Aliyu and Nkafamiya (2009). The calabash was broken into pieces by pounding in a mortar and pestle, washed in water and dried at ambient temperature for 48 hours, this was done to remove impurities e.g. sand particles that may be hidden in the calabash crevices. It was then transferred to an electrical oven that was set under control temperature of 35 °C for 4 hours, this was done in batches until the whole precursor was dried. The calabash fibre in broken pieces form were then divided into two equal parts of equal weight of 3.5 kg each. Calabash fibre part one (1) was treated with 10% w/v NaOH for 24 hours (alkali treatment) while calabash fibre part two (2) was left untreated.

2.2 Mercerization – Alkali Treatment to part One (1) of Calabash Fibre

This was done to depolymerise, and defibrillate the individual fibres so as to remove certain amount of lignin, wax and oils so as to increase surface roughness of fibres which consequently enhances fibre-matrix surface bonding, hence giving better mechanical interlocking, better mechanical strength and stiffness, by the transformation of crystalline cellulose to amorphous cellulose content as described by Maya, Rajesh, and Anandjiwala (2007). For each volume of water (20 litres), 10% aqueous solution of NaOH was added, stirred at room temperature before the calabash fibre was soaked in it. After 24 hours, the fibre was scooped out, and washed thoroughly under running water. The treated fibre was then spread on a clean mat under sun and allowed to dry. This procedure is as described by Mansour, Hocine and Nouredine (2011). The treated and untreated fibre were then stored in two different transparent polythene bags labelled part one (1) treated and part two (2) untreated. Both part one(1) and two(2) were milled (grinded) to particle sizes, sieved to the same mesh size of 1.18 mm (1180µm), measured to the same weight of 3.3 kg each with the aid of an electronic balance and stored in different labeled bags labeled treated particle fibre part one (1) and untreated fibre part two (2).

2.3 Composite Formulation

Conventional hand layup technique procedure was used in forming the composite as described by Ritesh et al (2012) [12]. The matrix (binder) polyvinyl chloride and the reinforcement (calabash fibre) were mixed in a plastic basin before been cast into a wooden mould of $32 \times 7 \times 3 \text{ cm}^3$ dimensions, potting time was 25 minutes and the curing time was 28 hours under ambient temperature. The above technique was used to cast the composite for the treated fiber part (1) and the untreated fibre part (2). For each part of Fibre 1 and 2 there were five (5) compositions of varying fibre content loadings, these are ; A (10wt %), B (20 wt%) , C (30wt%) , D (40 wt%) and (50 wt%). The method of compounding was as described by Ritesh et al ,(2012)

2.4 Experimental Design

Single Factor experimental design was used

$N = L^k \cdot n = 5^1 \times 3 = 15$ samples for Treated Calabash fibre and 15 samples for Untreated Calabash fibre .Where; L = levels = 5, K = factors = 1, n = number of replicas = 3

Total Number of Samples = $15 \times 2 = 30$ for the treated and untreated samples, the untreated sample served as control.

3.0 Physical and Mechanical Characterization

3.1 Tensile Test

The tensile test was carried out according to ASTM D 3039 for determining the tensile properties of polymer matrix composites at the Centre of Energy Research and Development Ile-Ife, Obafemi Awolowo University (OAU). The measurement was done with the aid of a Universal Mechanical Testing Machine UMTM (INSTRON - SERIES 3369) Load Cell Capacity – 50 KN. The dimension of the specimen size is a rectangular cross section measuring $65 \times 29.93 \times 9.62 \text{ mm}^3$ in Length x width x thickness .

3.2 Water Absorption Test

Percentage water absorption was conducted according to ASTM D-570. The samples were weighed and immersed in clean water for 24hours at room temperature. Their soaked weight was measured using a weighing balance. The percentage water absorption was calculated using the formula below:

$$\% \text{ Water absorption} = \frac{W-D}{D} \times 100 \quad (1)$$

Where:

D = weight of dry sample , W = weight of soaked sample

3.3 Flexural strength Test

As cited by Prakash (2009) , the Short Beam Shear(SBS) was performed on the composite samples at room temperature at the Center for Energy Research and Development Obafemi Awolowo University Ile- Ife to evaluate the value of Flexural Strength (FS) . It was a 3 point bend test, which generally promotes failure by inter- laminar shear. The SBS test was conducted as per ASTM D- 790 using the same UMTM. Span length of 65mm and cross head speed of 2mm/min were maintained according to ASTM D-790, the sample dimensions was 127 x 12.7 x 3.18 mm. The flexural strength (FS) of the specimen can be determined using the following equation:

$$FS = \frac{3PL}{2bt^2} \quad (\text{Prakash , 2009}) \quad (2)$$

Where L is the span length of the sample in mm , P is the load applied in Newton or Pascal (Pa), b and t are the width and thickness of the specimen respectively in mm. The flexural strength test measures the behavior of materials subjected to simple beam loading. The 3- point bending test was used to find the flexural strength, flexural modulus and strain at break of the calabash fibre reinforced polymer composite.

3.4 Scanning Electron Microscopy (SEM).

The surface of the raw fish scales and the composite specimens was examined directly by scanning electron microscope JEOL JSM-6480LV. The scales were washed, cleaned thoroughly, air dried and are coated with 100 Å thick platinum in JEOL sputter ion coater and observed on SEM at 10 KV (Prakash , 2009) . Similarly, the composite samples were mounted on stubs with silver paste, a thin film of platinum was then vacuum-evaporated on to the entire arrangement so as to enhance the conductivity of the samples.

3.5 Thermal conductivity Tests

The thermal conductivity of the samples of the composite of this work was determined with a modern equipment called the Modulated Temperature Differential Scanning Calorimetry (DSC) METLLER according to ASTM E-1952 at the Centre of Energy Research and Development Ahmadu Bello University (ABU) Zaria, Kaduna State.

3.6 Density Test

The specimen was weighed in a weighing balance and their weights recorded. Their volumes were calculated from their dimensions 75 x 25 x 17 mm³ according to ASTM D792. The density was then calculated using the formula:

$$Density = \frac{mass}{volume} (g/cm^3) \quad (3)$$

3.7 Specific Heat Capacity

The Specific Heat Capacity of the samples of the composite of this work was determined with the same equipment that was used to determine the thermal conductivity of the samples that is the Modulated Temperature Differential Scanning Calorimetry (DSC) METLLER at the Centre of Energy Research and Development Ahmadu Bello University (ABU) Zaria, Kaduna State.

3. 8 Thermal Diffusivity

Although thermal diffusivity can be experimentally measured with modern temperature measurement equipment by flash method, in this work it is calculated after knowing thermal conductivity, specific heat capacity and densities of the samples this procedure was also adopted by Malla Surya Teja et al , (2016)

$$\text{Thermal Diffusivity} = \frac{\text{Thermal Conductivity}}{\text{Density} \times \text{Specific Heat Capacity}} (\text{m}^2/\text{s})$$

4.0 Results / Discussions

4.1 Results

Table 4.1

Tensile/ Flexural Strengths Result.

S/N	Wt%	Tensile Strength (MPa)		Flexural Strength (MPa)	
		Treated	Not Treated	Treated	Not Treated
1	10	1.08926	0.81384	0.91764	0.88762
2	20	1.19817	0.90138	0.98716	0.90016
3	30	1.30708	0.98892	1.04686	0.91266
4	40	1.41599	1.07646	1.74702	1.39167
5	50	1.36257	1.05208	3.85872	2.66122

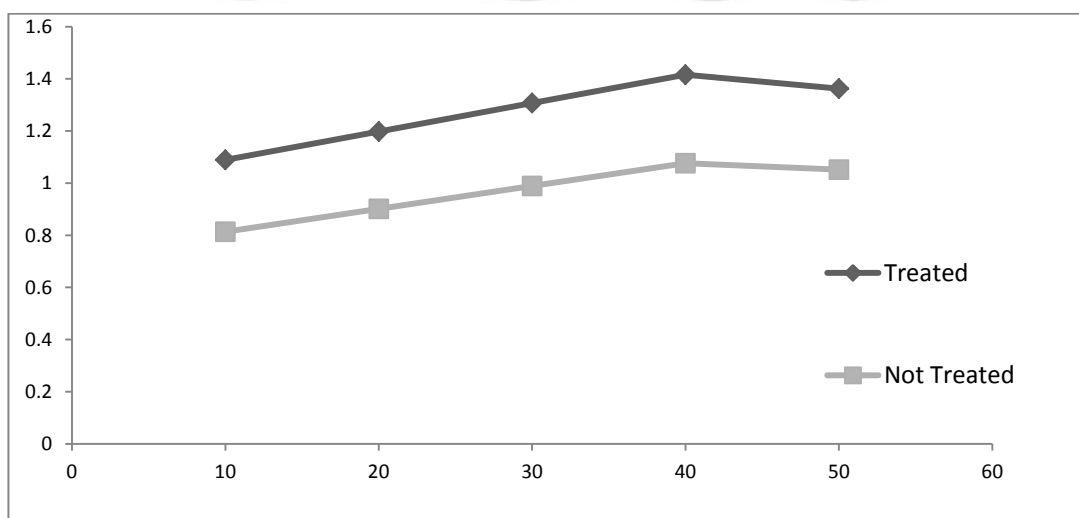


Figure 4.1 Graphs of Tensile strengths against Wt % Fibre content compositions of Treated and Not Treated calabash /PVC Composite

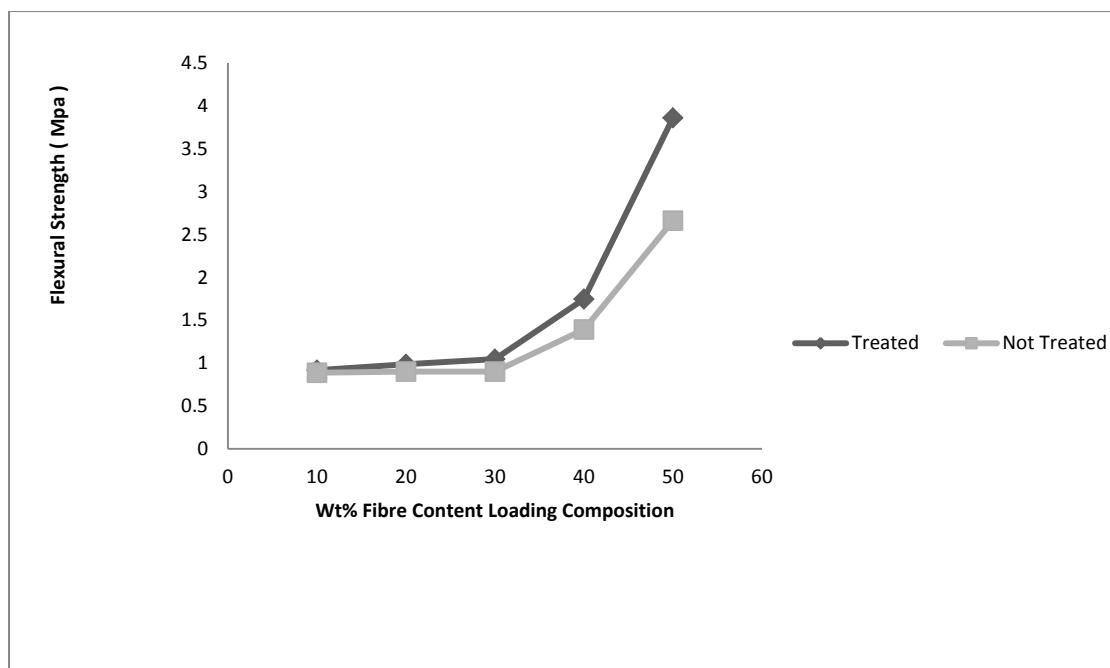


Figure 4.2 Graphs of Flexural strengths against wt % Fibre content loading compositions of Treated and Not Treated Calabash / PVC Composite

4.1.2 Thermal conductivity, water Absorption and Thermal Diffusivity

Table 4.2

Result of Thermal conductivity, water Absorption and Thermal Diffusivity

Wt% Fibre Load	Thermal Conductivity (W/m ² k)		Water Absorption		Thermal Diffusivity (m ² /s)	
	T	NT	T	NT	T x10 ⁻⁵	NT x10 ⁻⁵
10	0.162	0.752	0.41	0.44	9.45	37.66
20	0.154	0.758	0.46	0.49	10.86	40.39
30	0.147	0.764	0.51	0.54	13.65	43.87
40	0.14	0.77	0.55	0.59	20.31	48.37
50	0.18	0.735	0.59	0.63	69.53	51.49

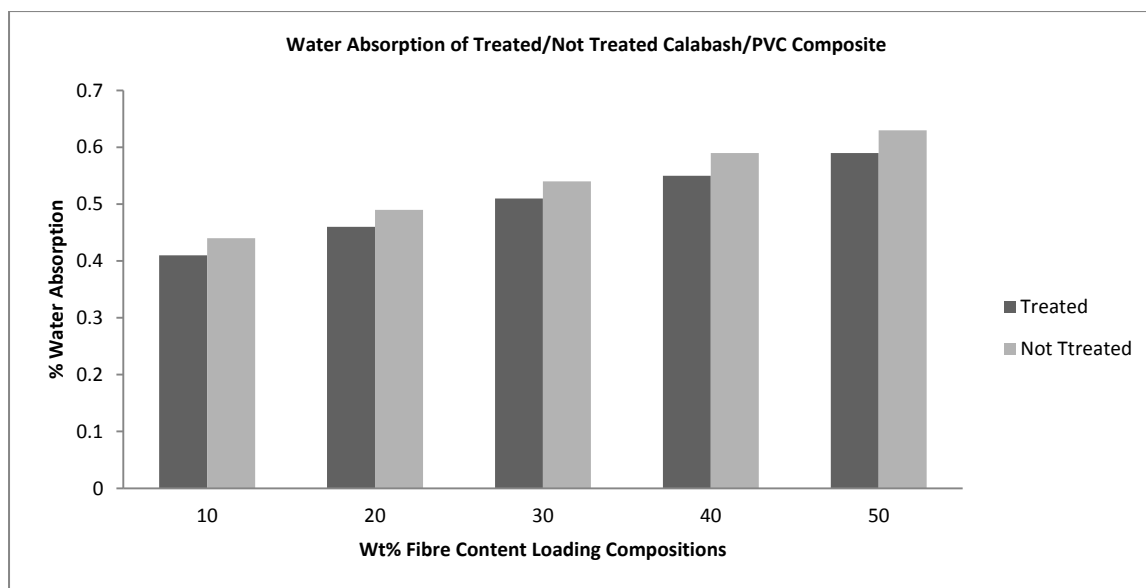


Figure 4.5 Graph of comparisons for percentage water Absorption of treated and untreated Calabash / PVC composite

4.1.3 Density

Table 4.3

Densities of Treated and Not Treated Calabash / PVC composites of varying fibre content loading

Wt%	Mass (kg)		Volume (m3)	Density (kg/m3)	
	Treated	Not Treated		Treated	Not Treated
10	0.041	0.042	3.1875×10^{-5}	1286	1312
20	0.032	0.038	3.1875×10^{-5}	1004	1187
30	0.023	0.034	3.1875×10^{-5}	722	1062
40	0.014	0.03	3.1875×10^{-5}	439	937
50	0.005	0.026	3.1875×10^{-5}	157	812

The Volume of all the samples are the same at $0.075 \times 0.025 \times 0.017 \text{ m}^3 = 3.1875 \times 10^{-5} \text{ m}^3$ while their masses vary as seen in Table 4.3

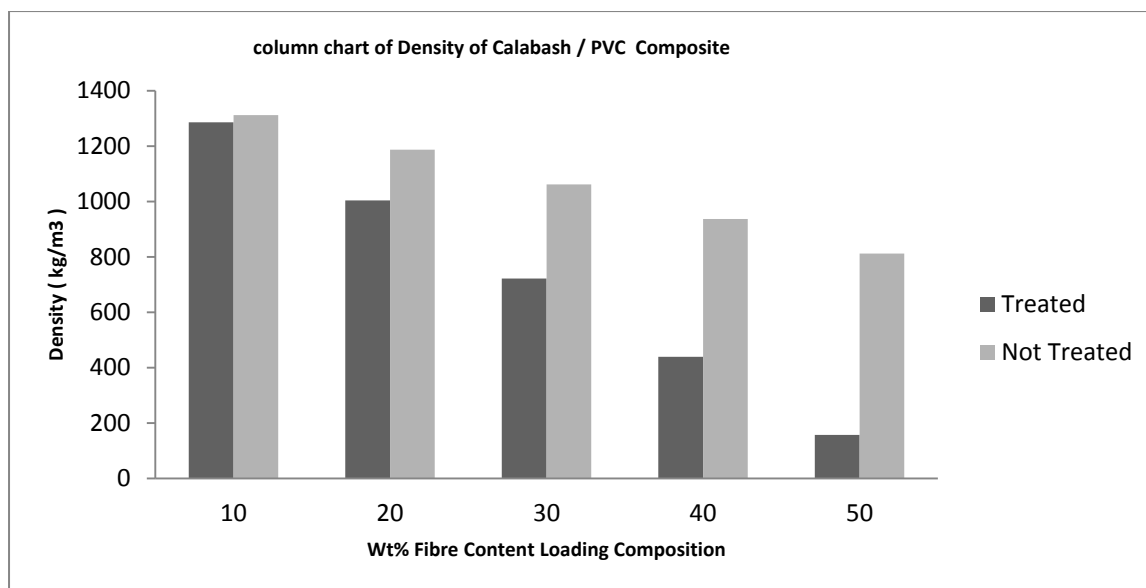


Figure 4.6 Graph of comparisons of Densities and percentage fibre content loadings of treated and Not treated Calabash / PVC Composite

4.1.4 Specific Heat Capacity

Table 4.4

Specific Heat Capacity (kJ /kg.°k) of Calabash/ PVC Composite

S/N	Wt% fibre Content Composition	Treated	Not Treated
1	10	1.333	1.522
2	20	1.412	1.581
3	30	1.491	1.640
4	40	1.570	1.699
5	50	1.649	1.758

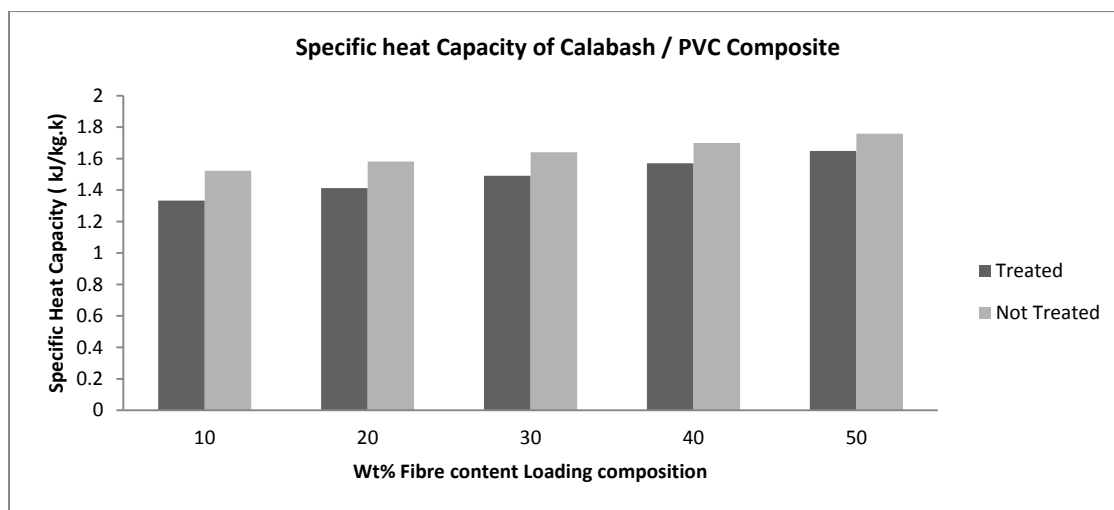


Figure 4.7 Graph of comparisons for specific heat capacity and percentage fibre content loadings of treated and Not treated Calabash / PVC Composite

4.1.5 Scanning Electron Microscopy

Below are the Scanning Electron Microscopy photo for (40wt %) fibre loading content of Treated and Untreated calabash / PVC Composite Presented in plates

Plate 1: 40 wt % of Treated Calabash /PVC Composite

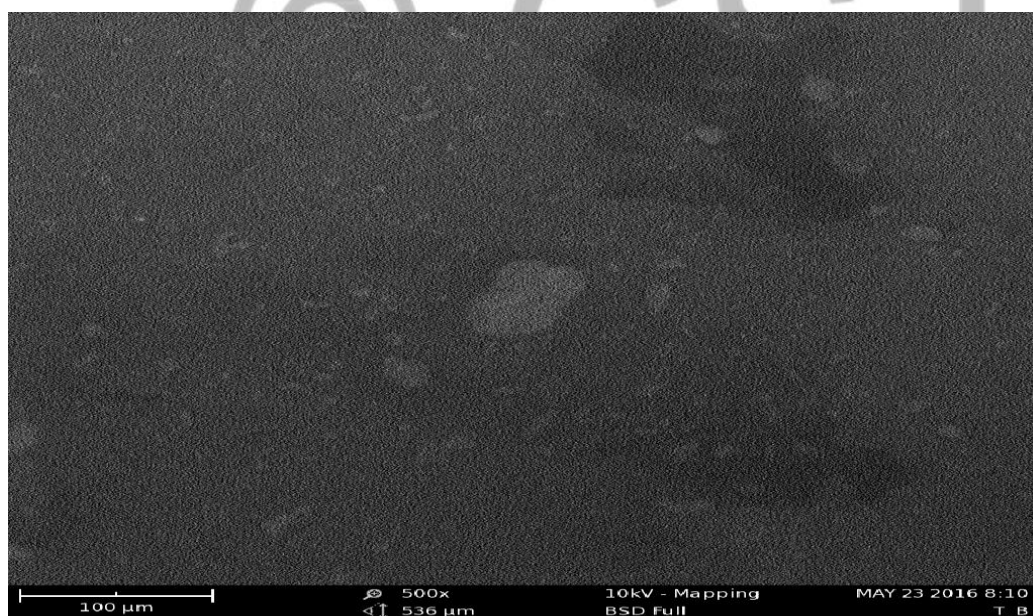
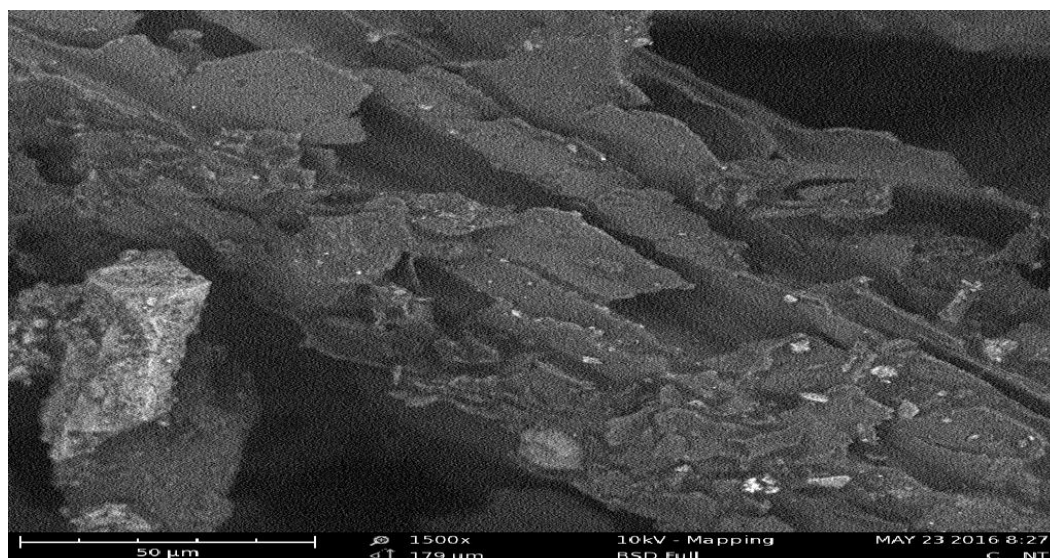


Plate 2 : 40 wt % of Untreated Calabash / PVC Composite



4.2 Discussions

4.2.1 Tensile Strength

From the Tensile test results in Table 4.1 the treated samples A, B,C,D and E of fibre Content Loading compositions of 10wt%, 20wt%, 30wt%, 40wt%, and 50% weight of composite have maximum tensile strength of 1.08926 MPa , 1.19817 MPa , 1.30708 MPa , 1.41599 MPa , and 1.36257 MPa respectively.

For the Not Treated samples A, B, C , D and E with the same compositions as that of the treated, is presented in Table 4.2 , the maximum tensile strength of A, B , C , D , and E are 0.81384 MPa , 0.90138 MPa , 0.98892 MPa , 1.07646 MPa and 1.05208 MPa respectively.

The result of analysis of variance (ANOVA) for tensile strength of treated and untreated samples shows that there is a significant difference in the tensile strength of the composites at $\alpha = 0.05$ and a confidence level of 95%. The mean tensile strength of the treated samples A, B, C, D and E is approximately 1.28 MPa, the variance is 0.017 and the standard deviation from the mean value is 0.131.

The mean tensile strength of the untreated samples in Table 4.1 is 0.966 MPa. The variance is 0.011 and the standard deviation from the mean is 0.108. The treated samples A, B, C , D and E presents better results than the untreated samples as a result of the alkaline treatment which removed lignin and wax from the fibre ,transforming it from crystalline to amorphous crystals , thereby enhancing better bonding of the fibre and matrix interface this is as also observed by Maya, Rajesh and Anandjiwala, (2007) . Treated composite sample D of 40wt% composition has higher tensile strength , It was also observed that as fibre content loading of treated samples increased, tensile strength also increased, this was also so for the untreated sample . The formulated composite of treated sample D of 40wt% composition has better tensile strength of 1.416 MPa compared to the tensile strength of the procured Flexible PVC synthetic resin value of 1.2 MPa.

4.2.2 Flexural Strength

From Table 4.1 the flexural test results of the treated samples A, B, C, D and E of fibre Content Loading compositions of 10wt%, 20wt%, 30wt%, 40wt%, and 50% weight of composite have Maximum flexural strength of 0.91764, 0.98716, 1.04686, 1.74702 and 3.85872 MPa. The untreated samples A, B, C, D and E with the same composition have Maximum flexural strength of 0.88762, 0.90016, 0.91266, 1.39167 and 2.66122 MPa respectively. It was observed that the treated and untreated samples flexural strength values were increasing with increase in fibre content loadings, this is as was also observed by Mansour, Hocine and Nouredine (2011) that for a fibre processing of 10% NaOH for 24 hours, the flexural strength and flexural modulus will improve.

The result of analysis of variance for the Maximum flexural strength (MFS) of the treated and untreated samples A, B, C, D, and E of 10wt%, 20wt%, 30wt%, 40wt% and 50wt% shows that there is no significant difference in the means of the samples at 95% confidence level and at $\alpha = 0.05$, the mean value for the maximum flexural strength for the treated samples A, B, C, D, and E is 1.711 MPa, the variance is 1.552. The standard deviation from the mean is 1.245.

The result of analysis of variance for the Maximum flexural strength (MFS) of the untreated samples A, B, C, D, and E of 10wt%, 20wt%, 30wt%, 40wt% and 50wt%, the mean value is 1.348 MPa, the variance is 0.584 and the standard deviation from the mean value is 0.764. Though there was no significance difference, the treated samples presents higher flexural strength results. For both the treated and untreated samples, the 50wt% fibre content loadings presents higher flexural strength results.

4.2.3 Thermal Conductivity

From Table 4.2 the Thermal Conductivity test results of the treated samples A, B, C, D and E of fibre Content Loading compositions of 10wt%, 20wt%, 30wt%, 40wt%, and 50% weight of composite have of 0.162, 0.154, 0.147, 0.140 and 0.180 W/m²K. The untreated samples A, B, C, D and E with the same composition have values of 0.752, 0.758, 0.764, 0.770 and 0.735 W/m²K respectively.

It was observed that as fibre content increased for the treated sample, thermal conductivity values decreased, while for the untreated samples increase in fibre content loadings resulted to increase in thermal conductivity values.

From the results presented, the treated sample of 40wt% composition has better thermal conductivity value of 0.14 W/m²K, the alkali treatment was sufficient in converting cellulose-I to cellulose-II which is thermodynamically more stable than cellulose-I. This was as also observed by Dedeepya, Dharma and Jayananda (2012).

The result of analysis of variance for the Thermal Conductivity of the treated samples A, B, C, D, and E of 10wt%, 20wt%, 30wt%, 40wt% and 50wt% shows that there is significant difference in the means of the Thermal Conductivity of the treated and untreated samples at 95% confidence level and at $\alpha = 0.05$, the mean value for the treated samples A, B, C, D, and E is 0.156, there variance is 0.000238. The standard deviation from the mean is 0.0154.

The result of analysis of variance for the Thermal Conductivity of the untreated samples A, B, C, D, and E of 10wt%, 20wt%, 30wt%, 40wt% and 50wt%, the mean value is 0.755, the variance is 0.00018 and the

standard deviation from the mean value is 0.0134. The treated samples presents lower thermal conductivity results, the lower the value the better the thermal insulation performance of the material. It was observed that while there was a decrease in the thermal conductivity value with increase in fibre content loadings for the treated samples, there was an increase in the thermal conductivity values of the untreated samples with increase in fibre content loadings.

4.2.4 Water Absorption

As seen in table 4.2 the treated sample A of 10 wt% fibre content loading composition has better water absorption of 0.41 compared to untreated sample A of the same composition which has water absorption value of 0.44, this is as a result of 10% NaOH alkali treatment which was sufficient in transforming the crystalline fibre to amorphous fibre thereby reducing its water absorption rate, this was as also observed by Isa et al (2014), they also asserted that 5% w/v of NaOH would have given minimal water absorption value than 10% w/v where water absorption is of major engineering concern.

The Analysis of variance shows that there's no significant difference in the water absorption values for treated and untreated samples A, B, C, D and E of the composites at 95% confidence level at $\alpha = 0.05$. The mean value for the treated samples is 0.504, the variance is 0.00508 and the standard deviation value is 0.0712. Also the average or mean value for the untreated samples A, B, C, D and E is 0.538. The variance is 0.00577 and the standard deviation is 0.0759 with standard error of 0.0339. It was observed that as fibre content loadings composition increases, water absorption value also increases, this is so because the matrix volume is been dominated by the fibre content and according to Maya, Rajesh, and Anandjiwala (2007) natural fibres are hydrophilic in nature as they are derived from lignocelluloses which contains strongly polarized hydroxyl groups. Thus increasing the quantity of fibre in polymer matrix increases its percentage water absorptions for both treated and untreated samples.

4.2.5 Density

The density of a material is critical in the choice of selection of engineering materials. From table 4.3 the treated sample E with 50wt% of fibre content load composition has better density value of 157 Kg/m³ when light weight is to be considered, 10% w/v of NaOH was sufficient in removing of natural and artificial impurities from the treated fibre (Mishra et al, 2001). It was observed from table 4.3 that as percentage fibre content increases the density of the sample decreases, treated samples A, B, C, D and E has densities 1286, 1004, 722, 439, and 157 kg/m³ respectively, the mean value is 721.70 kg/m³, the variance is 199233.30 and the standard deviation is 446.36. Also from table 4.3, the untreated samples A, B, C, D, and E of the same percentage fibre content loadings compositions have densities 1312, 1187, 1062, 937, and 812 kg/m³ respectively. The mean value for the untreated samples is 1062, the variance is 39062.50, and the standard deviation is 197.64. The removal of lignin, pectin and wax and the transformation of crystalline fibre to amorphous fibre by mercerization treatment was responsible for the difference in weight of the treated and the untreated samples (Modibbo, Aliyu and Nkafamiya, 2009).

4.2.6 Specific Heat Capacity

From Table 4.4 the Specific Heat Capacity test results of the treated samples A, B, C, D and E of fibre Content Loading compositions of 10wt%, 20wt%, 30wt%, 40wt%, and 50% weight of composite have values of 1.333, 1.412, 1.491, 1.570 and 1.649 KJ / kg.⁰k. The untreated samples A, B, C, D and E with the same composition have values of 1.522, 1.581, 1.640, 1.699 and 1.758 KJ / kg.⁰k respectively.

It was observed that as fibre content loadings increased for the treated and untreated samples, Specific Heat Capacity values also increased. The result of analysis of variance for the Specific Heat Capacity of the treated and untreated samples A, B, C, D, and E of 10wt%, 20wt%, 30wt%, 40wt% and 50wt% shows that there is no significant difference in the means of the treated and untreated samples at 95% confidence level and at $\alpha = 0.05$, the mean value for the treated samples A, B, C, D, and E is 1.491, the variance is 0.015. The standard deviation from the mean is 0.124.

The untreated samples A, B, C, D, and E of 10wt%, 20wt%, 30wt%, 40wt% and 50wt%, the mean value is 1.640, the variance is 0.008 and the standard deviation from the mean value is 0.093. The untreated samples present higher Specific Heat Capacity results. According to Malla Surya Teja et al (2016) as Specific Heat Capacity increases, thermal conductivity and density values decrease.

4.2.7 Thermal Diffusivity

From Table 4.2 the thermal diffusivity test results of the treated samples A, B, C, D and E of fibre Content Loading compositions of 10wt%, 20wt%, 30wt%, 40wt%, and 50% weight of composite have values of 9.45×10^{-5} , 10.86×10^{-5} , 13.65×10^{-5} , 20.31×10^{-5} and 69.53×10^{-5} m²/s. The untreated samples A, B, C, D and E with the same composition have values of 37.66×10^{-5} , 40.39×10^{-5} , 43.87×10^{-5} , 48.37×10^{-5} and 51.49×10^{-5} m²/s respectively.

It was observed that as fibre content loadings increased for the treated and untreated samples, thermal diffusivity values also increased.

The result of analysis of variance for the treated and untreated thermal diffusivity samples A, B, C, D, and E of 10wt%, 20wt%, 30wt%, 40wt% and 50wt% shows that there is no significant difference in the means of the treated and untreated samples at 95% confidence level and at $\alpha = 0.05$, the mean value for the treated samples A, B, C, D, and E is 0.0002476, the variance is 6.438×10^{-8} . The standard deviation from the mean is 0.0002537.

The untreated samples A, B, C, D, and E of 10wt%, 20wt%, 30wt%, 40wt% and 50wt%, the mean value is 0.0004435, the variance is 3.195×10^{-9} and the standard deviation from the mean value is 0.0000565. The untreated samples presents higher thermal diffusivity values. Thermal diffusivity increases with increase in fibre content loadings. The untreated samples have higher thermal diffusivity value, this is as a result of the presence of more moisture content in the untreated sample than the treated sample (Binu , 2016).

4.2.8 Scanning Electron Microscopy (SEM)

Treated Samples B (40wt%)

Plate photo 1 SEM result, shows the SEM result for treated sample B, the SEM shows a much better result, this is as confirmed by previous work done by Majid and Muhammad (2016). It shows better matrix – fibre interaction, no fibre crack and isolated void regions.. However one can see white regions surrounded by black regions where matrix flapped out of fibre indicating matrix failure i.e matrix de-bonding.

Untreated Samples B (40wt%)

From plate photo 2 SEM result, one can easily see white regions where matrix flaps out of fibre (matrix failure) indicating fibre and matrix de-bonding. Black cracked regions indicating fibre fracture, voids can also be seen due to fibre pull outs, this occurs as a result of excess matrix to fibre ratio. This was as mentioned by Amuthakkannan et al (2013).

4.3 Conclusion

The following conclusion can be made from the experiment:

1. Alkaline treatment of 10%w/v NaOH for 24 hours was sufficient to remove impurities from the fibre enhancing good interfacial fibre – matrix bonding, less voids, less fibre pull outs and matrix – fibre internal roll ups as observed from the SEM results.
2. The tensile strength of the treated samples presents better results than the untreated samples as a result of the alkaline treatment changing the crystalline fibre particles to amorphous particles. Increase in fibre content loadings resulted to increase in tensile strengths for the treated and untreated samples. The treated sample D (40 wt%) has higher tensile strength of 1.41599 MPa
3. The flexural strength of the treated samples presents better results than the untreated samples due to 10 % NaOH alkaline treatment. Increase in fibre content loadings resulted to increase in flexural strengths for the treated and untreated samples. The treated sample E (50 wt%) has higher flexural strength of 3.85872 MPa
4. The thermal conductivity result of the treated sample of 40 wt% percentage fibre composition of matrix has better thermal conductivity of 0.14 W/m °k.
5. SEM results of the untreated samples have higher degree of voids, fibre fracture, fibre-pullouts and fibre- matrix failure compared to the treated samples. All these indicates that 10% NaOH alkaline treatment was sufficient for better matrix – fibre interfacial bonding.
6. It was observed that as fibre content loading compositions increases, water absorption value also increases. This is so because the polymeric matrix volume is been dominated by the fibre reinforcement in the composite. In general the treated samples has better (lower) water absorption values than the untreated samples.

7. The treated sample E (50wt%) of fibre content loading has better density value of 157 Kg/m³ when light weight is to be considered. This is so because as percentage fibre content increases the density of the sample decreases.
8. The thermal diffusivity and specific heat capacity of the untreated samples have higher values than the treated samples. Increase in fibre content loadings resulted to increase in thermal diffusivity and specific heat capacity of the treated and untreated samples.

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