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Enhancement of Mechanical Properties of Cotton Fabric Using Coconut and Rice Fibre

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Abstract

The excellent properties such as biodegradability, regeneration, smoothness and hygroscopicity possessed by cotton fabrics made them highly popular among natural fabrics. This study is aimed at investigating the effect of the incorporation of coconut fibre and rice fibre on the mechanical properties of cotton fabric. The characterization of coconut fibre was determined by using FTIR BRUKER IFS 66V/S- Germany which showed the presence of (O-H, C-H, C=C, N=O, and C-N) functional groups and CARY-100 Conc UV–Vis spectro photo meter recorded UV-Visible wavelength of maximum absorption (λ_{max}) at 278.00nm. The experiment was carried out using the control and other six composite materials.The result of the Tensile Strength of the coconut-fibre and rice-fibre reinforced fabric ranged from 2.86-7.23MPa and 3.64-7.01MPa respectively which is lower than the reference fabric (12.10MPa). Also, the Elastic Modulus of the composite samples experienced the highest at 63.29MPa which is more than half of the control fabric (113.41MPa). However, the reinforced fabric's Elongation at break (15.42-22.15MPa) and the crease recovery angle (39^0-45^0)are higher than the reference fabric (12.03MPa and 39^0). This study showed that the incorporated fibres only affect the symmetrical distribution of the load rather than increasing the load bearing ability of the fabric.

Keywords: Coconut fibre, Rice fibre, Cotton fabric, Mechanical properties.

Introduction

The importance of textile finishing in the production of textile material cannot be overemphasized. The resultant effect of this includes imparting of high quality, greater touch effect, and desirable visual aspect to the material of interest [1]. The major concern of the textile industry is an appreciable strength loss and abrasion resistance of the refined fabric [2]. Cotton fabrics commands greater influence in the market because they are comfortable to wear always [3]. However, creasing of cotton fabric poses some disadvantages.This is a complex mechanism in cotton fabric that emanate as a result of inter-molecular hydrogen bonding

between hydroxyl groups of primary and secondary order in the polymer chains [4]. Crease recovery for this kind of fabric is highly paramount for good appearance [5]. Hence, crease resistant processing is commonly used in textile industries to impart crease resistant attributes to textile fibre due to the poor recovery of untreated cellulose [5].

The mechanical properties of cotton fabrics such as tensile strength, crease resistance etc. can be enhanced by various methods such as cellulose cross-linking, incorporation of active substance etc.[6]. Formaldehyde based N-methylol cross-linkers are often used to improve the crease resistance, durable press and anti-curl of textile fabrics. Nevertheless, they have adverse effect such as strength loss and also result in the release of formaldehyde which is highly carcinogenic to human beings [4].

A good alternative to the conventional formaldehyde-based Dimethylol Dihydroxy Ethylene Urea (DMDHEU) is the incorporation of fibre from plant biomass into cotton fabrics [6]. Fibre from plant biomass such coconut (*Cocos nucifera*) husk and rice (*Oryza*sativa) husk are good alternatives because of their ubiquity, renewability, lack of competition with food security and eco-friendly nature.

Coconut (*Cocos nucifera*) husk is gotten from the outer shell of coconut and are either brown fibre prepared from matured coconuts or white fibre prepared from immature coconuts. They exist in three forms which are: long fibres (bristle), relatively shortfibre (mattress) and mixed fibre (decorticated) and are categorized as hard structural fibres[7]. They are ubiquitous, resourceful, renewable, low-priced,and biodegradable ligno-cellulosic fibre used for the production of variety of products.

Coconut fibre has the capacity of withstanding strain 4-6 times compared with other natural fibres. The hybridization of coconut and sisal short fibres provides restrain in plastic shrinkage thereby controlling crack development at preliminary stages[8]. Coconut fibres are used as reinforcement in polymer–matrix compositesas well as fillers in many composite materials. Furthermore, it can be used as agro-industrial feedstock for the preparation of eco-friendly composite materials. Also, this fibre is often used in the production of mats, mattresses, brushes etc. and they are usually spin to produce yarn in mats or rope. It is relatively waterproof and is among the rare fibres that provides resistance to salt-water damage [9]. India and Sri Lanka are the major exporters of coconut husk, while the third, fourth and fifth country are Thailand, Vietnam and the Philippines respectively[2].

The yearly production of rice (*Oryza* sativa) across the nations of the world is approximately 600 million tons per annum. Rice husk-the outer shell of the rice grain derived from the milling of rice is a ubiquitous agro-industrial product across the globe. It is made up of approximately 40 % cellulose, 30 % lignin and 20 % SiO_2. In the rice milling industry, rice husk is often used in the parboiling process of rice grain (Lad et al., 2017).

Hwang et al. [8] investigated the effect of the incorporation of polyester resin on the mechanical properties of cotton fabrics. Also, Anju et al. [7] evaluated the mechanical properties of phenolic-jut/cotton fabric composites.

To best of our knowledge, sundry researches has been carried out to investigate the effect of synthetic fibres on the mechanical properties of cotton fabric but little or no research has critically investigate the impact of agricultural waste fibres on the mechanical properties of cotton fabric.

Hence, the aim of this study is to investigate the effect of the incorporation of coconut and rice husk fibre on the mechanical properties (tensile strength and crease recovery)of cotton fabric.

Materials and Method

Materials

The pure bleached cotton fabric was purchased from Oja-Oba market in Akure, Nigeria. The rice husk was procured from a rice milling industry in Ado-Ekiti, Nigeria. The coconut husk was extracted from a coconut plant harvested in the environment of The Federal University of Technology, Akure, Nigeria.

Preparation of cotton fabric

The procured cotton fabric was cut into seven pieces with each having a dimension of (15 cm X 10 cm) and corresponding to a weight of about 2.4-2.6 g on a dry weight basis. The pieces of cotton fabric was placed in a stainless steel and inserted into an oven set at 105^{o}C for 5 hours. Afterwards, they were removed from the oven, placed in the dessicator and their respective weight were recorded. The control was labelled F_0 while the next three pieces were labelled F_{R1},F_{R2}, and F_{R3} according to the weight and proportion of the rice fibre (RF) that was incorporated int+o the cotton fabric. Furthermore, the remaining three was labelled F_{C1}, F_{C2}, and F_{C3} according to the weight and proportion of coconut fibre (CF) that was incorporated into the fabric.

Preparation of Rice fibre

The procured rice husk was beaten in order to separate residual rice grains, and then sun-dried for about 48 hours. The dried rice husk was grinded into a powder form and then placed in a 500 ml beaker containing a specified amount of distilled water. The resultant solution was boiled for one hour, filtered and the filtrate (soluble rice fibre) was placed in another container where it was evaporated to dryness. The rice fiber slurry was oven-dried at 105˚C for five hours, cooled in a desiccator. The dried rice fibrewas pulverized and placed in an air-tight container for further use.

Figure 1.Pictorial view of dried rice fibre

Preparation and characterization of Coconut fibres

➢ Preparation of Coconut fibres

The extracted coconut husk was separated from the fruit, cut into smaller pieces and sun-dried for 7 days. The dried coconut husk was grinded into smaller particles and then placed in a 500 ml beaker containing a specified amount of distilled water. The resultant solution was boiled for two hours, filtered and the filtrate (soluble coconut fibre) was placed in another container where it was evaporated to dryness. The coconut fiber slurry was oven-dried at 105˚C for five hours, cooled in a desiccator. The dried coconut fibre was pulverized and placed in an air-tight container for further use and analysis.

Figure 2.Pictorial view of dried coconutfibre

➢ Characterization of Coconut fibres

The functional groups of coconut dye solution were analyzed in a Fourier Transform-Infrared Spectrometer. The sample solution was pelletized onto a substrate and analyzed in the range of

4000 to 350 cm−1 using FTIR BRUKER IFS 66V/S-Germany. The absorption spectra of the coconut dye solution were recorded using a CARY-100 Conc UV–Vis spectrophotometer (Varian, Palo Alto, CA) in the wavelength range of 250 - 750 nm.

Composite preparation

The seven labelled cotton fabrics was placed into seven different beakers with labels corresponding to the fabrics. This was followed by the addition of 200ml of distilled water to each of the beakers. Different proportion of powdered rice fibre ranging from 1g, 2 g and 3g was placed in the beakers labelled $F_{R1,}$ $F_{R2,}$ and F_{R3} respectively. Also, different proportion of powdered coconut fibre ranging from 1g, 2 g and 3g was placed in the beakers labelled $F_{C1,}$ $F_{C2,}$ and F_{C3}respectively. The composites were prepared by boiling the cotton fabric with different solutions of rice and coconut fibre at temperature of about 105^{o}C for 10 minutes with continuous stirring. The composites were oven-dried at about 105^{o}C for 6 hours, placed in a desiccator, accurately weighed and then stored in air tight containers for further analysis.

Mechanical properties of the composite

➢ Determination of tensile strength

Tensile test was carried out to determine the tensile properties of the treated and untreated cotton fabric. An instron “Model 1026” was used for the analysis of each sample with dimension of about 130 mm X 20 mm. At the end of the analysis, the results were obtained through a computer hybridized with the instrument.

➢ Crease Recovery Test

A portion (4.0 x 2.0 cm) of each of the seven composites were separated and carefully creased by folding into half. Afterwards, a hot electric iron was placed on each sample for 1 minute to impart the crease on the fabric. The iron was removed and the material was monitored for 1 minute to allow it recover from the crease. The recovery angle was measured using a protractor and recorded. The test was carried out on the seven composite samples in duplicates and the average recovery angle was calculated.

Result and Discussion

Characterization of Coconut fibre

➢ Determination of Functional groups

Figure 3revealsthe IR spectrum (%Transmittance against wave-number(cm^{-1})) for the coconut dye solution obtained from the FT-IR readout parameter.The FTIR peak bands for different functional groups are stated below. The various absorption bands present in the FTIR spectrum of coconut fibre extract were at 3426.42, 2931.42, 2354.28, 1619.52, 1524.09, 1450, 1107.57 and 600 cm^{-1} respectively.The absorption bands between 1450cm^{-1} and 600 cm^{-1} of the

spectrum occur in the finger print region. The strong absorption at 3426.42cm^{-1} represents an O-H (stretch, H-bonded) bond absorption indicating the presence of polyphenols. The peak at 2931.42 cm^{-1} might be attributed to an asymmetrical and symmetrical C-H alkyl stretch. The peak at 2354.28 cm^{-1} can be assigned to a carboxylic acid group. The strong absorption band of 1619.52cm^{-1} depicts an aromatic C=C bend, which is indicative of the presence of aromatic structures in the lignin molecule. The peak at 1524.09cm^{-1} maybe attribute able to the presence of an N=O nitro or nitroso group that is probably present in the molecular structure. The peak at 1107.57 cm^{-1} represents at C-N bond. Thus, FTIR analysis reveals the presence of various functional groups (polyphenol moiety).

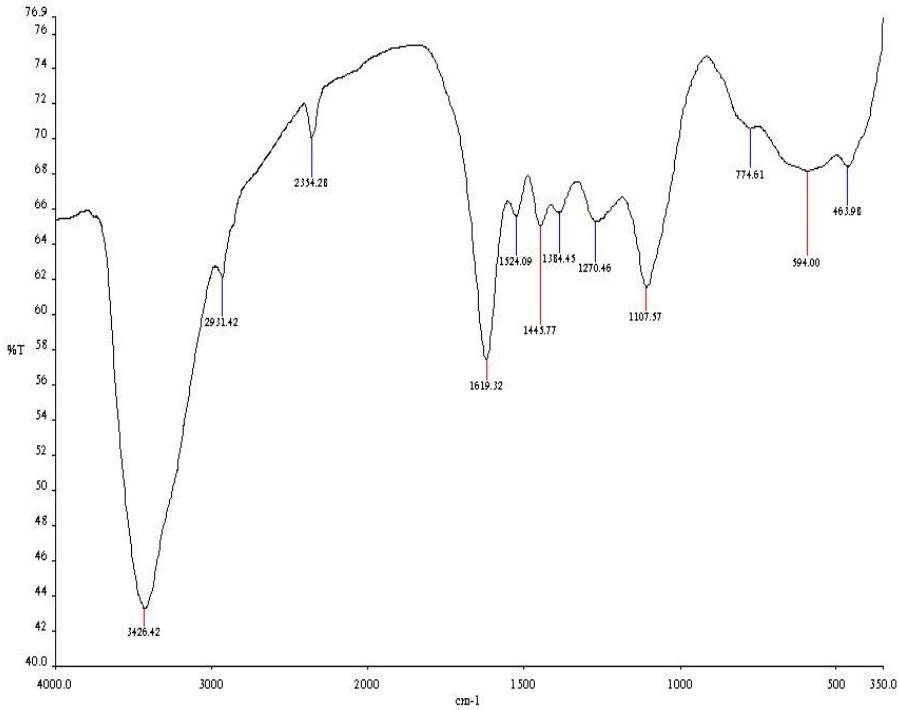

Figure 3.Infrared Spectrum showing peaks corresponding to the presence of function groups in the coconut dye sample

➢ Determination of UV-Visible Spectra of coconut dye solution

Figure 4 reveals the UV-Vis spectra of the solution containing 6.25-100 mg/L of coconut fibre solution at 250-750 nm. From the spectra, the wavelength of maximum absorption is 278.00nm. The wavelength was set at 278.00nm, and the absorbance of the aliquots at varying concentrations obtained from the UV-Visible Spectrophotometer 0.096, 0.201, 0.434, 1.013 and 2.012 at aliquot concentrations of 6.25, 12.5, 25, 50 and 100 mg/L respectively.

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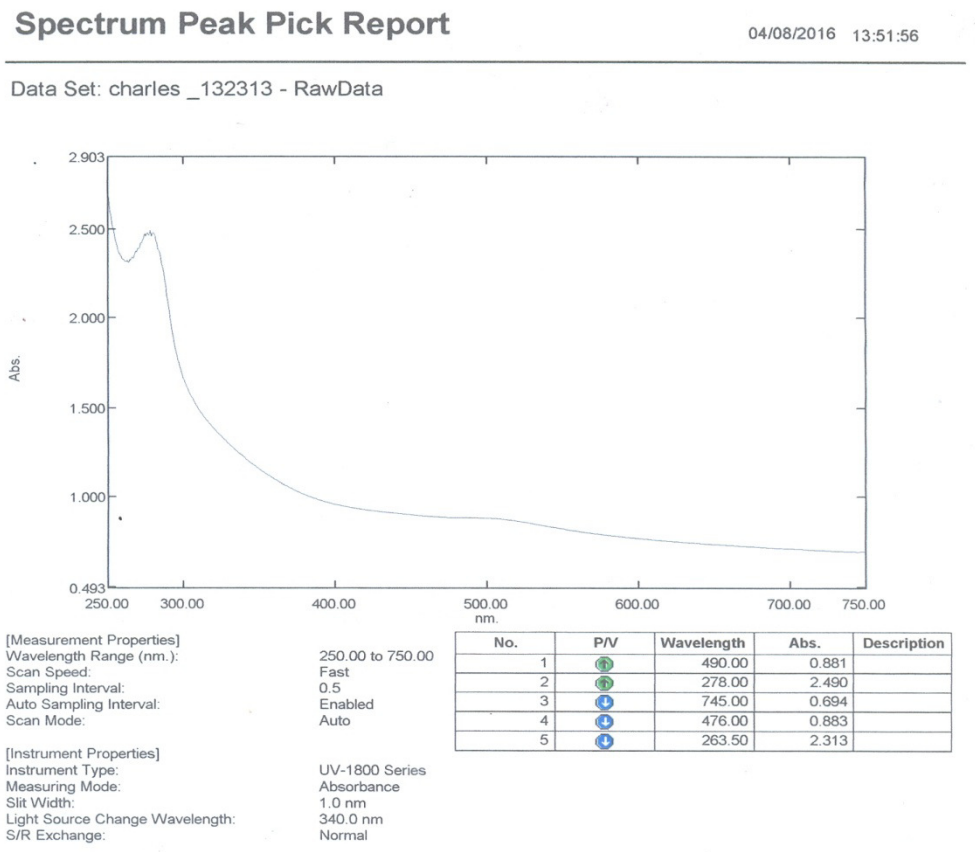

Figure 4.UV-Vis spectra of the solution containing 6.25-100 mg/L of coconut fibre solution at 250-750 nm

Tensile Parameters of the Composite materials

Table 1 reveals the tensile parameters of the control and other six composite materials. The tensile strength (TS) for the samples range between 2.86-12.10 MPa with F_0 having the highest and F_{C1} having the lowest tensile strength**.** Thereis a reduction in TS upon application of rice and coconut fibre. This may be attributable to the fact that the rice and coconut fibre form a thin film on fabric such that it cannot penetrate into the fibre regions of the fabric due to their relatively large particle size [10]. Consequently, it only affects the symmetrical distribution of the load rather than increasing the load bearing ability of the fabric [11].This is agreeable with the findings reported Chattopadhyay and Inamda [11] for the reinforcement of cotton fabric with nano-Chitosan. Hence, the reduction of the particle size of the fibres might bring about the desired result. Tensile strength measures the ability of a fabric to withstand external stress during extension [12].

The Elastic Modulus (YM) for the samples range between 33.46-113.41 MPa with F_0 having the highest and F_{R2} having the lowest Young Modulus. YM revealed a drastic reduction upon incorporation of rice and coconut fibre into the fabric. This may be attributable to the drastic decrease in TS because the lower the tensile strength the lower the Young Modulus [10]. These

values are not agreeable with the findings of Stina et al. [13] for the Elastic Modulus of Birch/Textile composite which recorded a 50 % increase with respect to the reference.

The Elongation at Break for the samples range between 12.03-22.15% with F_{R1} having the highest value andF_0 having the lowest value. The elongation properties increased owing to the addition of the rice and coconut fibres. This is suggestive of the absence of the formation of in situ 3D networks which would have resisted the alteration of the adjacent fibre molecules [14]. This finding is agreeable with the report of Prasad et al. [15]. Elongation at Break gives information about the fabric handle [16].

Table 1.the tensile parameters of the control and other six composite materials

Parameters	F_0	F_{R1}	F_{R2}	F_{R3}	F_{C1}	F_{C2}	F_{C3}
TS (MPa)	12.10	7.01	3.64	5.30	2.86	7.23	5.45
EM (MPa)	113.41	63.29	33.46	45.29	45.29	58.15	47.67
E@B (%)	12.03	22.15	16.27	19.31	15.42	20.35	20.17

F_0 = Control; F_{R1} = Cotton fabric with 1g of RB; F_{R2} = Cotton fabric with 2g of RB;
F_{R3} = Cotton fabric with 3g of RB; F_{C1} = Cotton fabric with 1g of CB;
F_{C2} = Cotton fabric with 2g of CB; F_{C3} = Cotton fabric with 3g of CB

Crease Recovery Angle of the Composite materials

Table 2 showed the crease recovery angles for the control and composite materials. The propensity for crease formation affects the aesthetic appeal of cotton fabric. Often times, this is usually overcome by impregnating cotton cloth with crosslinking agents such as aminoplast resins [16]. The crease recovery angle of the samples range between 39 - 45^o**.** F_{R3} has the highest crease recovery angle while F_0 has the lowest crease recovery angle.The result revealed that the incorporation of rice and coconut fibre slightly increase the recovery angle of the fabric with the exception of F_{C1} which has the same recovery angle as the control. Furthermore, rice fibre-reinforced cotton fabric is relatively higher than coconut fibre-reinforced cotton fabric viz-a-viz the recovery angle. The discrepancy may be attributed to the penetration of the rice fibre into the fabric than coconut fibre due to relatively small particle size compared to coconut fibre[15].

Table 2.The crease recovery angles for the control and composite materials

Sample ID	Weight of fibre (g)	Recovery angle (^{o})
F_0	0	39
F_{R1}	1	43
F_{R2}	2	43
F_{R3}	3	45
F_{C1}	1	39
F_{C2}	2	41
F_{C3}	3	42

Conclusion

The result showed that the Tensile strength and Young Modulus of the coconut-fibre and rice-fibre reinforced fabric is lower than the control fabric. This may be as a result of the formation of thin film on fabric such that it cannot penetrate into the inter-fibre regions of the fabric due to their relatively large particle size.The Elongation at break and the crease recovery angle of the reinforced fabric is higher than that of the reference fabric. This suggests that coconut and rice fibre have no effect on the mechanical properties of cotton fabric with the exception of the creasing effect.

References

1. Can, Y., Akaydin, M., Turhan, Y. and Ay, E. (2009). Effect of wrinkle resistance finish on cotton fabric properties. Indian Journal of Fiber& Textile Research, 34, 183-186.
2. Hauser, P.J., Smith. C.B. and Hashem, M.M. (2004). Ionic Cross linking of Cotton. Autex Research Journal, 4, 95-100.
3. Mortazavi, S.M. and Boukany, P.E. (2004). Application of mixtures of Resin Finishing to Achieve Some Physical Properties on Interlining Cotton Fabrics: I-Effect of Stiffening and Cross linking Agents, Iranian Polymer Journal, 13, 213-218.
4. Sahin, U.K., Gursoy, N.C., Hauser, P. and Smith, B. (2009). Optimization of Ionic Cross linking Process: An Alternative to Conventional Durable Press Finishing. Textile Research Journal, 79, 744-752.
5. Bellini, P., Bonetti, F., Franzetti, E., Rosace, G. and Vago, S. (2001). Finishing Reference Books of Textile Technologies, Acimit Fundation.
6. Hashem, M., Hauser, P. and Smith, B. (2003). Wrinkle recovery for cellulosic fabric by means of ionic cross linking. Textile Research Journal, 73, 762-766.
7. Anju Maryealias, Rajeena A. P., Sivadutt S., Asst. Prof. Life john, Asst. Prof. Anjupaul (2014) “Improvement of strength of concrete with partial replacement of Course aggregate with coconut shell and coir fibres. Journal of mechanical and civil engineering. Volume 11, issue 3: 16-24.
8. Chao-Lung Hwang, Vu-An Tran, Jhih-Wei Hong and You-Chuan Hsieh (2016), “Effects of short coconut fiber on the mechanical properties, plastic cracking behavior, and impact resistance of cementitious composites” Construction and Building Materials 127: 984-992
9. C. Mathiraja (2013), “A study on concrete using bottom ash, manufacturing sand and hybrid steel and coir fibres” iosr journal of mechanical and civil engineering; Volume 10, issue 1 , pp 55 -57
10. Jay. J. Lad, Prof. A. R. Darji, Dr K. B.Parikh (2017). Strength and Durability Study of Concrete by Using Rice Husk Ash and Coconut Fiber. International Journal for Research in Applied Science & Engineering Technology (IJRASET) ISSN: 2321 -9653; Volume 5 Issue VII; 887-900

11. Kan, C.W.; Yuen, C.W.M.; Lam, Y.L.; Chan, C.K. "Effect of enzymatic treatment and reactive dyeing on the low stress mechanical properties of linen fabric. Fibers Polym. 2009, 10, 325-332.
12. Debapriya Chattopadhyay & M S Inamdar "Improvement in properties of cotton fabric through synthesized nano-chitosan application". Indian Journal of Fibre & Textile Research Vol. 38, March 2013, pp. 14-21
13. Majid Ali, Anthony Liu, HouSou and Nawawi Chouw (2012), "Mechanical and dynamic properties of coconut fibre reinforced concrete", Construction and Building Materials 30: 814-825.
14. StinaBjorquist, Julia Aronsson, Gunnar Henriksson and Anders Persson (2017). Textile qualities of regenerated cellulose fibers from cotton waste pulp, Textile Research Journal. DOI: 10.1177/0040517517723021.
15. G Krishna Prasad, R Guruprasad, G T V Prabu, Sheela Raj & P G Patil "Low-stress mechanical properties and fabric hand of cotton and polylactic acid fibre blended knitted fabrics". Indian Journal of Fibre & Textile Research Vol. 43, September 2018, pp. 381-384.
16. Chi-Wai Kan and Yin-Ling Lam, "Low Stress Mechanical Properties of Plasma-Treated Cotton Fabric Subjected to Zinc Oxide-Anti-Microbial Treatment". Materials 2013, 6, 314-333; doi: 10.3390/ma6010314 ISSN 1996-1944 www.mdpi.com/journal/materials.

