

Comparative Studies Of Physico-Mechanical Properties Of Composites Made From Agricultural Wastes; Corn Cob And Kenaf Fibre Using Polyvinyl Alcohol/Starch Blends As Matrix For The Production Of Egg Crate

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Abstract: This study evaluate the potential of using waste material from corn harvesting operation and kenaf fibre in thermoplastic composites at commercial scale. The study also compares the properties of the composites using two different binders, polyvinyl alcohol (PVA) and polyvinyl alcohol-starch blend. The properties such as, Bulk density, Tensile strength, moisture uptake and water uptake where investigated. The result showed that composite with PVA binder alone had good mechanical properties (B: L = 0.1KN, T: S = 3Mpa, B: D = 1.14gcm⁻³, %E = 3.97) but low moisture and water Absorption (M.A = 13.1%, W.A = 75.4%). The PVA/Starch hybrid blends (1:1) and (1:3) had moderate mechanical properties (B:L = 0.01KN, T:S = 2.0Mpa, B:D = 0.33gcm⁻³, %E = 1.42),(B:L = 0.04KN, T:S = 1.0Mpa, B:D = 0.25gcm⁻³, %E = 1.35) and had better moisture and water uptake (20.8%43.40)and(64.23%,77.23%).This paper also emphasizes that PVA/starch blends can be utilized in commercial scale for the production of egg crate based on its economic evaluation.

Keywords: Plant fiber, corn cob, Tensile strength, Bulk density, water uptake, moisture uptake, breaking Load and % Elongation

I. INTRODUCTION

Natural fiber composite is still undergoing development till date in spite of its pioneering work in the 70's[1].The potential of biodegradable polymers especially bio-composites from agro-waste have long been well established and it is

attracting increasing level of interest[1-2].Plant based fibers are known to exhibit high mechanical properties and are thought to have the potentials to possible replace some synthetic composite reinforcement[2].Unlike synthetic fibers ,natural fibers are inexpensive lower in density, yearly renewable and are known to pose no health

hazards[3,4]. However, many factors can prevent natural fibers from displaying their full potential due to resin-reinforcement incompatibility and the presence of surface impurities.

This challenge has been overcome by chemical treatment method to clean the surface of fibers in order to remove unwanted component, such as waxes, pectin, hemicelluloses and lignin. The removal of these materials has been observed to help with improving inter-facial bonding with commonly used industrial resin [5]. In addition, since the cellulose content increases the fiber tensile properties also improve. However, the success of treatment of cellulose based Fiber depends not only on the type of the treatment, but also on the treatment parameters, such as time, concentration and temperature. Fiber-matrix has affected very strongly on the overall performance of the complete composite material [6]. Fiber-matrix interaction can be improved by surface or structure modification of the fibers using various processes such as alkali treatment, bleaching and steaming [7].

There is equally a growing interest in the use of plant fibers as reinforcement in thermoplastic and thermo set. Although thermoplastics have added advantage of recycling possibilities; thermo set are targeted to obtain mechanical properties as compared to thermoplastic in the resulting composite. Plant fibers such as jute, sisal, kenaf, coir, banana, flax and ramie are available in different parts of the world. These are commonly used as cordage, sacks, mats, ropes, wall covering and filler for mattresses and cushions. Also, it is reported that the use of plant fiber reinforced composite in polymer matrix with a view to replace more expensive and non-renewable synthetic fiber such as glass, can reduce the material cost. Recently, it has been agreed that the mechanical properties of short-fiber reinforced Composite depends on several factors such as type of fiber, orientation and dispersion caused during processing, fiber content/loading, type of matrix in which the fiber is dispersed and any treatment undergone before compounding and most importantly the type of technology used for consolidation.

Starch, promising agro-resource for the production of biodegradable polymer as matrixes for bi-composite application, is a raw material for use in bio-plastics [8]. However, due to starch excessive hydrophilicity and brittleness, blending starch with conventional thermoplastic polymer is a promising approach to improve its drawbacks [5]. Among synthetic water-soluble polymers throughout the world, PVA is the largest which has broad applications [10]. Interestingly, it possesses a lot of magnificent features such as high tensile strength, biodegradability, biocompatibility, chemical resistance, gas barrier, and excellent adhesive properties

These two polymers can be an excellent pair for blending duo to their biodegradable features. In addition, PVA can mix evenly with the starch because of its water solubility [9]. Because of these facts; researchers have focused a lot on PVA/starch.

Kenaf is an abundant, versatile, renewable, cheap and biodegradable fiber used for making a wide variety of products and has been tested as filler or reinforcement in different composite [3]. Available information indicates that limited work has been carried out to synthesize polymer matrix composite materials and value-added products

thereafter using the industrial wastes like red mud and/or fly ash and plant fibers [11, 12]. In view of the above, polymer-based composites have been synthesized with different combinations of the pre-characterized wastes and/or the plant fibers (as fillers/reinforcements).

The incorporation of treated kenaf into formulations with starch and poly (vinyl) alcohol can be a good alternative for low cost composite and possibly improving their mechanical properties. Thus, the main objective of the present study is to compare the physico-mechanical properties of the kenaf fibers in the thermoplastic/starch resin with the aim of manufacturing composite with high mechanical performance for the production of egg crate.

II. MATERIALS

Kenaf fiber used was imported from Malaysia Poly(vinyl)alcohol was supplied by SIGMA-ALDRICH, Corporation (St.Louis, MO). The corn cob used was obtained as agro-waste residue in Zaria, Kaduna state, Nigeria. Starch used [modified] was obtained from Cormat Limited, Nigeria under the license of TGI-Ireland.

A. EXPERIMENTAL

a. TREATMENT OF KENAF FIBER

Kenaf fibers were treated using NaOH. The NaOH solution was prepared by dissolving NaOH pellets in deionized water to make up a 5% w/w of NaOH solution. The Kenaf fibers cut into small bundles were alkali treated for 2 hours, at a temperature of 800C. After the treatment was complete, the fibers were rinsed thoroughly in distilled water until a neutral pH was obtained. The fibers were later dried in a vacuum oven at 800C for 24 hours to ensure that all residual moisture was removed.

b. TREATMENT OF AGRO-WASTE (CORN COB)

The corn-cob were grinded into granules using a milling machine. This was sieved using a mesh of 2mm in diameter and subjected to pre-treatment with NaOH. The corn cob were introduced into already prepared NaOH(5% w/v) solution and treated for 2 hours at a temperature of 800C. After the treatment, the corn-cobs were rinsed thoroughly in distilled water until a neutral pH was obtained. The treated samples were dried at 1000C and stored in desiccators until needed.

c. PREPARATION OF POLY (VINYL) ALCOHOL RESIN, STARCH AND POLY (VINYL) ALCOHOL/STARCH BLENDS.

100g of polyvinyl alcohol (PVA) was transferred into a 2000ml beaker; 1000ml of distilled water was added to the PVA and heated with continuous stirring in a water bath until there was proper dissolution of the mixture. 40g of modified starch were dissolved in 100mls of distilled water at room temperature and stirred until there was proper dissolution. The

PVA/starch combination was obtained based on the ratio of PVA to Starch in the composite.

III. SAMPLE PREPARATIONS

A. COMPOSITE CONTAINING POLY(VINYL) ALCOHOL (PVA)

374mL of PVA solution (34gw/v) was transferred into a beaker. 24g of corn-cob (filler) was put into the PVA solution and stirred until there was proper mixing. 56g of treated kenaf fiber was added to the mixture and mixed thoroughly to obtain an even dispersion. The composite obtained was transferred into a rectangular container and dried in the oven at a temperature of 800C for 24 hours.

B. COMPOSITE CONTAINING PVA/STARCH IN A BLEND RATIO 1:1

PVA solution (34gw/v) and Starch solution (34gw/v) were properly mixed together to obtain a homogenous phase. 24g of corn-cob was put into the mixture and mixed thoroughly via manual means. 56g of treated kenaf was also added, mixed thoroughly to obtain even dispersion. The composite obtained was transferred into a rectangular container and dried in the oven at a temperature of 800C for 24 hours.

C. COMPOSITE CONTAINING PVA/STARCH IN A BLEND RATIO 1:3

PVA solution (8.3w/v) and Starch solution (34gw/v) were thoroughly mixed to obtain a homogenous phase. 24g of corn-cob and 56g of kenaf fiber were added to the PVA/Starch blend in succession mixed to obtain an even dispersion of the mixture. The composite obtained was transferred into a rectangular container and oven dry at 80°C for 24 hours.

IV. FABRICATION USING VULCANIZED HOT PRESS

The three categories of composites were compression moulded in a hot press at 170-190 for short period of time at a pressure of 10-30 tones with a mould thickness of 2mm. After the above procedure, the composites was cut into the required dimension [110mm by 15mm by 2mm] for analysis using a jig saw.

V. CHARACTERIZATION

A. TENSILE TESTING

Tensile strength (TS), Breaking load (BL) and elongation at break (e) were determined according to ASTM D882, under ambient conditions, using an Instron 3369 Universal Testing Machine. The testing conditions used were; 20mm/min and load cell of 0.2 KN. The films tested were 110mm long and 15mm wide and the thickness of the specimen 2mm. The

results were recorded and calculated by the instrument software

B. BULK DENSITY

The density of specimens was determined using the full thickness of composites. The density of composites was calculated using

$$D = m/v \text{ (gcm}^{-2}\text{)}$$

Where m is the mass of the composites and v is the volume of the composite. Mass determination was carried out by weighing the composites to one decimal place on an analytical balance (GT4000V). The dimensions of the samples were measured using a micrometer screw gauge. All samples were oven-dried at 50°C for 24 hrs before mass and volume determination was conducted.

C. WATER ABSORPTION TEST.

Water absorption tests were carried out according to ASTM D5229. The composite

Samples were immersed in distilled water at room temperature (25°C) respectively. The

Water absorption was determined by weighing the samples at regular intervals. A top loading

Balance type GT4000v was used, with a precision of 1 mg. The percentage of water content

(t), M_t was determined as follows:

$$M_t (\%) = \frac{W_w - W_c}{W_c} \times 100$$

Where W_w is the wet weight and W_c is the conditioned weight of the sample. An average value from three measurements will be reported.

D. MOISTURE ABSORPTION TEST

The moisture absorption of the samples were carried out in a chamber filled with a saturated solution of a salt (NaCl) that can give a predetermined relative humidity. Prior to the test, the samples were oven dried at 50°C for 24 hours. The samples were put inside the chamber for 24hrs. The moisture uptake was calculated as the percentage increase in weight.

VI. RESULTS AND DISCUSSIONS

Binder	B.D (gcm-3)	T.S (MPa)	B.L (KN)	e (mm)	E (%)	W.A (%)	M.A (%)
PVA only	1.14	3.0	0.1	4.0	3.97	50.04	13.10
PVA/Starch[1:1]	0.33	2.0	0.01	0.30	1.42	64.23	20.80
PVA/Starch[1:3]	0.25	1.0	0.04	0.15	1.35	77.23	43.40

Table 1: Results of Physico-mechanical parameters of composites with different binders

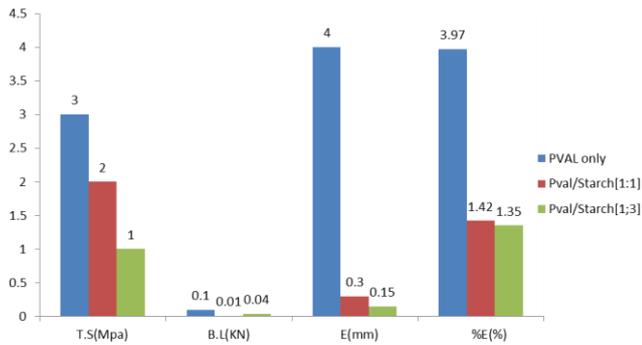


Figure 1: comparison of mechanical test for composites with different binders

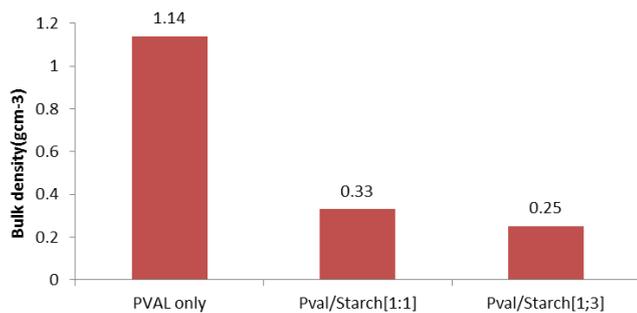


Figure 2: comparisons of Bulk density for composites with different binders

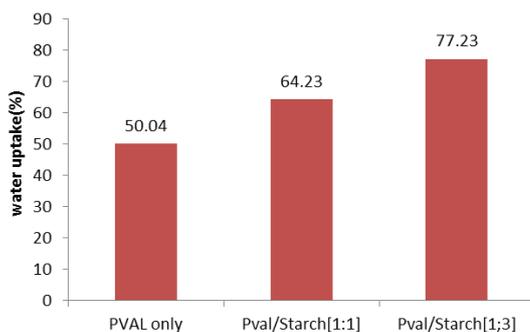


Figure 3: Comparisons of water absorption for composites with different binders

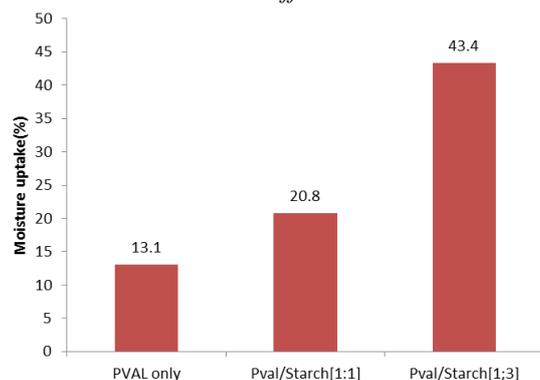


Figure 4: Comparisons of moisture absorption for composites with different binders

A. MECHANICAL TEST

The result in Fig 1 shows that the PVA matrix polymer [3Mpa] had better tensile properties compared to the PVA/starch hybrid composite 1 and 2, [2Mpa] and [1Mpa] respectively. This is an indication that the PVA matrix had better Reinforcement- matrix adhesion due to strong fibre/filler-matrix interaction compared to the PVA/starch hybrid which was lower in strength. The PVA matrix composite in Fig 1 also had higher breaking load and extension [0.1KN, 4.0mm] compared to the PVA/starch (1) [0.01KN, 0.01mm] and PVA/starch (2) [0.15KN,0.04mm] respectively. The reinforcement-matrix association in the PVA matrix composites promoted efficient stress transfer between the matrix and the fibers compared to the PVA/Starch hybrid matrix composites. The PVA matrix composite in Fig 1 also recorded higher extension at break [3.97%] compared to the PVA/Starch composite 1[1.42%] and 2[1.35%]. This was due to interfacial bond strength established in the PVA matrix which requires much strength to overcome compared to the PVA/starch hybrid composite.

B. BULK DENSITY

The result in Fig 2 shows that the PVA matrix composite had higher bulk density [1.14gcm⁻³] compared to the PVA hybrid composite (1:1) [0.3gcm⁻³] and (1:3) [0.21gcm⁻³]. The PVA matrix composites has a better formulation, strength and compactness owing strong interfacial- adhesion established between the PVA matrixes bringing about better Reinforcement matrix interaction and compactness. The kenaf fibre and corn cob are held in position by the high bond strength of PVA matrix which reduces the voids and spaces within the fibre/filler- matrix interface. The low density of the PVA/starch hybrid 1 and 2 was due to minor voids in the composite as a result of the low bond strength of the PVA/Starch matrix and this decreases its density.

C. WATER ABSORPTION

The result in Fig 3 shows that PVA/starch hybrid matrix composite had higher moisture absorption [64.23% and 77.23%] compared to the PVA matrix composite [50.04%]. This is due to the presence of the free hydroxyl group in the PVA and starch structures, which holds more water via hydrogen bonding [increases due increase hydroxyl group], which has the capacity to absorb water and moisture. This phenomenon makes the composite to be more hydrophilic. The PVA matrix composite had lower water absorption due to less hydroxyl group which only exists in the PVA structures and this accounts for its lower water absorption the rate compared to the PVA/starch matrix composite

D. MOISTURE ABSORPTION

Moisture absorption in the PVA starch matrix (in Fig 4) is considerably higher owing to more hydroxyl ions in its structure which increases the affinity for water. The PVA matrix composite has less hydroxyl ions in its structure and this accounts for its low moisture absorption.

VII. CONCLUSIONS

Reinforcement of polyvinyl alcohol and polyvinyl/Starch hybrid composites using kenaf fibre and corn-cob to determine its physic-mechanical properties. The result of the study shows that the PVA matrix composite exhibited better ultimate tensile strength, breaking load and percentage elongation compared to the PVA/Starch matrix composite, owing to better reinforcement-matrix adhesion, bond strength, compatibility and reinforcement-matrix interaction.

PVA/Starch hybrid matrix composite had superior water and moisture absorption due to higher number of OH groups in the PVA/starch structure which increases affinity for water compared to the PVA matrix composite. This research indicated that PVA matrix reinforced with treated kenaf fibers and corn-cob have superior characteristics when compared to PVA/Starch matrix. However, based on economic evaluations and cost implication, PVA as a thermoplastic binder is expensive and will not be viable on a commercial scale. A PVA/Starch matrix formulation in optimized proportion could be a viable alternative binder system that will be cost effective even in the production chain.

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