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Effects of Snail Shell as Filler on the Mechanical Properties of Terephthalic Unsaturated Polyester Resin

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ABSTRACT

The mechanical properties of snail shell reinforced unsaturated polyester composite was assessed in this study. Ground snail shells of particle size 65µm were introduced at different percentages into the unsaturated polyester resin. The powdered shells were characterized using FTIR to determine the functional groups present. The tensile test was performed using an Instron universal testing machine operated at a cross head speed of 10mm/min. The tensile test specimen preparation and testing procedures were conducted in accordance with ASTM D412. The hardness test was carried out using Brinell's hardness testing machine. The mechanical properties including ultimate tensile strength, tensile strain at maximum load, bending strength at peak, deformation at peak, impact strength and hardness were tested using standard methods. The results obtained showed that the flexural strength at 20% snail shell loading was greatly enhanced; the impact and hardness properties were greatly improved at 5% filler loading. Thus snail shell filler could be considered for applications in areas where high impact strength is a requirement such as some parts of automobiles. The snail shell reinforcements of 20% can be used in place of pure polyester for applications where flexibility is of utmost importance

Keywords*:* Snail shell, unsaturated polyester, composite, terephthalic.

INTRODUCTION

The use of polymer matrix composite has found wide application in modern day goods. This is as a result of inherent properties which polymers possess. These include lightweight, ease of processing, among others. One of the factors which make plastics attractive for engineering application is the possibility of property enhancement through modifications like fibre reinforcement [1]. The major thermosetting resins used in conjunction with glass fibre reinforcement are unsaturated polyester resins and to a lesser extent epoxy resins. The most important advantages which these materials can offer are that they do not liberate volatiles during cross-linking and they can be moulded using low pressures at room temperature [2]. Natural fibre-reinforced polymer provides reduction of cost and weight and of course there is an increase in the degradable capability of the resulting product. Fibres like oil palm fruit bunch, kola Nitida wood fibre, sisal, coconut fibres, etc as well as several fillers such as rice husk have been used as reinforcement materials for different thermoplastic and thermosetting plastic resins [3,4,5]. There is an overwhelming interest in filler and natural fibre reinforced polymer owing to their ease of processing, and low cost as some of these fillers are regarded as waste. In the development of polyester/eggshell particulate composites, the density and hardness values of the polyester/eggshell particulate composites increased steadily with increasing eggshell addition, compressive strength, flexural strength and impact energy increased [6]. An investigation into the fibre glass waste/polyester resin composites showed the impact strength to be excellent [7]. The study into some tensile properties of unsaturated polyester resin reinforced with varying volume fractions of carbon black nanoparticles revealed that tensile strength, percentage elongation and tensile toughness at fracture increased as the volume fractions of carbon black nanoparticles increased from 1% to 5% [8]. The effect of untreated and treated coconut shell reinforced unsaturated polyester composites were studied. It was observed that the mechanical and thermal properties of unsaturated polyester/coconut shell composites were enhanced [9]. In the study of the effect of kaolin powder into unsaturated polyester matrix to prepare particulate composite results showed that kaolin improved the compression strength, flexural modulus, impact strength, hardness and also increased the flexural strength of unsaturated polyester [10]. In the study of the tensile behaviour and hardness of coconut fibre-ortho unsaturated polyester composites, the results showed that the tensile properties at 10% fibre load were greatly enhanced [11]. Their versatility in use allows unsaturated polyester resins to be used in a host of composite applications. Composite parts can be made at temperatures as low as 15°C to as high as 150°C depending on the processing requirement of the application.[12]. Unsaturated polyester resins also have excellent service temperatures. Polyester resins are produced industrially because of its particular advantages which include its capability to cure at room temperature and transparency among others. This study focuses on the determination of the effects of Snail Shell filler on mechanical properties of unsaturated polyester.

MATERIALS AND METHODS

Snail shells were collected from the popular Yanga market in Benin City, Edo state, Nigeria. Polyester resin (unsaturated), Methyl ethyl ketone peroxide (catalyst), Cobalt Naphthanate (Accelerator), all were of commercial grade, and obtained from a sales outlet in Benin City.

Preparation of Snail shell Filler

The shells were thoroughly washed with clean water to remove dirt and sun dried. After drying, the shells were ground and sieved with a sieve size of 65 µm and were further heated in an Oven at 105^{o}C for 3 hrs.

The formulation used for the particulate is given below:

Table 1: Formulation of filler/polyester composite

Reagents	Weight in grams.					
Percentage of Snail shell	5%	10%	15%	20%	25%	30%
Percentage of Orthophtallic unsaturated polyester	95.0	90.0	85.0	80.0	75.0	70.0
Methylethyl ketone peroxide (catalyst) (g)	1.0	1.0	1.0	1.0	1.0	1.0
Cobalt naphthanate (accelerator) (g)	0.5	0.5	0.5	0.5	0.5	0.5

In synthesizing the polyester composites, the mass of the polyester was varied with that of the reinforcement to give a total of 100grams (i.e. for every 100gram composition of the polymer composite, there will be 95 grams of polyester and 5grams of reinforcement (snail shell) for the 5% composition. This was subsequently done for 10%, 15%, 20%, 25%, 30%) and was 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 min.

Casting of the mix

The mixture was poured into a mould and allowed to cure for two hours. This procedure was repeated for all compositions. After curing, the samples were stripped from the mould.

Figure 1: Raw Snail shell sample [13]

Figure 2: Powder Snail shell after grinding and sieving [13]

Figure 3: Cast samples of unsaturated polyester/snail shell composite

Characterization of Composite samples

The samples were characterized for Tensile strength, Hardness, Flexural, Impact test according to standard methods. The FTIR analysis was done using the FTIR-8400 series test equipment.

RESULTS AND DISCUSSION

FTIR Analysis of the Snail Shell Powder and the composites

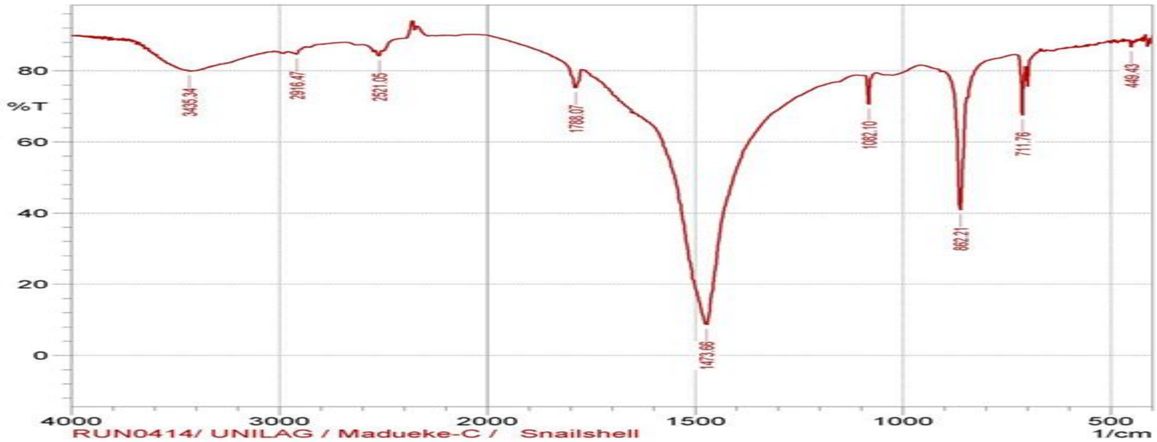

Figure 3: FTIR spectrum of Snail shell powder.

Infrared spectrum of snail shell powder is shown in Figure 3. The snail shell powder shows characteristic absorption bands for carbonate ions ($CO_3{}^{2-}$) at 862, 1082, 1473, and 1788 cm^{-1}, respectively. The broadband at 1473 cm^{-1} indicates the presence of $CO_3{}^{-2}$ and was found to be more intense. The weak peak at 3435 cm^{-1} corresponds to vibration mode of moisture [14]. The sharp intensity peak at 3435 cm^{-1} represents the presence of vibration mode of OH- ion in calcium hydroxide.

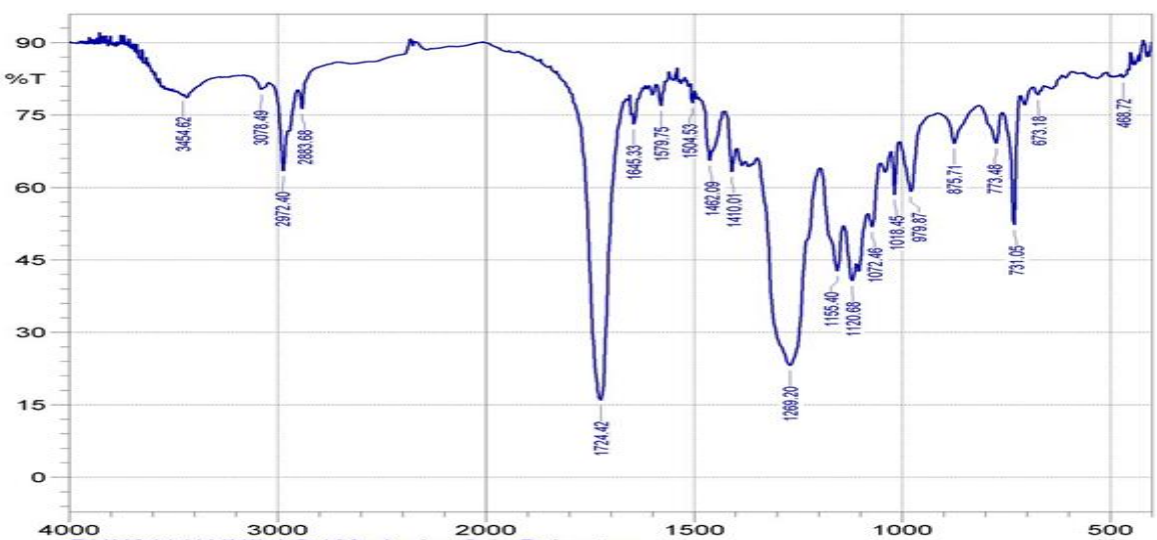

Figure 4: FTIR spectrum of the Polyester resin

FTIR spectra of snail shell/polyester composites are shown in Figure 4. The band at 3454 cm^{-1} is related to stretching vibrations of OH groups. It is probable that hydrogen bond may occur between polyester and shell samples. The bands in the range 2800– 3000 cm^{-1} correspond to stretching vibrations of CH groups such as CH_2 and CH_3. It is noticed that the stretching vibrations of CH groups have approximately the same absorption bands after curing the polyester with snail shell powder. In the spectrum of snail shell/ polyester composite, a very intensive band was observed at 1724 cm^{-1} due to stretching vibrations of C=O group. Weak bands at 1410, and 1462 cm^{-1} observed in the spectrum of polyester composite can be assigned to aromatic ring. It can be said that these bands attributed to aromatic ring do not change their positions. No interaction occurs between aromatic ring and the snail shells powder. The strong band at 1269 cm^{-1} which appears in the spectrum of polyester is due to twisting vibration of CH_2 groups.

Effects of filler concentrations on mechanical properties of the composites

Table 4: Effects of filler concentrations on mechanical properties of the composites.

Filler concentration Wt.(%)	Bending strength at peak/break (MPa)	Deformation at peak (mm)	Impact strength (Joules)	Brinell hardness (BHN)	Ultimate tensile strength (MPa)	Tensile Strain (mm/mm)
0	30.85	5.170	3.81	24.87	12.0539	0.0395
5	40.48	3.0520	5.13	31.20	5.7765	0.0342
10	31.54	2.8280	3.10	29.47	4.4247	0.0261
15	20.43	3.8250	4.20	24.20	7.2458	0.0178
20	46.24	3.0320	4.80	21.06	5.4060	0.0161
25	35.43	2.7780	4.24	20.52	5.4324	0.0153
30	30.21	2.5880	3.60	20.10	8.2354	0.0322

Flexural properties: Bending strength at peak /break

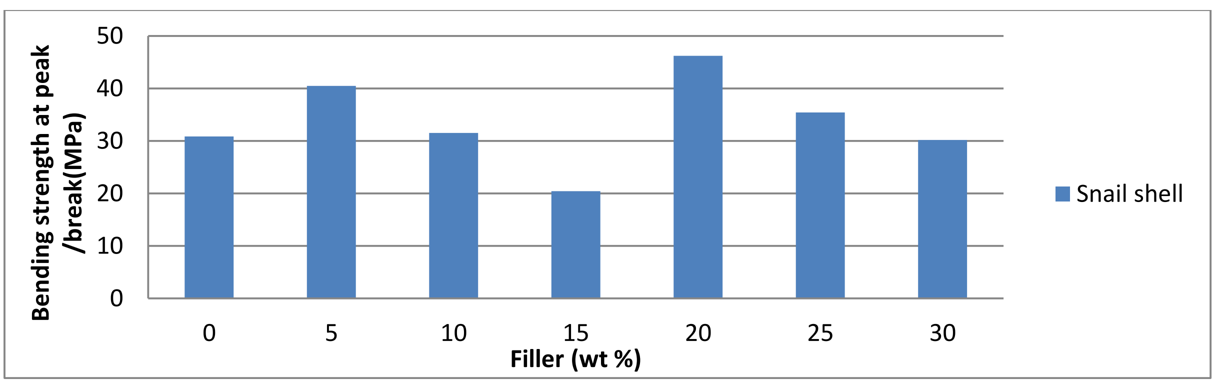

Figure 5: Effects of filler concentration on the bending strength

From Figure 5 above, the snail shell reinforcement had its maximum bending strength at peak at 20% filler concentration after which it continually dropped because the increase in weight percent of filler reduced the deformability of the matrix, and in turn reduced the ductility of the composite. The bend strength is the stress in a material just before it yields in a flexure test. It represents the highest stress experienced within the material at its moment of yield [15]. The reduction in the bending strength at peak of the snail shell reinforcements could be attributed to controlled mobility of matrix by filler particles. As the amount of reinforcement increases, there is reduction in total surface area available for matrix-filler interaction [16]. This corroborates the report of Chris-Okafor et., al.[13].

Deformation at peak

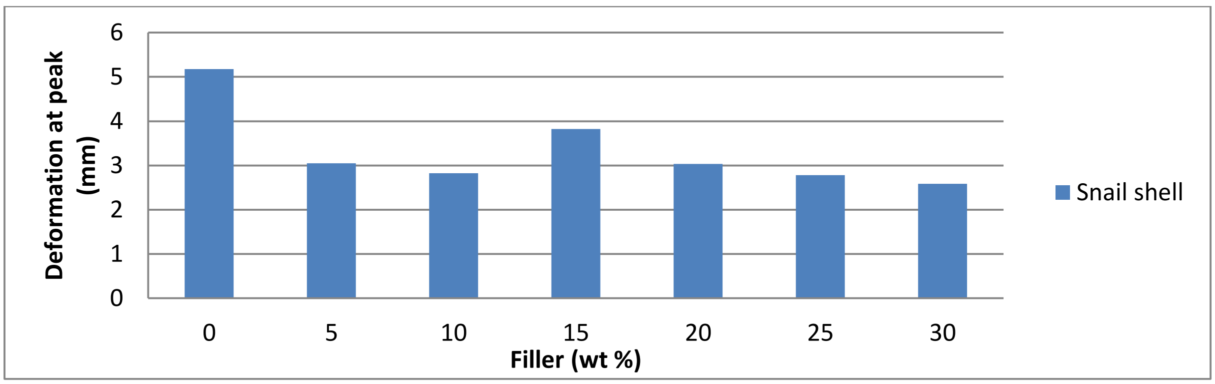

Figure 6: Effects of filler concentration on the deformation at peak

Figure 6 shows the effects deformation at peak of the reinforcement showing an undulating/sinusoidal pattern. The snail shell reinforcement shows a steady decrease in deformation at peak between 15% and 30%.

Impact test

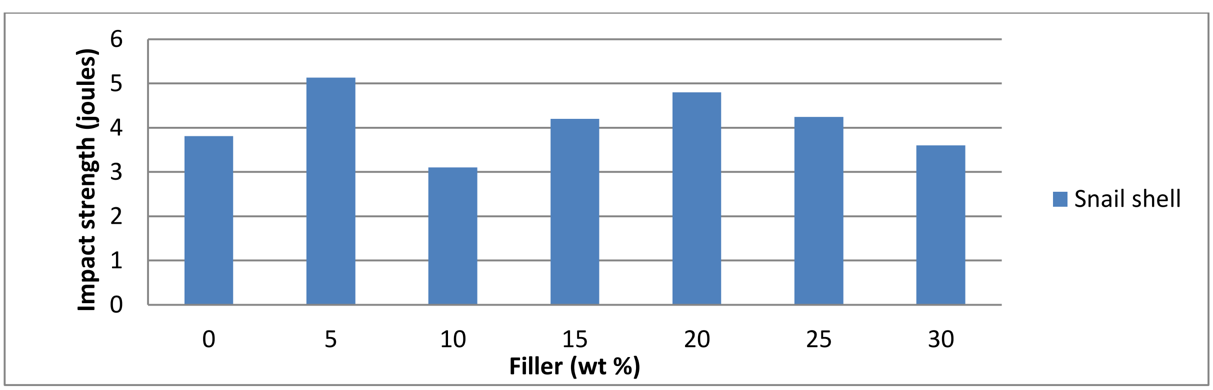

Figure 7: Effects of filler concentration impact strength

The Figure 7 above shows the amount of energy the samples can absorb prior to fracture. It was observed that the snail shell absorbs maximum energy at 5%. The impact strength decreases as the filler content increases. This is mainly due to the reduction of elasticity of the material due to filler addition and thereby reducing the deformability of matrix. An increase in concentration of filler reduces the ability of matrix to absorb energy and thereby reducing the toughness, so impact strength decreases. This is contrary to the report of Onuegbu and Igwe on snail shell filler on polypropylene [16].

Hardness test

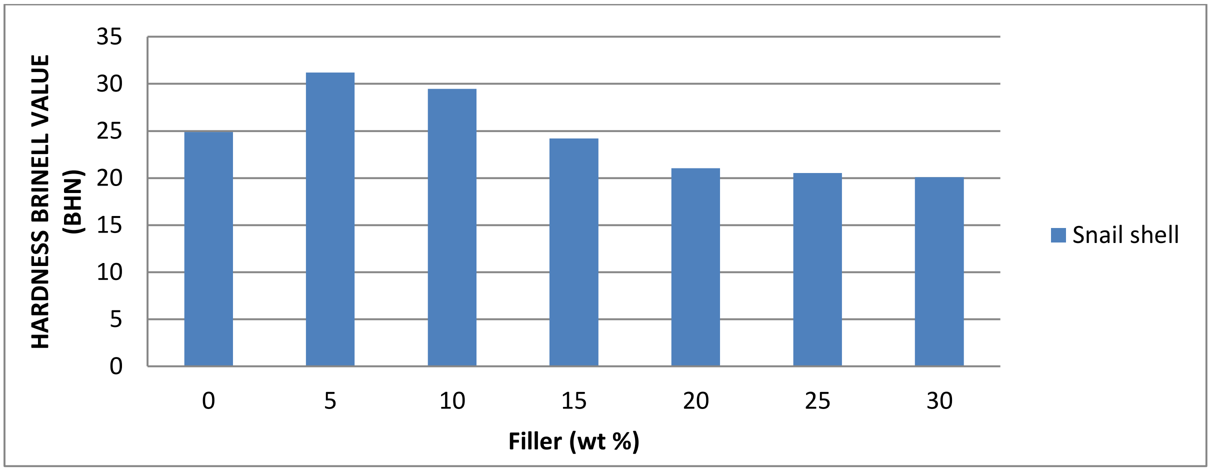

Figure 8: Effects of Filler Concentration on the Hardness

From the Figure 8 above, the highest level of hardness by the snail shell reinforcement was at 5%. The irregular/unpredictable pattern of the hardness may be attributed to the poor interfacial bonding or surface adhesion of the fillers and polyester resin [13].

Tensile properties

(i) Ultimate Tensile Strength (UTS)

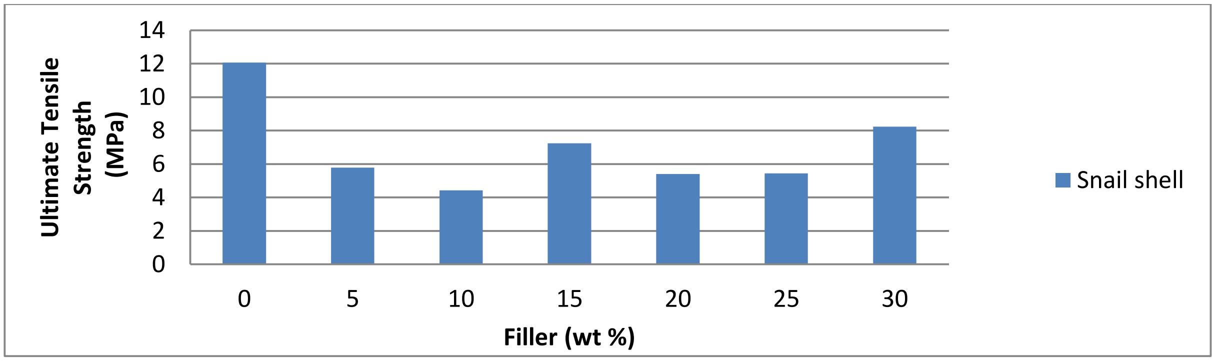

Figure 9: Effects of Filler Concentration on the ultimate Tensile Strength

The Figure 9 above shows the effects of ultimate tensile strength of the composite sample against its corresponding percentage reinforcement. It was observed that the highest UTS were at 30% filler concentration which was less than that of the control sample.

The ultimate strength of a composite depends on the weakest fracture path throughout the material. Hard particles affect the strength in two ways. One is the weakening effect due to the stress concentration they cause, and another is the reinforcing effect since they may serve as barriers to crack growth [16] In this case (as seen in figure 3.5 above), the weakening effect is predominant and thus the composite strength is lower than the matrix; and in other cases, the reinforcing effect is more significant and then the composites will have strengths higher than the matrix.

Prediction of the strength of composites is difficult. The difficulty arises because the strength of composites is determined by the fracture behaviours which are associated with the extreme values of such parameters as interfacial adhesion, stress concentration and defect size/spatial distributions. Thus, the load-bearing capacity of a particulate composite depends on the strength of the weakest path throughout the microstructure, rather than the statistically averaged values of the microstructure parameters.

The good tensile strength at higher filler content for snail shell reinforcements could be attributed to better dispersion of the reinforcement in the polyester resin matrix, better wettability, absence of void or porosity and good interfacial bond.

(ii) Tensile Strain at maximum load

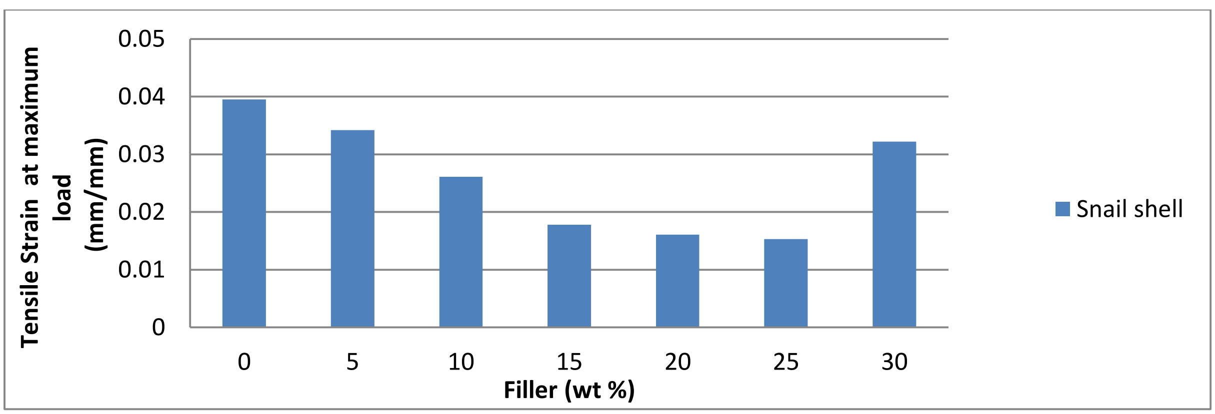

Figure 10: Effects of filler concentration on the tensile strain

Here the snail shell composite showed the highest tensile strain at maximum load at 5%, additional 5% snail shell filler concentration did not bring about any improvement on the strain.

CONCLUSION

The use of snail shells for the reinforcement of polyester resin was feasible in this study. It was observed that the mechanical properties of polyesters can be greatly improved by reinforcing it with snail shell. From the study; it is clear that the snail shell sample of 20% reinforcement showed the highest resistance before shattering. The implication is that the snail shell reinforcements of 20% can be used in place of pure polyester for applications where flexibility is a major consideration.

It is also evident that the snail shell sample of 5% reinforcement had the capacity to absorb the highest amount of energy before shattering relative to other samples, the impact test was performed on and highest surface hardness compared to other samples tested. Therefore the snail shell reinforcement of 5% can be used in place of pure polyester where impact strength and surface hardness is a major factor. The performance of the composite tested was poor when subjected to tensile loading. The tensile strength and strain of the pure polyester reduced when it was reinforced. This implies that the use of these composites should not be considered in applications that would subject it to tensile loading.

Thus, snail shell/polyester composite can be used in place of pure polyester depending on the filler content and user application.

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