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Effect of Particle Size and Fiber Loading on Some Properties of Sugarcane Bagasse Reinforced Unsaturated Polyester Composites

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Abstract

In recent times, the use of sugarcane bagasse as reinforcement in plastic composites has been receiving greater scientific attention due to its abundance, light weight and good mechanical properties. This research has investigated the mechanical properties of the composite by hardness strength, impact strength, chemical resistant test, and water absorption test with different particle size and loading of sugarcane bagasse (SCB) as reinforcement in unsaturated polyester resin (UPR) composite. Bagasse fiber was treated with sodium hydroxide (10%), potassium permanganate (5%), hydrogen peroxide (5%) to enhance better adhesion between the fiber and the matrix. Sugarcane bagasse reinforced unsaturated polyester resin composite was prepared using the compression molding technique, the mold was undergoing a curing process for 5 minutes with 130^0 c and 2.5Mpa of pressure. The result of the mechanical properties were evaluated, the mechanical properties (flexural strength, hardness strength) increases with increase in bagasse content while the impact strength increase and then decreases, the maximum mechanical properties was obtained from the composite made of 400µ and 25 wt% fiber loading compared with the control sample. The improvement in the mechanical

properties is attributed to the extent of good interaction between the fiber and the matrix. The composite show increase in water absorption with increasing fiber loading and increasing number of days up to when the samples reaches their saturation when no water absorption was observed, 25wt% of 710μ has the highest absorption and this is due to its bigger particle size and fiber loading. The mechanical and physical properties shows that the composite has potential applications in structural materials such as particle board, fiber board, library shelf's, partitioning panels, ceiling boards.

Keywords: Sugarcane Bagasse, Unsaturated Polyester, Chemical Properties, Mechanical Properties, Physical Properties

INTRODUCTION

Composite can be referred to as a material that is made up of two or more constituents that are combined at microscopic level in which one constituent is called the reinforcing phase and another one in which the reinforcement is embedded is called the matrix phase and these constituents are not soluble in each other (Autar, 2006). Reinforcement provides rigidity and strength, helping to support structural load. The binder or matrix whether organic or in-organic gives an advantage of maintaining the position and orientation of the reinforcement (Chandramohan and Marimuthu, 2011).

The matrix phase materials are generally continuous while the reinforcement phase material can either be flakes, fiber or particles. Some of the examples of composite systems are epoxy reinforced with graphite fibers and concrete reinforced with steel. Examples of naturally found composites include wood and bones, for the wood, lignin is the matrix which is reinforced with cellulose fibers while for the bones, the bone-salt plates that is made up of phosphate and calcium ions reinforce soft collagen (Autar, 2006).

Composites can be classified based on the type of matrix as polymer matrix composite (PMCs), Ceramic matrix composite (CMCs), metal matrix composites (MMCs) and carbon–carbon composites or by the geometry of the reinforcement as particulate, fibers and flake (Autar, 2006). Therefore, this research is focused on polymer matrix composites (PMCs) as the matrix used is a polymer matrix while the reinforcement is in particulate form.

There are various types of techniques that can be employed in the fabrication of polymer composites and these techniques or methods include: compression moulding, injection moulding, hand lay-up, vacuum bag moulding, spray-up, filament winding, pultrusion, vacuum - assisted resin transfer or vacuum infusion moulding and resin transfer moulding (RTM). However, each of the aforementioned composite fabrication techniques has advantages and limitations (Rangaswamy *et al.,* 2021). The development of polymeric composites with the aid of synthetic fibres as reinforcement resulted from the growing demand in the world for more versatile materials suitable for industrial applications. However, the use of these synthetic chemicals which have been proven to have adverse effect on the already stressed state of environmental pollution has caused a growing concern and protest in the recent decade. This necessitated the shift of focus to utilizing natural fibres with the aim of replacing the synthetic fibres, by making emphasis on their advantages of being environmental friendly, economical, lower densities, recyclability, higher filling levels, renewable and biodegradable (Bisht and Gope, 2015).

Fibers reinforced polymer composites have many applications as class of structural materials because of their ease of fabrication, relatively low cost and superior mechanical properties compared to polymer resins. For example in the automotive industry, the effort to reduce weight in order to improve fuel economy and to comply with tighter governmental regulations on safety and emission has led to the introduction of increasing amounts of plastics and composites materials in place of the traditionally used steels (Farag, 2008).

The advantages of using natural fiber in composite materials are process friendly, lower in specific weight and exhibits thermal and acoustic insulating properties. Nevertheless, the shortcoming with the natural fiber in composites are variation in the quality, limitation in processing temperature, strength properties, durability, poor fire resistance and supply chain (Nabi and Jog, 1999).

In general natural fibers are hygroscopic in nature and they absorb or release moisture depending on environmental conditions which leads to a moisture build-up in the fiber cell wall (fiber swelling) and also in the fiber matrix interface. This in turn becomes responsible for changes in the dimensions of cellulose-based composites, particularly in the thickness and the linear expansion due to reversible and irreversible swelling of the composites (Rowell, 1997).

MATERIALS AND METHODS

Unsaturated Polyester, Methyl Ethyl Ketone Peroxide (MEKP), Cobalt Naphthalene (Accelerator) (NYCIL NIG). Sodium Hydroxide, Acetic Acid, potassium Permanganate, Distilled water, Benzene, Potassium hydroxide.

Sample Collection

Sugarcane bagasse sample was collected from zakirai Sugarcane market, gabasawa local government of Kano state, were the stalk of the sugarcane was manually extracted to remove the juice and remains collected. The residue called bagasse was collected for further fibre preparations and unsaturated polyester resins (UPR) were used as matrix, methyl ethyl ketone peroxide (MEKP) which acted as a catalyst and cobalt nephthenate which acted as an accelerator.

Retting

This was done by submerging sugarcane bagasse in water. The water penetrating into the central
portion swells the inner cells bursting the outer most layers, thus increasing absorption of both
moisture and decay producing bacteria. Retting time must be carefully observed, under retting
makes separation difficult and over retting weakens the fibre (Tahir *et al,*2011).

Preparation of Fibre

The sugarcane bagasse (SGB) fibers were soaked in water (retting) for three (3) days to remove the impurities from the fibre and then dried for seven (7) days. Thereafter, SGB fibres were grinded and treated with 10% NaOH, followed by 5% $KMnO_4$ and then 5% hydrogen peroxide. The sugarcane bagasse fibres were sieved in to three (3) different particle sizes (180, 400, and 710 microns). These particles were obtained by using standard sieve of different sizes.

Sugarcane bagasse/unsaturated polyester resin composite

Composites of bagasse and unsaturated polyester resin were prepared by weighing the required volume of UPR, accelerator and catalyst. The corresponding amount of bagasse is shown in Table 1

Table 1: Formulations of particulate bagasse/ unsaturated polyester composite

S/N	Specimen size (μ)	Composition (g)			
		Particulate Bagasse Filler	Unsaturated polyester	Methyl ethyl Ketone peroxide (Catalyst)	Cobalt naphthanate (accelerator)
1	180	10.0	90.0	1.0	0.5
2	180	15.0	85.0	1.0	0.5
3	180	20.0	80.0	1.0	0.5
4	180	25.0	75.0	1.0	0.5
5	400	10.0	90.0	1.0	0.5
6	400	15.0	85.0	1.0	0.5
7	400	20.0	80.0	1.0	0.5
8	400	25.0	75.0	1.0	0.5
9	710	10.0	90.0	1.0	0.5
10	710	15.0	85.0	1.0	0.5
11	710	20.0	80.0	1.0	0.5
12	710	25.0	75.0	1.0	0.5

Preparation of the Unsaturated Polyester/Bagasse Composite

The required materials were weighed out using an electronic weighing balance. Unsaturated polyester matrix composites were produced with varied weight fractions of particulate bagasse filler. The weight percentages of the constituents are shown in Tables 3.1 In preparing the reinforced polyester composites, the mass of the unsaturated polyester was varied with that of the reinforcement to give a total of 100grams. The sugarcane bagasse was added into the polyester resin and stirred continuously with a glass rod for about two minutes until a uniform mixture was observed. Thereafter, 1g of catalyst was added with the help of disposable syringe and stirred for about two minutes, after which 0.5g of accelerator was also added and stirred for about two minutes. The mixture was poured into a mould already coated with paper tape and hydraulic oil which served as mould release agent and allowed to cure for two hours. This procedure was repeated for other specimen as shown in Table 3.1 with changes in the weight percentages of the particulate fillers. A control sample was also produced (Chioma *et al.,* 2014). Using the compression molding machine, the mold was undergoing a curing process for 3 minutes with 130^{o}c and 2.5Mpa of pressure. Next, the mold was cooled off for about 10 minutes at room temperature the

samples after 24 hours were cut in rectangular and dog-bone sizes for further characterization.

Characterization of Composites

The characterization was carried out according to ASTM standards for testing materials.

Mechanical tests

After the fabrication of the composites, the samples were conditioned for 24hrs and later subject to the following tests.

Hardness Test

The Rockwell hardness test was carried out in accordance with ASTM E-18 using indentec universal hardness testing machine (MODEL: 8187.5 LKV (B)), the sample were cut into 30 x 20 mm of length, breadth and height respectively. The readings obtained as a function of the degree of indentation. The Rockwell hardness test method is based on the difference in depth of the indenter at two specific times during the testing cycle.

Impact Test

Charpy impact testing machine (MODEL: Cat.Nr.412 Charpy impact tester) following ASTM D-256 standard three cured samples was subjected to a 15Joule impact at 3.21m/s suspended with a pendulum whose mass was 25kg.

Water Absorption Test

Water absorption test was carried out on three different composites of each particle sizes and control samples in accordance with ASTM D-570 standard procedure. Samples were weighed designated as (w_1), then immersed in distilled water for 24 hours, removed and allowed to dried and, reweighed after immersion (w_2). The test was continued for several days until constant thickness was obtained.

The percentage gain/loss water was evaluated according to equation 3.4:

$$\%\ weight\ gain\ loss = \frac{w2-w1}{w1} \times 100 \quad \text{..... eqn (3.4)}$$

The chemical resistance test was conducted in accordance with ASTM D-543 -87. Three cured composites from each sample were tested using different chemicals and the mean of the results obtained was evaluated using the equation employed as in water absorption test (Omale and Dauda, 2016, Bam *et al.,* 2019).

The percentage gain/loss chemical resistance test was evaluated according to the following equation 3.7:

$$\%\ weight\ gain\ loss = \frac{w2-w1}{w1} \times 100 \quad \text{.....eqn(3.7)}$$

RESULTS AND DISCUSSION

Hardness Strength

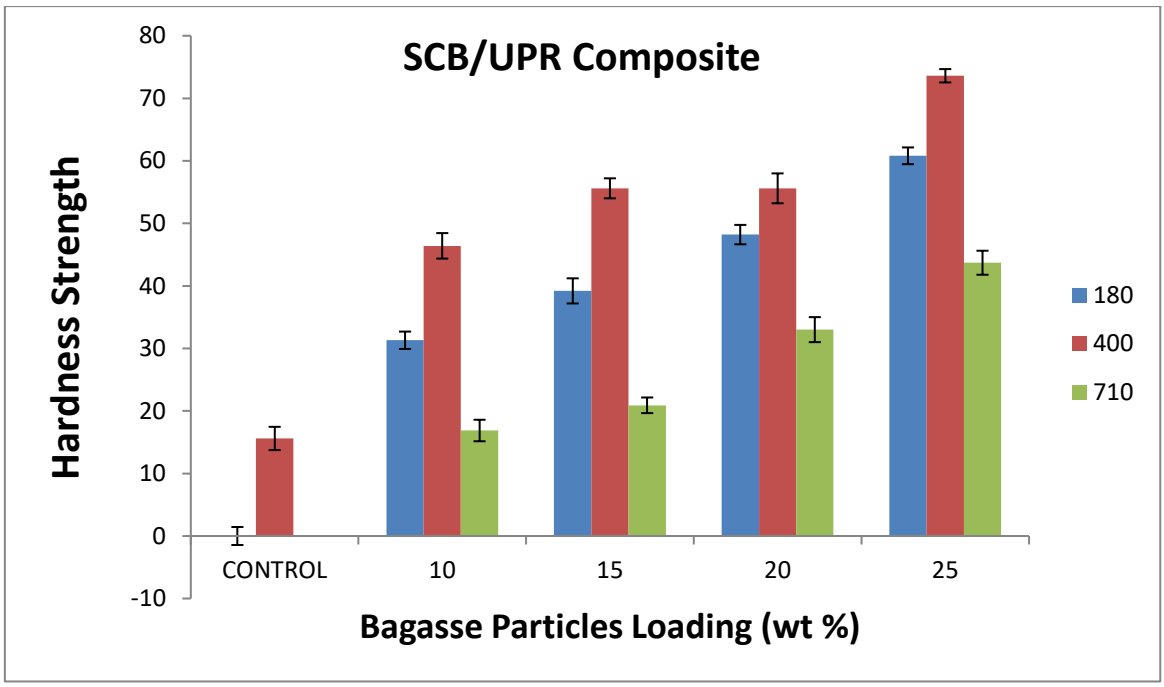

Figure 1: variation of hardness strength versus filler loading for bagasse/UPR composite.

Effect of Particle Size and Filler Loading on Hardness Test

The effect of filler content and particle size on hardness strength of unsaturated polyester bagasse composite is presented in figure 1. The hardness test was carried out on the prepared composite at different filler content of 0, 10, 15, 20, 25 and different particle size of 180, 400, and 710 micron respectively. From the result obtained it can be deduced that there was a gradual increase in hardness strength of 10%filler to 25%. It can be seen from the result obtained that hardness for the composites increased with increasing filler loading. The increase in hardness may be attributed to the strengthening effect of the fibres incorporated in to polymer matrix. Fibres are usually added in to polymeric materials to improve their rigidity and strength. The higher the percentage of fibres incorporated, the harder the material, and more rigid it becomes. The findings also agreed with those

reported by Cao *et al,*(2006) and Arrakhiz *et al* (2013). The hardness increases when resistance of the materials to the deformation increases. This happen when more filler is added; the composite becomes harder and the materials hardness improves.

Impact Strength

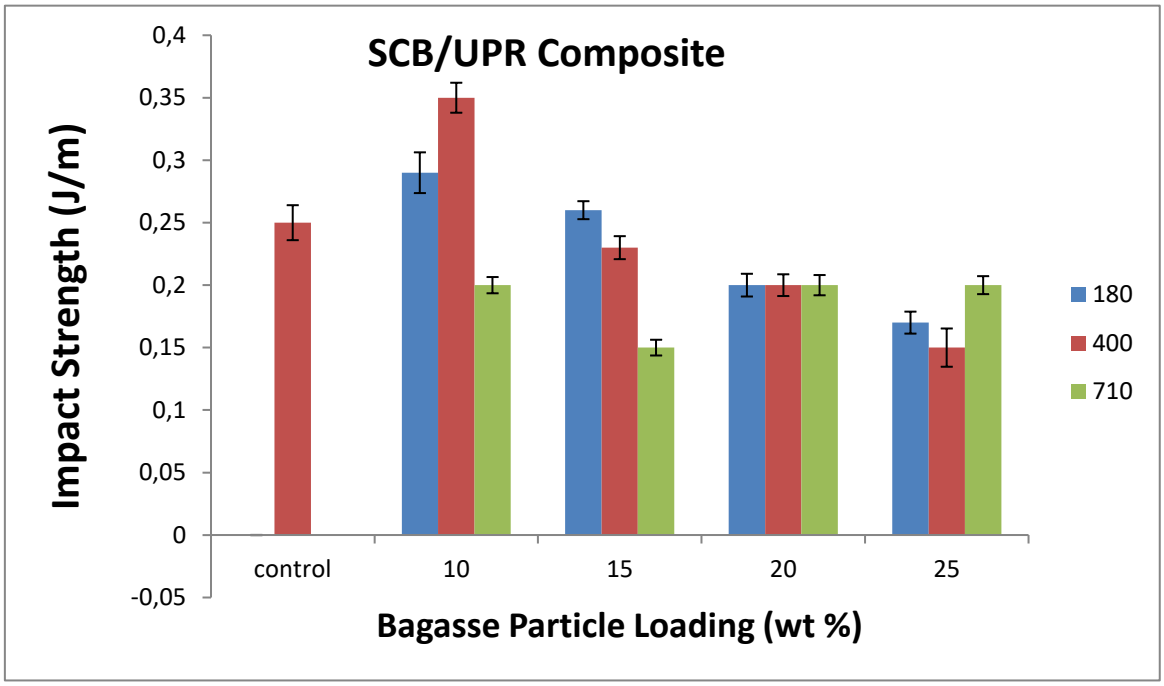

Figure 4.5 variation of impact strength versus filler loading for bagasse/UPR composite.

Figure 2 shows the results of the impact strength which decreases with increase in filler loading. The decrease in the impact strength can be arising from saturation of the UPR by the filler, thus, preventing proper bonding of the fillers to form strong composites. It was observed that the composite with 20% filler loading show the same impact strength, this means that the composite can withstand medium energy impact. The improvement in absorbing energy of the composite could be due to better interaction of the filler and the matrix. Similar result have been reported by Ali and Jamila, (2016).

Water Absorption

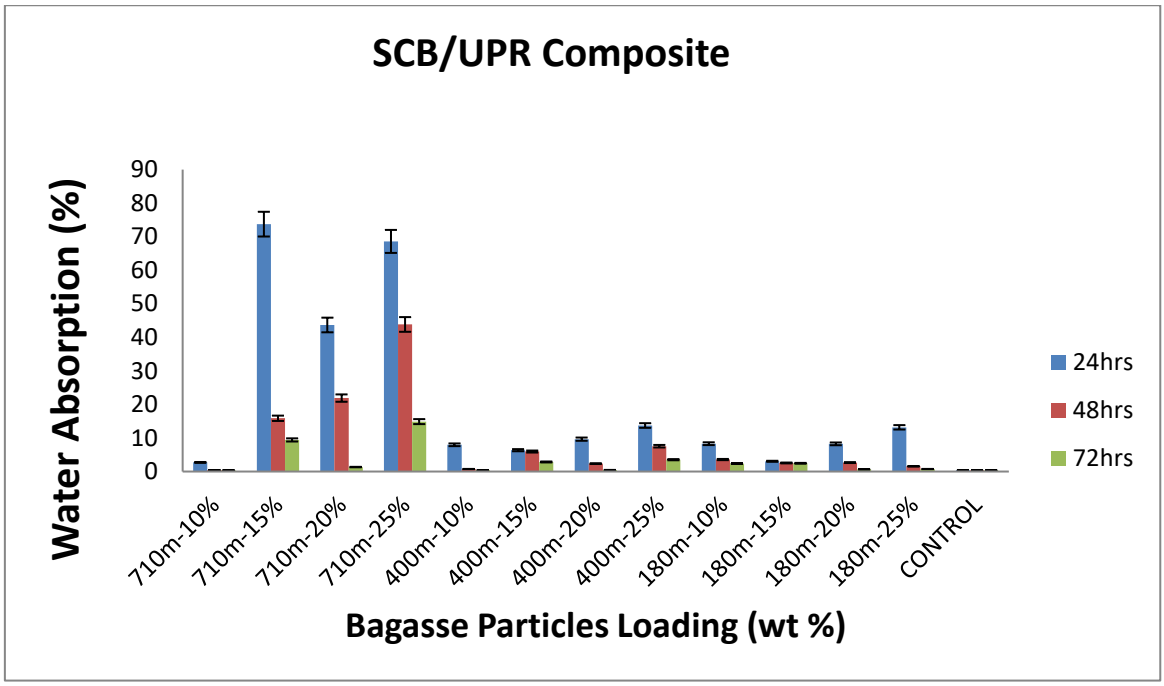

Figure 3: Variation of water absorption versus filler loading for bagasse/UPR composite

Figure 3 show the percentage water absorption of bagasse/unsaturated polyester at different particles size and different filler loading for 1-3 days intervals. The general trend is that as the filler loading increases the sample exhibits higher water absorption. This may be due to the fact that, bagasse fibre is hygroscopic in nature; it is a well-known fact that natural fibre are generally hydrophilic in nature, whereas polymer molecules are hydrophobic in character i.e. they do not contain any polar group as such, the polymer does not easily bond to water molecules explaining its ability to stay dry (Kabir *et al.,*2011). It was observed that the fibre with higher loading absorbed more water as shown in the figure above whereas the control with 0% filler loading absorbed small amount of water as compared to others which is due to hydrophilic nature of UPR polymer molecules as described. However sample with filler loading of 25% of 710µm showed higher water absorption with increasing number of days compared to samples with 10% filler loading. The 25% of 710µm having 14.88% while the10% of 710µm has 0.36% then 25% of 400µm has 3.53% and 10% of 400µm has 0.43% lastly 25% of 180µm has 2.39% and 10% of 180µm having 0.74% water absorption. Cellulosic fibres tend to absorbed more moisture as they are expose longer in water there by gradually degrading in the composite by the microorganism in the water creating voids in the structure which reduce the strength of the

composite. This is in accordance with works of Agarwal *et al* (2010) on their study on tensile behavior of glass fibre reinforced plastics subjected to different environmental conditions.

Effect of Particle Size and Filler loading on chemical Resistance of the Composite

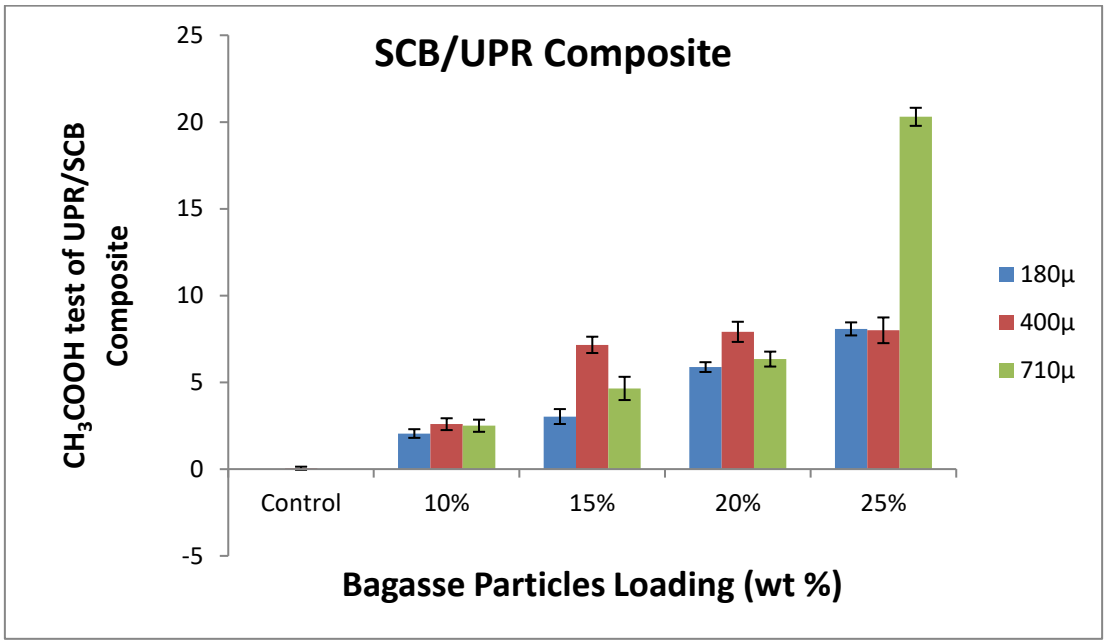

Figure 4: variation of chemical resistance with acetic acid versus filler loading for bagasse/UPR composite

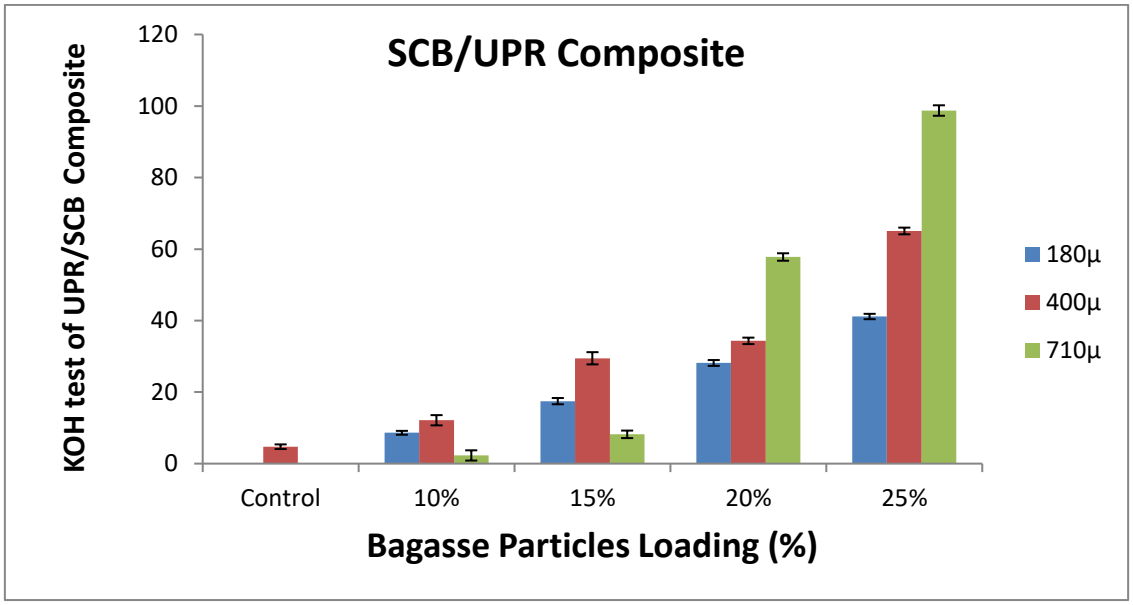

Figure 5: Variation of chemical resistance with KOH versus filler loading for bagasse/UPR composite.

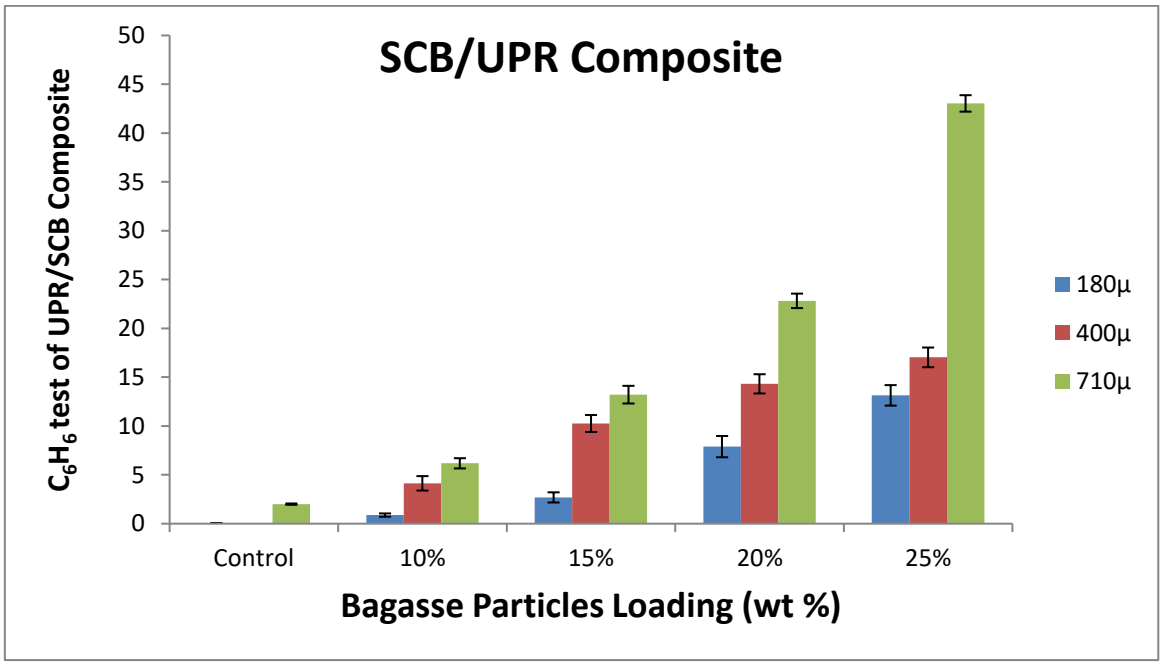

Figure 6: Variation of chemical resistance with benzene versus filler loading for bagasse/UPR composite.

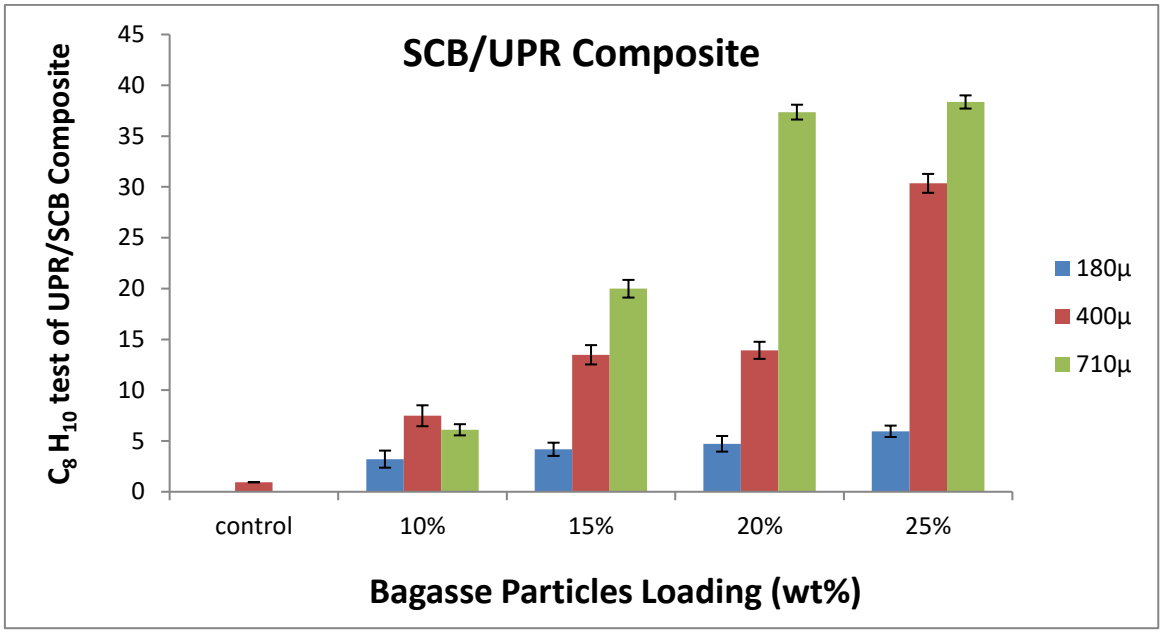

Figure 7: Variation of chemical resistance with xylene solvent versus filler loading for bagasse/UPR composite.

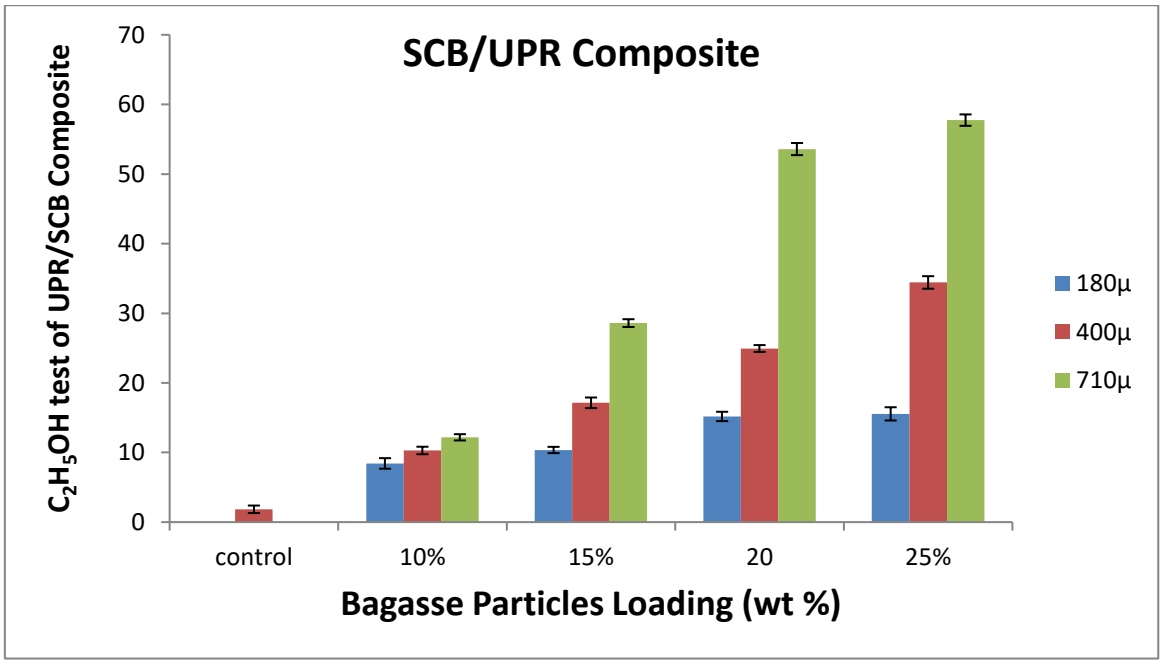

Figure 8: Variation of chemical resistance with ethanol solvent versus filler loading for bagasse/UPR composite.

The result obtained in the chemical resistance test showed that, the composite are resistant to all chemicals used, an increase in weight of the composite is noticed. This is due to the

interaction of the composite with the chemicals as shown in figures above. Increasing of the bagasse filler loading resulted in moisture weight gain of the exposed composite samples. The obatined increase in weight is regarding the absorption of reagents. The absorption in chemical resistance test was increased as noticed in water absorption test and the absorption is more with composite reacted with base followed by solvent then acid. It is clear that the entire composite did not lose their weight and therefore they not seem as if any erosion occurred.

CONCLUSION

In conclusion, chemically treated sugarcane bagasse fiber reinforced unsaturated polyester composite at various fiber loading and particle size were prepared using a compression molding technique, Chemical treatments had strong effect on the fibre-matrix adhesion and the resulting mechanical properties of the composite produced, The result obtained in chemical resistance test showed that all the composites were resistant to all chemicals used; an increase in weight of the composite was noticed.

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