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Effects of Alkaline Treatment on Flexural Strength and Hardness Values of Okra Bast Fibre/Unsaturated Polyester Resin Composites

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ABSTRACT

Composites of okra bast fibre (OBF) reinforced unsaturated polyester resin (UPR) was produced using the hand layup technique. The fibres were treated with of 5%, 10% and 15% concentrations of NaOH solutions and composites were prepared with variations in filler content. The composites were subjected to tests to evaluate their mechanical properties. Tensile strength, young's modulus, flexural and hardness were found to increase with increase in filler content and NaOH concentration. This could be due to better interfacial bonding between the OBF and UPR.

Keywords: Okra bast fibre, unsaturated polyester resin, tensile strength, Young's modulus, Hardness, and flexural strength.

INTRODUCTION

Nowadays the development of materials and processes is strongly being influenced by principles of sustainability, eco-friendliness and sustainable packaging as well as production materials. This is due to ever increasing environmental awareness and protection zeal which calls for provision of biodegradable reinforcements in the production of composites. Natural fibre composites have proved to be strong, light weight and have the potential to meet this requirement.

The application of natural fibres in composite reinforcement may not be unconnected with their low cost, low density and excellent mechanical properties. Natural fibres such as sisal, jute, hemp and flax have extensively been used as reinforcement in polymeric matrix composites.

Other fibres are banana, PALF, coir and palm (Sreekumar, *et al*, 2011, Kabir, *et al*, 2012, Virk, *et al*, 2012).

Natural fibre composites made of biodegradable products represent a suitable alternative to traditional glass fiber reinforced composites and provide yet another source of income to the agricultural community. Okra plant belongs to the species 'esculentus', in the family 'malvaceae'. It is cultivated throughout the tropical and warm temperate regions of the world for its fibrous fruits or pods containing round, white seeds. The fruits are usually harvested when immature and eaten as vegetable which may be collected from the plant for up to a period of 3–6 months. After harvesting the plant stem or stalk is mostly subjected to direct combustion. This operation causes not only environmental pollution but also waste of valuable fibre components.

The chemical composition of OBF is α-cellulose (60–70 %), hemicelluloses (15–20 %), lignin (5–10 %) and pectins (3–5 %) along with trace amount of water-soluble materials (Khan, *et al*, 2009). Though it contains higher percent of cellulose, it may have potentiality to make good-quality composite with thermoplastic/ thermoset resins (Fortunati, *et al*, 2013). Thermoset resins are promising materials for natural fibre composites because they are insoluble and infusible and have high-density networks. A number of studies have been reported on thermoset plastics/natural fibre composites.

MATERIALS AND METHOD

Materials

Okra stems were obtained from a small farm in Gwarzo local government area of Kano state. Caustic soda, unsaturated polyester resin (UPR), cobalt accelerator and catalyst (MEKP) were purchased from a chemical store. All chemicals were used directly without further purification.

Okra Fibre Extraction

The fibres considered in the present research were extracted by water retting method. The okra bark was peeled off and bundled in ribbon form then immersed in water retting bath. A little pressure was applied to the soaked bundle to ensure that the bark remained fully submerged for a period of 10 days. During this time the cementing materials such as pectin, lignin, cellulose, and hemicelullose become loosened and softened. On the 10th day, the retted ribbon was removed and washed with sufficient quantity of water until the gum was completely detached from fibres. The fibres were shredded and combed to have finer fibres after which they were allowed to dry at room temperature. After drying, the fibres were chopped into short lengths (5-10mm) which was used in this work for fabrication of the composites.

Fibre Treatment

Sodium hydroxide solutions by weight concentrations of 5%, 10% and 15% were prepared using distilled water. The fibres were treated in the solutions for a period of thirty minutes each with continuous stirring, removed and rinsed with water. Fibres were later neutralized with 1% acetic acid and finally rinsed with distilled water.

Preparation of the Composites Samples

Short Okro bast fibre reinforced unsaturated composites were prepared by hand-lay-up technique. The calculated amount of Unsaturated Polyester Resin (UPR), accelerator (cobalt) and catalyst (MEKP) were weighed out and thoroughly mixed. The corresponding amount of okra fibres were weighed out and added to the UPR. It was thoroughly mixed to ensure even distribution of fibres. The mixture was then poured in to a glass mould (200 x 120 x 80 mm) on which foil paper has been laid for ease of removal of the fabricated composites. On addition of the promoters,(MEKP and Cobalt) the resin became more viscous until it reached a state where it lost ability to flow (gel point). The reaction was exothermic which speed the whole process, and later on the resin obtained its full hardness and properties. The fabricated composites cured under laboratory conditions before they were subjected to mechanical analysis.

Characterization of Composites

Tensile Testing

Tensile strength and elongation at break were carried out using Mosanto Tensometer machine at the department of Mechanical Engineering Ahmadu Bello University, Zaria. The test was performed according to ASTM D638. Test samples where clamped between the upper and lower jaw of the tensometer and the machine was started. The sample was stretched gradually with application of force until it reached the breaking point. Readings of maximum load and elongation at break were taken accordingly. The test was repeated Three (3) times for each of the composites and the average values were recorded.

Flexural Test

The flexural test was conducted according to ASTM D790 using the Cat Nr Universal Testing Material testing machine at the Department of Mechanical Engineering , Ahmadu Bello University, Zaria using the three point bend test. The flexural strength was calculated using Equation $FS = {}^{3PL}/_{2bd^2}$ Where;

L=is the span length of the sample (gauge length);
P is the load applied;
b and t are the width and thickness of the specimen respectively.

Hardness Testing (Rockwell Hardness)

The Indectec Universal testing Machine Model 8187.5 LKV B Rockwell hardness HRF indentor (1/6") steel ball with minor load 10kgf and major load 60kgf was used in measuring the hardness of the samples according to ASTM 2240. The sample with parallel flat surface was placed on the anvil of the apparatus and the steel ball lowered onto its surface. The dial was adjusted to zero on the scale

under minor load (10kg) and the major load (60kgf) was immediately applied by releasing the trip lever. After 15 second the major load was removed and the specimen was allowed to recover for 15 seconds.
The test was repeated three times and an average of each test result was recorded.

RESULTS AND DISCUSSIONS

Tensile Strength

In this work, an increase in tensile strength at 15% alkali treatment 15% filler loading with a value of 22.21 Mpa, was observed. This indicates that the alkali treatment has improved the adhesive characteristics of the fibre surface by removing the natural and artificial impurities there by producing rough surface topography. The treatments also leads to fibre fibrillation i.e. that is breaking down the fibre bundles into smaller fibres, this also increase the chance of effective surface area to be available for contact with the matrix.(Sirgar, *et al,* 2010). A decrease was observed for 10% alkali treatment with increase in filler content 17.86 to 8.74Mpa as shown figure1.respectively. This is because excess delignification of the okro fibre occurs at higher alkali concentration, resulting in weaker fibres (A.K. Bledzki and J. Gassan,1999) Hence a drastic decrease in the tensile strength of composites after a certain optimum concentration of alkali is attained (Rokbi, *et.al.,*2011).

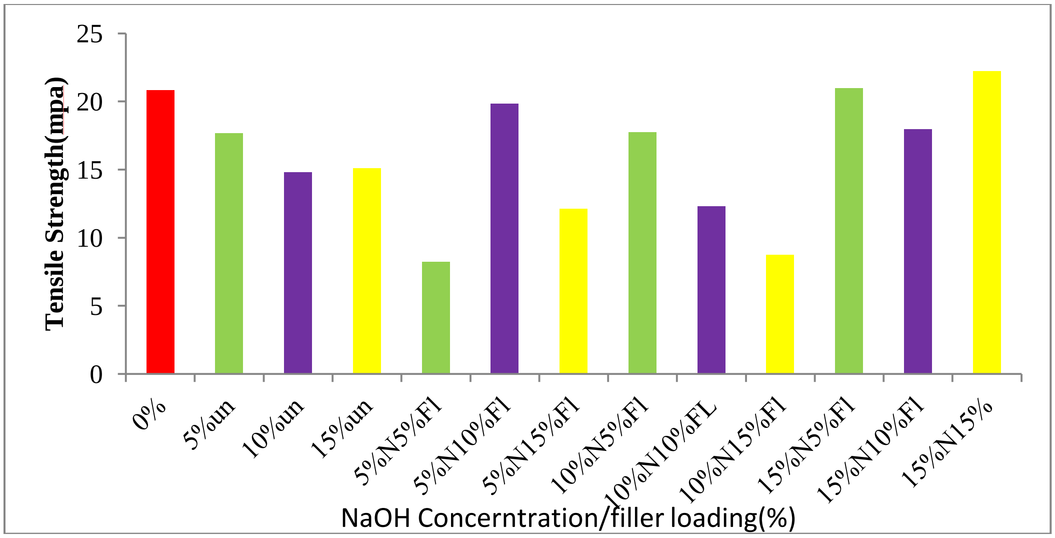

Figure1: Tensile strength of treated and untreated OBF/UPR

Similar trend was observed for 5% alkali treatment content with a decrease corresponding to 19.82 to 8.25Mpa. The observed decrease could be attributed to improper fibre wetting due to increased tendency of fibre entanglement with increasing short fibre as well as the possibility of increasing fibre-rich and/or matrix-rich areas within the composite (Sumaila, *et al.*, 2013).

It was also observed that values obtained for the untreated okra bast fibre/unsaturated polyester resin composites is lower than that of the control sample and some treated okra bast fibre/ unsaturated polyester resin composites values obtain are 17.64,14.79 and 15.09Mpa.The observed decrease in strength of the untreated okra fibre UPR composites could be attributed to poor fibre/matrix adhesion which leads to micro cracks formation at the interface under loading and non uniform stress transfer due to fibre agglomeration in the matrix.(Sanjay *et al.*,2009). This implies that the fibre modification has improved the strength of these composites and can be useful in application such as ceiling board, particle board and partitioning board.

Young's Modulus

As illustrated figure 2 above, alkali treatment has improve the young's modulus of the composites at varying NaOH concentrations. The maximum stiffness was obtained at 15% alkali treatment at15% filler loading having the value of 286Mpa which is similar to the result obtained for tensile strength, and greater than the control sample and the untreated okra bast fibre/UPR composites. However, it was noticed that the untreated okra bast fibre /UPR composites modulus increases with increasing filler content, corresponding from 125.75 to 227.53 MPa. The same trend was observed for 5% and 10% NaOH treated okra fibre/UPR (137.5to 202Mpa) and (133.18 to 268Mpa) respectively.

Nara *et al.,* (2012) observed that the young's modulus, which is an indication of load bearing capacity increases with fibre weight fraction. As fibre is the stiffer component in the composite, resistance towards deformation increases with increase in fibre content, this consequently increases the stiffness of the composite. Hence the variation in the modulus observed in the various researches could be attributed to the variation in the weight fractions of the fibres, the difference in matrix and the nature of the fibres used (Sreekala *et al.,* 2002).

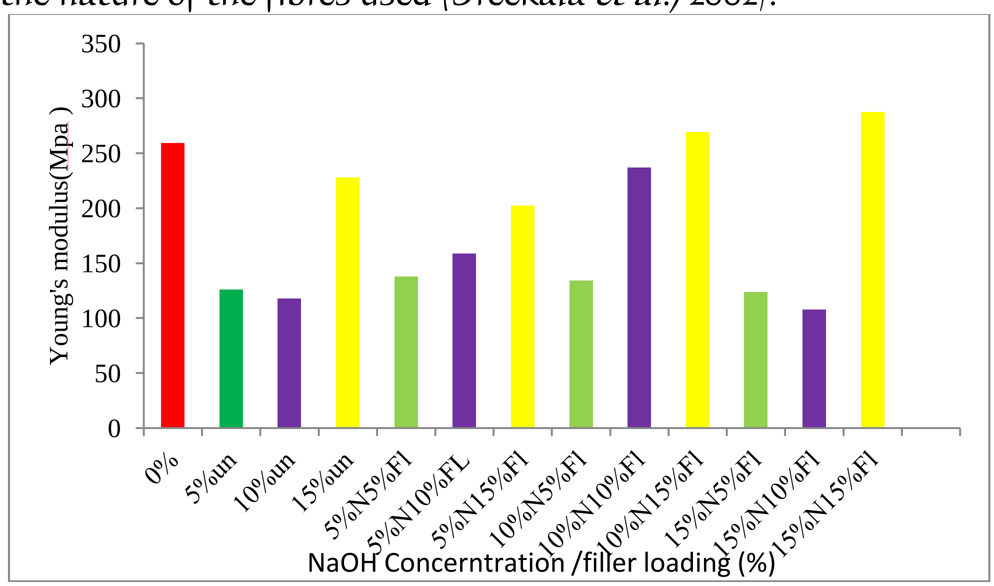

Figure 2.Young's Modulus of Treated and Untreated OBF/UPR Composites

Hardness

Figure 3 shows the variation in hardness of treated and untreated okra bast fibre /unsaturated polyester resin composites. It was observed that they is variation in hardness value of the composites with increase in filler content. Hence the highest value indicates greater resistance of the composites to indentation. An increase in hardness value for 15% alkali treated okra bast fibre /UPR composites was noticed with increase in filler loading content with the observed values are 52.3 to 68.4HRF. The increase in hardness value could be attributed to the increase in stiffness and the dispersion of the fibres into the matrix , minimization of voids and stronger interfacial bonding between the matrix and the fibre as a result of the treatment this is similar to the findings of (Siregar *et al.,*2010).The 5% alkali treated okra bast fibre/unsaturated polyester resin composites shows average values of hardness with increase filler loading the hardness value decreases from 60.3 to 47.8 HRF and further increase to 49.0 HRF for 5,10,15% filler loading. Similar trend was observed for 10% alkali treated okra bast fibre /UPR having a value of 53.6, 48.0 and 52.6 respectively. The untreated sample shows a moderate improvement in hardness value from 52.8, 45.2 and 49.2HRF. The decrease in hardness value could be attributed to poor/weak interfacial bonding between the okra bast fibre and the unsaturated polyester resin matrix.

On introduction of okra fibre into the polyester matrix air may be trapped inside which leads to micro crack formation in the interface under loading and non uniform stress transfer due to the fibre agglomeration in the matrix.(Sanjay *et al.,* 2009).

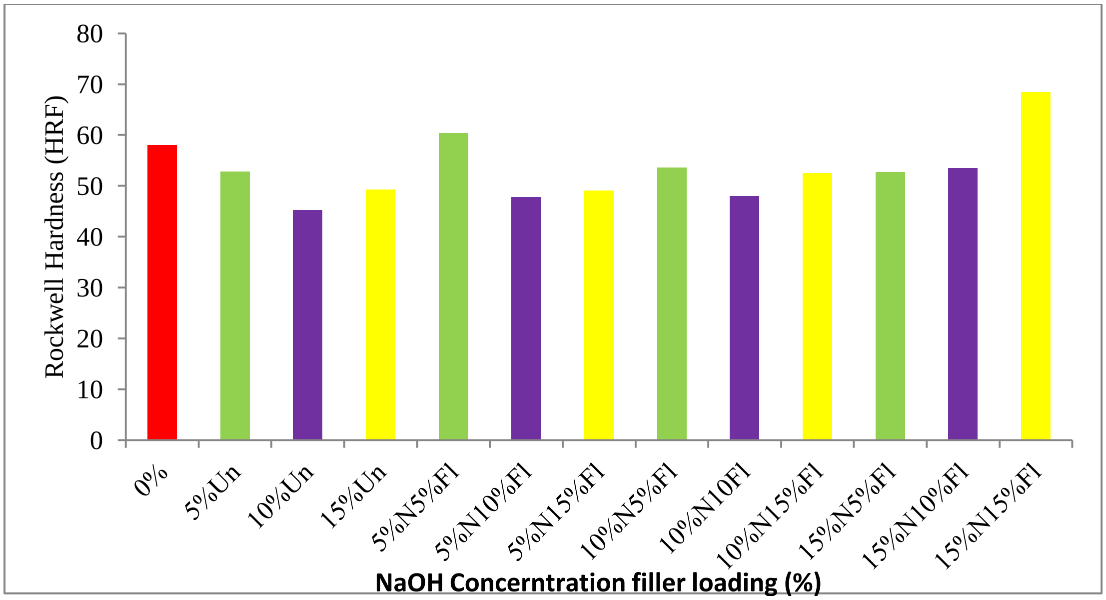

Figure 3: Hardness against NaOH concentration/filler loading of treated and untreated OBF /UPR Composites

Flexural Strength

In figure 4 above shows a variation in flexural strength with increasing filler loading and NaOH concentration content for both treated okra bast fibre /unsaturated polyester resin composites. The untreated okra bast fibre /unsaturated polyester resin composites increases with increasing filler loading from 17.3 to 29.27Mpa .The increase in flexural strength of composites is primarily due to effective stress transfer from the fibres to the matrix (Sanjay *et al.*,2009) . 5% alkali treatment shows the lowest value (7.35, 7.95, 12.58Mpa) when compared to 10% and 15% NaOH treatment. This remarkable increase in flexural modulus may be an indication of better adhesion between the matrix and the treated okra bast fibre due to surface modification of the fibre. At 10% NaOH treatment the flexural strength increases from 18.45Mpa to 44.72Mpa which is the highest value obtained from all the samples in this work, at 15% NaOH treatment it also exhibit similar trend that is the flexural strength increases with increase in filler loading corresponding to 11.48Mpa, 34.39Mpa to 35.81Mpa.This could be due to good intermolecular interaction between the okra bast fibre and the resin. Similar results were obtained by (Tran huu, *et al*, 2011) in their study on effect of alkali treatment on interfacial and mechanical properties of coir fibre /poly(butylenes succinate) biodegradable composites.

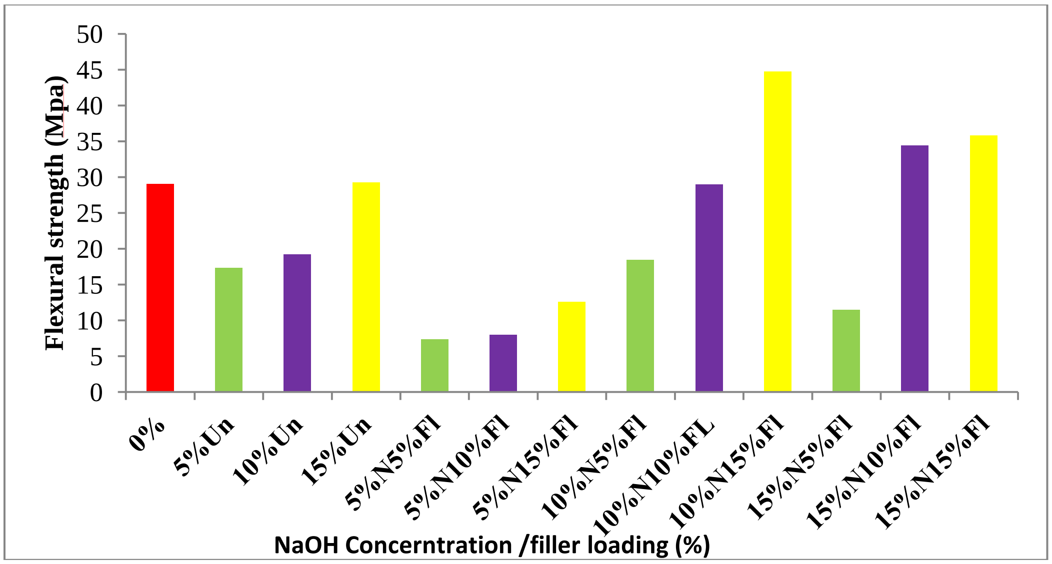

Figure 4: Flexural strength against NaOH concentration/filler loading of treated and untreated OBF/UPR composites.

CONCLUSION

Alkaline treated Okra bast fibre/unsaturated polyester resin composites were produce and analyzed. The result shows that useful materials could be produced from OBF. The tensile strength, young's modulus, and hardness have their highest value at 15%NaOH treatment while 5%and 10% NaOH have moderate values. The highest value of flexural strength was observed at 10% NaOH and 15% filler loading. The potentials of Okra bast fibre in composites material can be used to produce materials that can find uses in our homes and industries.

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