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EFFECT OF ALKALI TREATMENT AND FIBER CONTENT VARIATION ON THE TENSILE PROPERTIES OF COIR FIBER REINFORCED CASHEW NUT SHELL LIQUID (CNSL) COMPOSITE

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Abstract

The effect of alkali treatment and fiber content variation on the tensile properties of coir fiber reinforced cashew nut shell liquid (CNSL) composite was studied. Biocomposite consisting of coir fibers and cashew nut shell liquid resin was produced using the hand lay-up technique. The fibers were treated with 5% NaOH and varied between 0% to 40% weight fractions. Composite laminates with untreated coir fibers were also produced with same fiber loadings. The results showed that tensile strength and modulus of the CNSL/COIR composite increased as the weight fraction of coir fibers was increased up to a fiber content of 30%. Also the composites exhibited reduction in elongation at break as fiber content was increased. The alkali- treated CNSL/COIR composite laminates showed improved tensile properties and this was attributed to an improvement of interfacial fiber-matrix adhesion in the composites.

Keywords: cashew nut shell liquid resin, coir fiber, tensile strength, elongation, interfacial bonding

1. Introduction

Fiber reinforced plastics consisting of petroleum-based matrix, embedded with high-strength fibers, such as glass, aramid and carbon have gained considerable application in aerospace, leisure, construction, sport, packaging and automotive industries[1]. The widespread use of synthetic fiber reinforced polymer composites and in general, “artificial” composites have a tendency to decline because of their high initial cost and more importantly, their adverse environmental impact [2-4]. Synthetic fibers have very serious drawbacks such as: (i) non-renewability (ii) non-recyclability, (iii) high energy consumption in the manufacturing process; (iv) health risk when inhaled and (v) non-biodegradability [3]. According to Singleton et al [5], although glass fiber-reinforced composites have been widely used for many years due to its advantages of low cost and moderate strength, to provide solutions to many structural problems, the use of these materials, induces a serious environmental issues that most western countries are concerned about.

Recently, due to a strong emphasis on environmental awareness worldwide and the pressure on manufacturers of materials to consider the environmental impact of their products at all stages of their life cycle, including recycling and ultimate disposal, attention of researchers is shifting to the development of recyclable and environmentally sustainable composite materials. Thus biodegradable composites based on natural fibers and biodegradable polymeric matrices made from cellulose, starch, and other natural resources (green composites) have been developed because of their environmentally beneficial properties [6-8]. In general, the research and development of natural fiber biodegradable composites from renewable resources for a wide range of applications is increasing due to their advantages, such as eco-friendliness, lightweight, carbon dioxide reduction and biodegradable characteristics [9].

The natural fibers which have been shown to strengthen polymer matrices include: hemp; jute; kenaf; coir; sisal; flax; bamboo, banana, palm, silk, cotton, and wood etc. These fibers are renewable resources and offer specific benefits such as low cost, low density, low pollutant emissions, acceptable specific properties, renewable characteristics, enhanced energy recovery and complete biodegradability [10-

12]. Hence these fibers are considered as substitutes to replace the conventional glass fiber due to eco-friendliness. However, plant fibers contain strongly polarized hydroxyl groups and are hydrophilic in nature and because of the presence of hydroxyl and polar groups in various constituents of plant fibers, moisture absorption of these fibers is very high and this leads to poor interfacial bonding with the polymer matrices [13]. Moisture absorption and hydrophilic character of fibers are reduced by surface chemical modification [14, 15].

Depending on their origin, natural fibers can be grouped into bast (jute, banana, flax, hemp, kenaf, mesta), leaf (pineapple, sisal, henequen, screw pine) and seed or fruit fibers (coir, cotton, oil palm)[16]. Among the plant fibers, coir fibers are extensively used in many industrial applications such as in producing erosion control blankets, woven geo-textiles, sheets, brushes, discs, floor mat, door mats, brushes, mattresses, floor tiles etc and it is gradually gaining useful application in the production of composite materials [17]. Coir consists of cellulosic fibers with hemicellulose and lignin as the bonding materials for the fibers.

Researches are on-going on the use of coir fibers as a reinforcement of polymer matrices but most of these works have focused on the use of coir fibers in reinforcing artificial or synthetic polymers. A few other researches aimed at producing a completely biodegradable polymer have been on coir-polylactic acid (PLA) and coir-poly (butylene succinate) composite systems [9]. Composite systems consisting of coir fiber and plant-based polymers have been relatively unexplored.

This work investigated the effects of alkali treatment and fiber content variation on the tensile properties of coir fiber-reinforced cashew nut shell resin-based composite. The combination of coir fibers and cashew nut shell liquid (CNSL) based biopolymer can produce an environmentally-friendly biodegradable composite.

2. Materials and Method

2.1. Coir fiber

Coir fiber is obtained from the fibrous mesocarp between the exocarp and the endocarp of the coconut fruit (cocos nucifera). The coir fibers used in this work were supplied by JuNeng Nig Ltd Nsukka. The fibers were treated with 5% NaOH solution in a glass beaker for 48hours at room temperature. The fibers were taken out of the solution, washed several times in fresh water and subsequently air dried for 2 days. The reaction of sodium hydroxide with coir fiber is described as follows

$$\mathrm{Coir} - \mathrm{OH}^{-} + \mathrm{NaOH} = \mathrm{Coir} - \mathrm{O} - \mathrm{Na}^{+} + \mathrm{H_2O} \quad (1)$$

2.2. Cashew nut shell liquid resin

The cashew nut shell liquid (CNSL) is an alkylphenolic oil contained in the spongy mesocarp of the cashew nut (anacardium occidentallis). The main constituents of cashew nut shell liquid are cardanol, anacardic acid, cardol, 2-methyl cardol and small amount of polymeric material [18]. The CNSL used in this work was extracted from cashew nuts at the chemistry laboratory of the University of Nigeria, Nsukka.

2.3. Composite fabrication

The hand lay-up technique was used in the production of composite laminates used in this work. The extracted cashew nut shell liquid was mixed with polyester at the ratio of 50:50 and poured into a wooden mould measuring 300 × 300 × 3mm. The inner surfaces of the mould were coated with wax to enhance the removal of the composite after curing. 0.4 wt % of methylethyketone peroxide and cobalt amine nephthenate were added to act as catalyst and accelerator of curing respectively. The fiber weight fraction was varied from 10% to 40% in both alkali- treated and un-treated conditions. Length of coir fibers was incrementally varied. All the specimens were post cured at 50°C for 12 hours in order to minimize residual stresses. Tensile specimens were fabricated from the laminate plates.

2.4. Tensile test

The tensile specimens of 300 x 15 x5mm were cut from pure CNSL-based polymer and composite and kept in a desiccator at ambient conditions. The specimens were uniaxially pulled in a Hounsfield Monsanto universal tensometer in accordance with ASTM D638 standard using a maximum beam load of 2500N. Strain was measured using an extensometer. The mean tensile properties of the samples were obtained from five specimens for each fiber content and process variation.

3. Results and Discussion

The tensile strength of un-treated and alkali-treated coir-fiber reinforced cashew nut shell resin-based composite is presented in figure 1 as a function of fiber content. As shown in the figure, the tensile strength of the composite material increases as the weight fraction of coir fibers is increased but reaches a maximum value at 30% fiber content before reducing. The figure also reveals that the tensile strength of alkali-treated fiber reinforced (CNSL) composite are higher than those of the composite reinforced with un-treated coir fibers. At 30% coir fiber weight fraction, the tensile strength of the composite material increased by 70.9% with alkali treatment while the un-treated fibers produced only 39.0% increase in strength of the unreinforced

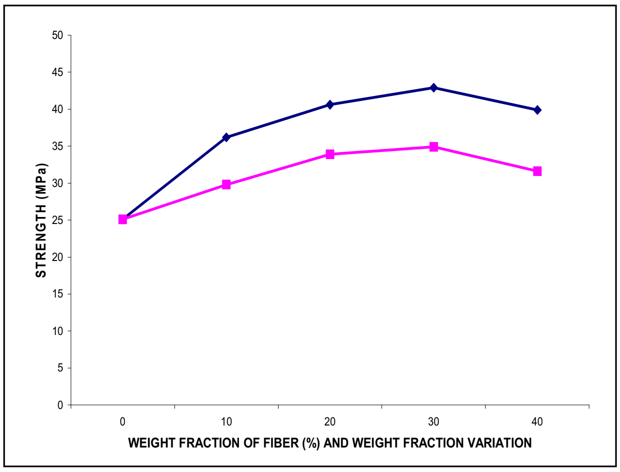

Figure 1: Effect of alkali-treatment and weight fraction variation on the tensile strength of CNSL resin/coir fibre composite.

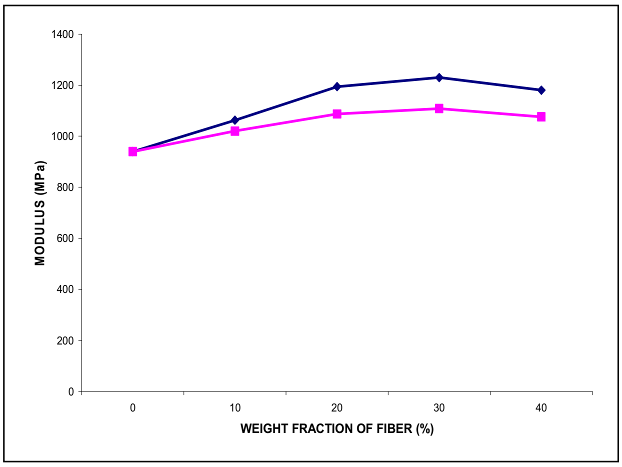

Figure 2: Effect of alkali-treatment and weight fraction variation on the modulus AT of CNSL resin/coir fibre composite.

plastic. Again, figure 1 also reveals that maximum strengthening effect of the coir fibers occurred at 30% weight fraction in both the treated and un-treated coir fiber reinforced composite.

The effect of fiber content and sodium hydroxide treatment of coir fibers on the tensile modulus of CNSL resin/coir fiber composite is shown in figure 2. As illustrated in the figure, alkali treatment improved the tensile modulus of the composite material. Notably, from the figure, the tensile modulus of CNSL/coir fiber composite increases as the fiber content is increased and attains peak value at 30% weight fraction of coir fibers.

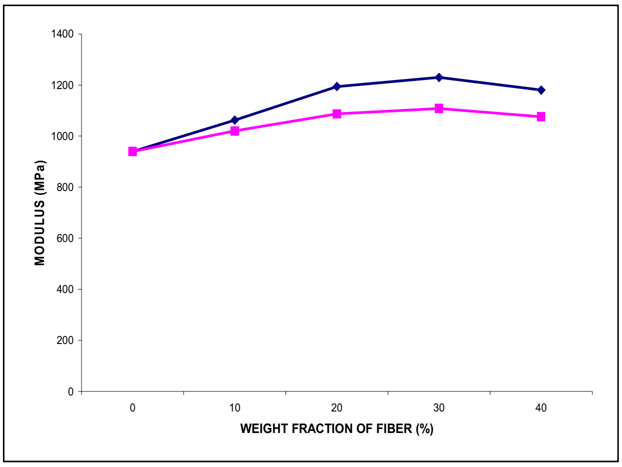

Figure 3: Effect of alkali-treatment and weight fraction variation on the elongation at break of CNSL resin/coir fibre composite.

Increase in strength and modulus of the CNSL/coir fiber composite with the increase in coir fiber content could be attributed to the fact that the coir fibers are stronger, stiffer and capable of adhering to the CNSL resin matrix. This enabled, load transfer from the matrix to the fibers through the fiber/matrix interface [19]. However, alkali treatment improves the fiber-matrix adhesion due to the removal of natural and artificial impurities from the fiber surface as well as changing of the arrangement of units in the cellulose macromolecule [20]. Thus alkali treatment increases the surface roughness and the amount of cellulose exposed on the surface of the fiber surface resulting in better mechanical interlocking and fiber matrix interfacial bond and, resulting in increased mechanical properties [21]. Besides, the increase in tensile strength and modulus up to 30% fiber content is due to adequate wetting of the fibers by the matrix and reasonable amount of fibers to bear applied load. The decrease in strength and modulus at fiber content, of 40% probably resulted from poor wetting, because the CSNL resin content is not sufficient to wet all the fiber surfaces, leading to poor interfacial adhesion.

Figure 3 shows the effect of coir fiber content and alkali treatment on the elongation at break of CSNL/coir fiber composite.

Notably from figure 3, the elongation exhibited by this composite material at breaking load decreases as the fiber content of the composite is increased. This is probably as a result of the structural integrity of the CNSL resin being destroyed by the loading of coir fibers and increasing fiber content imply poor interfacial fiber-matrix adhesion, leading to quicker fracture than pure CNSL resin [22]. This also indicates that the ductile nature of CNSL resin decreases with the addition of coir fibers.

4. Conclusion

Coir fiber/CNSL composites with different fiber contents have been developed. The effect of alkali treatment on the tensile properties of coir fiber/CNSL composite has been studied. The following conclusions can be drawn from the study:

1. Alkali treatment of coir fiber increased tensile strength and modulus of coir fiber/CNSL composites.

2. The strength and modulus of coir fiber reinforced CNSL composite increase as the weight fraction of coir fiber is increased in the composite material.

3. The coir fiber content for optimum strength and modulus is 30

4. The experimental results in the present work suggest that a useful composite with good strength and modulus could be successfully developed using coir fiber as a reinforcing agent for CNSL matrix.

References

1. Ku, H, Wang, H, Pattarachaiyakoop, N and Trada. M. A Review on the Tensile Properties of Natural Fiber Reinforced Polymer Composites. *Composite Part B*, Vol. 42, 2001, pp. 856–873.

2. Christian, S.J. and Billington, S.L. Mechanical Response of PHB and Cellulose Acetate Natural Fiber Reinforced Composite for Construction Applications. *Composite Part B*, Vol. 12, 2001, pp. 245 – 260.

3. Cheung, H.Y, Mei, P.H, Lau, K.T and Hui, D. Natural Fiber-reinforced Composites for Bioengineering and Environmental Engineering Application. *Composites Part B*, Vol. 40, 2009, pp. 655 – 663.

4. Lopresto, V, Leone, C and Lorio, D. Mechanical Characterization of Basalt Fiber reinforced Plastic. *Composite Part B*, Vol. 42, 2011, pp. 717 – 723.

5. Singleton, A.C, Baillie, C.A. and Beaumont, P.W. On the Mechanical Properties, Deformation and Fracture of a Natural fiber/recycled Polymer Composite. *Composite Part B*, Vol. 34, 2003 pp. 519 – 526.

6. Lui, L, Yu, J, Cheng, L. And Yu, W. Mechanical Properties of Poly (butylene succinate) (PBS) Biocomposite Reinforced with Surface Modified Jute Fiber. *Composite Part A*, Vol. 40, 2009, pp. 669 – 674.

7. Han, S.O, Lee, S.M, Park, W.H. and Cho, D. Mechanical and Thermal Properties of Waste Silk Fiber-reinforced Poly(butylene succinate) Bio composites. Journal of Applied Polymer Science, Vol. 15, 2009, pp 4972 – 4980.

8. Ochi, S. Development of High Strength Biodegradable Composites Using Manila hemp Fiber and Starch based Biodegradable Resin. *Composites Part A*, Vol. 37, 2006, pp. 1879 – 1883.

9. Tran, H.N, Shinji, O.T, Nguyen, H.T and Satoshi, K.A. Effects of Alkali Treatment on Interfacial and Mechanical Properties of Coir Fiber Reinforced Poly (butylene succinate) Biodegradable composites. *Composites Part B*, vol. 42, 2011, pp. 1648 – 1656.

10. Mohanty, K, Misra, M and Hinrichsen, C. Biofibers, Diodegradable Polymers and Biocomposites: An overview. *Macromolecular Materials Engineering* Vol. 276, 2000, pp. 1 – 24.

11. Monteiro, S.N, Lopes, P.D and Ferreira, A.S. Natural Fiber Polymer-matrix Composites, Cheaper, Tougher, and Environmentally Friendly. *Journal of Materials*, Vol. 61, 2009, pp. 17 – 22.

12. Zhang, M.Q, Rong, M.Z. and Lu, X. Fully Biodegradable Natural Fiber Composites from Renewable Resources. *All Plant Fiber Composites Science Technology*, Vol. 65, 2005, pp. 2514 – 2525.

13. Westerlind, B.S and Berg, J.C. Surface Energy of Untreated and Surface-Modified Cellulose Fibers. *Journal of Applied Polymer Science*, Vol. 39, 1998 pp. 523 – 534.

14. John, M.J and Anandjiwala, R.D. Recent Development in Chemical Modification and Characterization of Natural Fiber-reinforced Composites. *Polymer Composite*, Vol. 29, No. 2, 2008, pp. 187 – 207.

15. Prasad, S.V, Pavithran, C. and Rohatgi, P.K. Alkali Treatment of Coir Fibers for Coir Polyester Composites. *Journal of Materials Science*, Vol. 18, 2000, pp. 1443 – 1454.

16. Herrera-Franco, P.J and Valadez-Gonzalez, A. A Study of The Mechanical Properties of Short Natural-fiber Reinforced Composites. *Composite Part B*, Vol. 36, 2005, pp. 597 – 608.

17. Wikipedia, the free encyclopedia. *Coir.* http://en.wikipedia.org/wiki/coir. Accessed on October 26, 2011.

18. Mwaikambo, L.Y. and Anseli, M.P. Cure Characterization of Alkali Catalyzed Cashew Nut Shell Liquid-Formaldehyde resin. *Journal of Materials Science*, Vol. 36, No. 15, 2001, pp. 3693 – 3698.

19. Prasad, S.V, Pavithran, C and Rohatgi, P.K. Alkali Treatment of Coir Fibers for Coir-Polyester Composites. *Journal of Materials Science*, Vol. 18, 1998, pp. 1443 – 1454.

20. Rahman, M.M. and Khan, M.A. Surface Treatment of Coir (cocos nucifera) Fibers and its Influence on The Fiber Physico-Mechanical Properties. *Composite Science Technology*, Vol. 67, 2007, pp. 2369 – 2376.

21. Valadez-Gonzalez, A, Cervantes-Uc, J.M. and Herrera-Franco, P.J. Effect of Fiber Surface Treatment on the Fiber-Matrix Bond Strength of Natural Fiber Reinforced Composite. *Composite Part B*, Vol. 30, 1999, pp. 309 – 320.

22. Lui, L., Cheng, L. and Yu, W. Mechanical properties of poly (butylene Succinate pbs) biocomposite reinforced with surface modified jute fiber. *Composites Part A*, vol. 40, 2009, pp. 660 – 674.