International Journal of Advanced Engineering and Technology
ISSN: 2456-7655
www.newengineeringjournal.com
Volume 1; Issue 1; March 2017; Page No. 22-27

The effects of particle size on the flexural strength, tensile strength and water absorption properties of uncarbonized coconut shell /polyester composite

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Abstract
This research was carried out to investigate the effect of particle size on the flexural strength, ultimate tensile strength, density and water absorption characteristics of uncarbonized coconut shell/unsaturated polyester composite. Two particle sizes of 425micron (fine Sample UFS) and 170microns (coarse Sample UCS) of uncarbonized coconut shell particles were used as reinforcement. Flexural strength, ultimate tensile strength, density and morphological properties of the developed composites were determined. Maximum flexural and ultimate tensile strengths were both obtained at 20wt. % for the 425microns sample reinforced composite. The 30wt% of the 425microns coconut shell reinforced composite sample absorbed more water. The density of both composite particle sizes decreased with increase in filler content indicating use in applications requiring light weight.

Keywords: Freshwater SIS fish, smoke-drying, water-reconstitution, quality-assessment

1. Introduction

Composites consist of one or more discontinuous phases embedded in a continuous phase. The discontinuous phase is usually harder and stronger than the continuous phase and is called the 'reinforcement or 'reinforcing material', whereas the continuous phase is termed as the 'matrix' (Bhaskar & Singh, 2013) [2, 17]. Etcheverry and Barbosa, (2012) [9], observed that most composites have been created to improve combinations of mechanical characteristics such as strength, stiffness, toughness, ambient and high-temperature.

Coconut is a popular plantation and is grown in more than 90 countries worldwide.

Monteiro *et al.* 2008 [10], and W. Wang and G. Huang, (2009) [18], estimated the harvest of coconuts yearly as 33 billion all over the world with only 15% of these coconuts being utilized for fibers and chips. In Nigeria, the coconut palm is found mostly in the Southern states and in some marginal areas up to 10ºN. The largest coconut palm plantation is found in the Badagry local government area of Lagos State located in the South West of Nigeria (Odewale *et al.* 2012) [11]. Coconuts are mainly cultivated in the coastal clays and sands and sporadically distributed in other areas. The coconut takes one year from pollination to maturity and only during the second and subsequent years its fruits can be harvested (Saman, et al., 2002) [6]. The fruit consists of 4 parts: about 35% husk, 12% shell, 28% meat and 25% water (Perundingan, 2002) [4].

Researches all over the world today are focusing on ways of utilizing, either industrial or agricultural wastes as a source of raw materials for the industry. These wastes utilization would not only be economical, but may also result to foreign exchange earnings and environmental pollution control (Bienia *et al.* 2003 [3] and Aigbodion *et al.* (2010) [1]. Agunsoye *et al.* 2012 [12], observed that natural lignocellulosics such as coconut shell powder (cocosnucifera) has outstanding potentials as reinforcement in plastic.

In their work, Sapuan and Harimi, (2003) [8], further highlighted that properties such as high strength and high modulus make coconut shell as important filler for the development of new composites. Increase in coconut shell content as was observed by Husseinsyah and Mostapha, (2011) [7] increased the tensile strength, Young's modulus and water absorption rate however, there was a reduction in the elongation at break of coconut shell filled polyester composites. Sarki *et al.* (2010), reported an increase in tensile modulus and tensile strength values with increase of coconut shell particles content in a coconut shell reinforced epoxy resin composite.

In this study, coconut shell particle of different particle sizes in polyester resin were formulated and tested for various mechanical & physical properties.

2. Materials and Method

2.1 Materials

Materials used in this research work were coconut shell from Ogbete, Enugu; unsaturated polyester resin (matrix), methyl ethyl ketone peroxide (catalyst), cobalt Naphthanate (accelerator) were used AA supplied by Ndidiamaka Trading Company Enugu Nigeria

2.2 Method

2.2.1 Coconut shell processing (Particle size)

The coconut shell was sundried for 48 hours. It was crushed to powder using a pulverizing machine. Sieve Model 567924/173281Endecotts Test Sieves, Ltd, England was used

to sieve the ground coconut shell to different particle sizes. A particle size analyzer in accordance with ASTM standard was used to obtain two particle sizes of 425microns and 170microns.

2.2.2 Chemical characterization of the coconut shell

Mini Pal compact energy dispersive X-ray spectrometer (XRF) was used for the elemental analysis of the coconut shell ash. The system is controlled by a PC running the dedicated Mini Pal analytical software. This test was done at Ahmadu Belo University, Zaria.

Similarly, Proximate Analysis in observance of ASTM standards E-871, E-1755, E-872 for moisture at 110^{O}C, ash at 715^{O}C and volatile matter at 925^{O}C using a muffler furnace was used to determine the chemical composition of the coconut shell particles.

The Proximate Analysis provided information on moisture, ash, volatile matter and fixed carbon content on dry or weight base. The fixed carbon content was determined by subtracting the sum of the values of weight percent of moisture, ash and volatile matter from 100%.

$$Fixed\ Carbon\ (FC)\ (\%) = 100 - (Ash + Moisture + Volatile\ Matter)\% \quad (1)$$

2.2.3 Composite sample preparation

A mold of 420 mm × 50 mm × 15 mm having a base of mild steel sheet and sides of wood was used for casting the composite sheets. About 2000ml measuring cylinder was used to measure out the volume of the polyester resin and the corresponding coconut shell particulate. The volume fraction percents of coconut shell particles carbonized and un-carbonized (i.e. 10, 20 and 30 weight %), were mixed with the matrix. Care was taken to avoid formation of air bubbles during pouring and the mixture was covered to avoid buckling and allowed to cure at room temperature for 48 hours.

2.2.4 Density Measurement

Specimens of size 10x10x15 mm^3 were taken from the cast composite sheet. The weights of these samples were measured using a digital scale-precisa XB6200D weighing machine. Density calculation was done using the formula:

$$Density = mass/volume\ of\ sample \quad (2)$$

2.2.5 Flexural test procedure

Flexural test was performed using Universal Testing Machine model TUE-C-100, according to ASTM D790.The composite samples were tested at a three-point bending test at a cross head speed of 5 mm/min. In each case, three samples were taken and average value of the flexural force was recorded.

The flexural stress was computed using the following equation:

$$\sigma max = \frac{3P_{max}L}{bh^2} \quad (3)$$

Where, P_{max} is the maximum load at failure (KN), L is the span (mm); b and h are the width and thickness of the specimen (mm) respectively.

2.2.6 Tensile test procedure

The tensile test was carried out on the material to determine its strength and ductility. The tensile test was performed on INSTRON 1195 testing machine at Kwara State University, Ilorin. This test was conducted by loading the specimen into a universal testing machine that can apply a load to the specimen at a specific rate. The specimen was axially loaded in tension; the distance between the gauge marks was monitored. The specimen was elongated by the moving crosshead, load cell and extensometer measured the magnitude of the load and the elongation.

$$UTS = UTL/A\ (N/mm^2) \quad (4)$$

Where, UTS - ultimate tensile strength
UTL – Ultimate tensile load
A – Cross-sectional area of the specimen.

2.2.7 Water absorption test procedure

This test was done at Standards Organization of Nigeria, Enugu. The composite samples were ovum dried at 60ºC for 2 hours, weighed and immersed in distilled water at room temperature. The water absorption was determined by weighing the samples at regular intervals of twenty-four hours for five days i.e. one hundred and twenty hours. The specimens were periodically taken out of the water, wiped with tissue paper to remove surface water and weighed. Two specimens each for the coarse and fine particles un-carbonized composite samples were used. A digital scale-precisa XB6200D was used to weigh the samples.

The percentage of water absorption, % W_a was calculated by:

$$\%\ Wa = \frac{W1 - W2\ x\ 100\%}{W1} \quad (5)$$

Where W_a is percentage of water absorbed after one hundred and twenty hours; W_1 and W_2 are original dry weight and weight after exposure i.e. after one hundred and twenty hours respectively.

2.2.8 Microstructure test procedure

The microstructure of the produced composites was studied using a Phenom ProX Scanning Electron Microscope. The sample was placed on sample holder and the images were captured under various magnifications. Prior to it, sample was applied with the gold coating to avoid charge effect, so to obtain clear images. The SEM was operated at an accelerating voltage of 5kV to 20 k.

3. Results and Discussions

3.1 Particle Size Analysis Result

Table 1*:* Particle Sizes Analysis Result

Grade	ASTM Number	Sieve Size
Coarse	12	1.70mm
Fine	40	425micron

Two particle sizes of 1.70mm referred to coarse particle corresponding to ASTM No 12 and 425 µm referred to fine particle corresponding to ASTM No 40 of the ground coconut shell particles as shown in Table 1 were collected at

designated sieve numbers after sieving and were used to Reinforce the virgin unsaturated polyester resin to develop the composite samples.

3.2 Chemical analysis result

Table 2: XRF Analysis Result of coconut shell

Oxides of Element	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	Na_2O	SiO_2	MnO	ZnO
%	15.48	0.67	14.4	0.49	17.02	0.65	43.11	0.52	0.37

Table 3: Proximate Analysis Result (Wt %)

	Fixed Carbon	Volatile Matter	Ash	Moisture
Un-carbonized coconut shell	18.23	73.92	2.55	5.3

Silicon dioxide, iron oxide and alumina are known to be among the hardest substances. The presence of these hard elements like SiO_2, Al_2O_3 and Fe_2O_3 (Table 2) explains the hard nature of coconut shell. This suggests that coconut shell can be used as particulate reinforcement in a polymer matrix. Also, the fixed carbon content of the un-carbonized coconut shell is as can be seen in Table 3. It shows that coconut shell in the un-carbonized state contains mainly volatile matter with a fixed carbon of about 18.23%. Also, lignin and cellulose which contain most of the polar hydroxyl (OH) group in coconut shell are contained in the volatile matter. This makes uncarbonized coconut shell prone to water absorption.

Table 4: Density of uncarbonized coconut shell particle reinforced composite

Wt. % of particulate	Sample code	Density Value g/cm^3	Sample code	Density Value g/cm^3
0%	Control	1.367	Control	1.367
10%	UFS	1.253	UCS	1.288
20%	UFS	1.246	UCS	1.285
30%	UFS	1.241	UCS	1.268

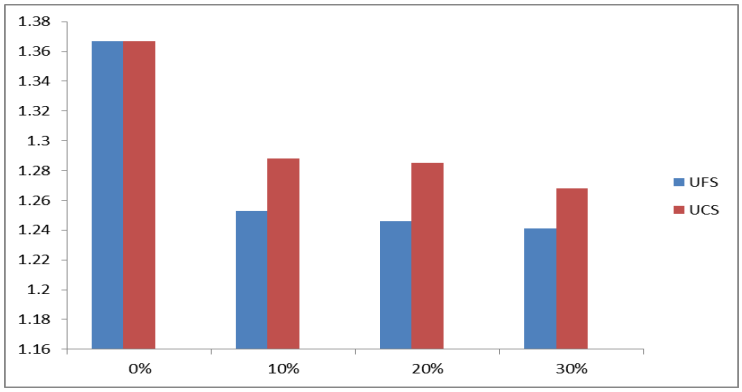

Fig 1: The effects of particle size on the density of fine and coarse uncarbonized coconut shell coarse particle reinforced

3.3 Density

The unreinforced polyester had the highest density value of 1.367g/cm^3 as can be seen in Table 4. The density of the composites decreased as the quantity of the reinforcement increased for the uncarbonized fine and coarse coconut shell particles reinforced composite samples as illustrated by Figure 1. The coarse coconut shell particle reinforced composite samples had the highest density values of 1.288g/cm^3 at 10wt. % for while the fine coconut shell particle reinforced composite sample had the lowest density value of 1.241g/cm^3 at 30wt. %. The observed decrease in density with increase in weight percent of the reinforcement may be attributed to the light weight of coconut shell particles.

3.4 Flexural Test Result

Table 5: Flexural Test Results of uncarbonized coconut shell composite samples

Weight % of Particulate	Sample Designation	Flexural force	Flexural Strength	Sample Designation	Flexural force	Flexural Strength
0%	Control	2.148	39.371	Control	2.148	39.371
10%	UFS	3.905	71.590	UCS	0.663	12.146
20%	UFS	4.440	81.400	UCS	3.210	58.850
30%	UFS	3.690	67.650	UCS	3.205	58.758

Wt. % filler content

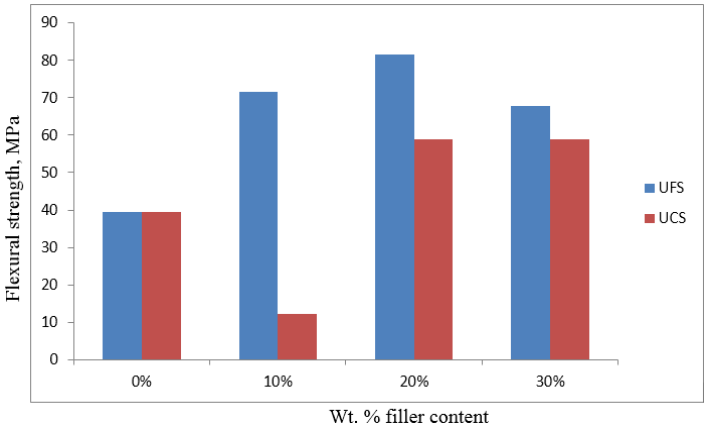

Fig 2: The effects of particle size on flexural strength of uncarbonized coconut shell coarse and fine particle reinforced unsaturated polyester composite

As could be observed in Figure. 2, the flexural strength of the composite increased with increase in reinforcement content at 10wt. % for the fine particle coconut shell reinforced composite sample. At 20wt. %, uncarbonized fine coconut shell particle reinforced composite sample had a higher increase in flexural strength than any other sample and exhibited the maximum flexural strength of 81.4MPa (Table 5). This may be attributed to further reduction in particle size.

At 30wt. % reinforcement, the flexural strength decreased which may likely be as a result of poor distribution and agglomeration of the reinforcement within the matrix. At 10wt. %, the coarse coconut particle reinforced composite showed a decrease in flexural strength and may be due to insufficient reinforcement in the matrix and reduced surface area of the reinforcement.

3.5 Tensile test result

Table 6: Tensile Test Results of Uncarbonized Composite Samples

Weight % of Particulate	Designation of Sample	Ultimate tensile strength MPa	Designation of Sample	Ultimate tensile strength MPa
0%	Control	18.58	Control	18.58
10%	UFS	8.21	UCS	9.57
20%	UFS	10.65	UCS	5.90
30%	UFS	5.66	UCS	7.70

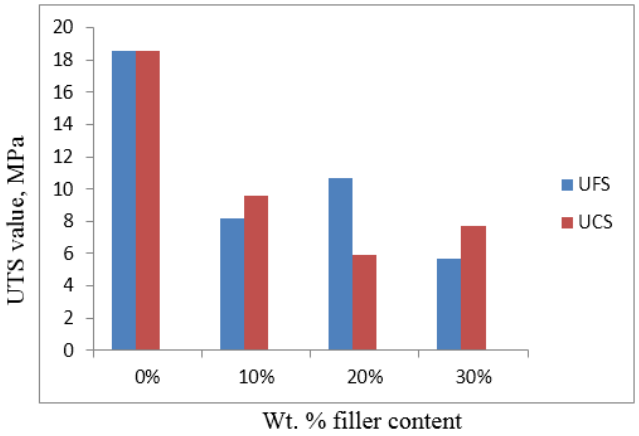

Fig 3: The effects of particle size on ultimate tensile strength of uncarbonized coconut shell coarse and fine particle reinforced unsaturated polyester composite.

Although, the ultimate tensile strength of the reinforced composites are lower than the unreinforced sample, however, it can be seen from Figure 3 that the tensile strength values of the composites generally increased with increase in weight percent of the coconut shell particles within the matrix of the composite. The tensile strength increased with increase in filler content reaching a maximum tensile strength value of 10.65MPa for the uncarbonized fine coconut shell particle reinforced sample at 20wt. % but declined on further filler addition This agrees with the findings of Teipel, 2011, where CS addition produced an initial increase in tensile strength of the composites up till 40 % of CS before it declined with further addition of CS as was reported in (Adeosun *et al.* 2015), Thermo-Mechanical Properties of Unsaturated Polyester Reinforced with Coconut and Snail Shells. The lignin content in coconut shell particles consist of polar hydroxyl groups, benzene rings and non-polar hydrocarbon which is capable of enhancing the adhesion between the reinforcement and the matrix as was observed by Salmah *et al.* 2013. In addition, this increase in tensile strength could equally be attributed to increase in surface area, good distribution and dispersion of the reinforcement in the matrix and this is in line with the work of (Durowaye *et al.* 2014) and **(**Singh *et al.* 2013) in their works Mechanical Properties of Particulate Coconut Shell and Palm Fruit Polyester Composites and Study of mechanical properties and absorption behavior of coconut shell powder-epoxy composites respectively. The coarse uncarbonized coconut shell particle reinforced composite sample had a maximum ultimate tensile strength of 9.57MPa at 10wt. % and decreased afterwards with increase in reinforcement reaching a lowest tensile strength value of 5.9MPa at 20wt. %. The observed decrease in ultimate tensile strength value may be due to poor distribution and dispersion within the matrix.

3.6 Scan Electron Microscope (SEM) Result

Fig 4: SEM Micrograph of reinforced polyester composite. (a) Unreinforced polyester resin (b) 10% uncarbonized fine coconut shell particles (c) 30wt. % uncarbonized coarse coconut shell particle. International Journal of Research in Advanced Engineering and Technology

Figure 4a represents the micrograph of the unreinforced polyester composite. Figures 4b and 4c show the distribution of fine and coarse uncarbonized coconut shell particle reinforcement within the polyester matrix at 10wt. % and 30wt. % respectively. Both figures 4b and 4c show some detachment of filler from matrix and may be attributed to insufficient bonding between the matrix and coconut shell particles and as a result, less adhesion occurred between them. This led to observed decrease in homogeneity between the coconut shell particles and the matrix with increase in the coconut shell particles (Figure 4c). This explains the decrease in tensile strength with increase in the coconut shell particles Content within the matrix structure of the composite.

3.7 Water absorption result analysis

Table 7: Result of water absorption of coarse coconut shell/ polyester composite

Weight % of Particulate	Sample Designation	Initial mass (g)	Mass after 24hrs (g)	Mass after 48hrs (g)	Mass after 72hrs (g)	Mass after 96hrs (g)	Final Mass after 120hrs (g)	Water Absorption (%)
10%	UCS	40.5	40.6	40.7	40.9	41.2	41.3	1.973
20%	UCS	37.10	37.30	37.50	37.60	37.80	37.90	2.156
30%	UCS	45.00	45.20	45.40	45.60	45.50	46.0	2.22

Table 8: Result of water absorption of fine coconut shell/ polyester composite

Weight % of Particulate	Sample Designation	Initial mass (g)	Mass after 24hrs (g)	Mass after 48hrs (g)	Mass after 72hrs (g)	Mass after 96hrs (g)	Final Mass after 120hrs (g)	Water Absorption (%)
10%	UFS	43.20	43.42	43.68	43.90	44.00	44.08	2.04
20%	UFS	68.00	68.50	68.93	69.15	69.33	69.50	2.20
30%	UFS	35.30	35.70	35.85	35.98	36.11	36.15	2.40

Wt. % filler content

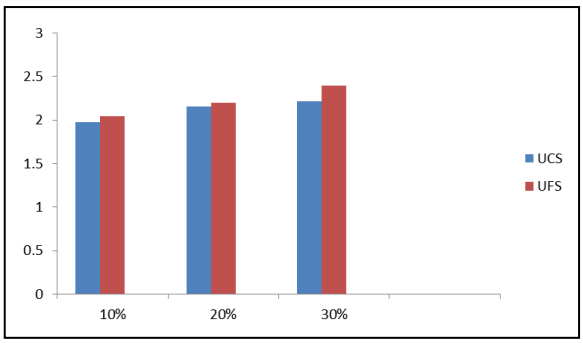

Fig 5: The effects of particle size on water absorption behavior of uncarbonized coarse and fine particle coconut shell reinforced unsaturated polyester composite.

The water absorption of the composites showed a similar pattern where initial sharp water absorption uptake was followed by a gradual increase for the length of time of immersion in water. From the water absorption Figure 5, maximum water absorption occurred in the 30wt. % uncarbonized fine coconut shell particle at 2.40% while minimum water absorption was observed in the 10wt% uncarbonized coarse coconut shell particle composite sample at 1.973%. This may be due to presence of the polar hydroxyl group (OH) in the cell wall of the uncarbonized coconut shell. The polar hydroxyl group is responsible for water absorption in coconut shell. The more water absorbed by the fine coconut shell composite sample may be likened to increased surface area of the coconut shell particle.

4. Conclusion

The effect of uncarbonized coconut shell particles reinforced polyester composite has been studied and the following conclusions drawn.

1. 1The 30wt% uncarbonized fine size coconut shell reinforced composite sample absorbed more water while the 10wt% uncarbonized coarse particle size coconut shell composite sample absorbed the least quantity of water.
2. Flexural and ultimate tensile strengths are very sensitive to particle size such that they increased with increase in particulate content but decreased with increase in particle size
3. Although, the density showed insensitivity to particle size however, it decreased with increase in particle content.

5. References

1. Aigbodion VS, Hassan SB, Ause T. Nyior GB Potential Utilization of Solid Waste (Bagasse Ash), Journal of Minerals & Materials Characterization & Engineering, 2010; 9(1):67-77.
2. Bhaskar J, Singh VK, Physical, Mechanical Properties of Coconut Shell Particle Reinforced-Epoxy Composite", J. Mater. Environ. Sci. 2013; 4(2):227-232.
3. Bienia J, Walczak M, Surowska, B, Sobczaka J Microstructure and corrosion behavior of aluminum fly ash composites, Journal of Optoelectronics and Advanced Materials, 2003; 5(2),493-502.
4. Biro Penyelidikan Dan Perundingan, 'coconut shell and its ash as a replacement of aggregate or cement in producing concrete and particleboard'Universiti Teknologi Mara 40450 Shah Alam, Selangor Malaysia. 2002.
5. Durowaye SI, Lawal GI, Akande MA, Durowaye VO, "Mechanical Properties of Particulate Coconut Shell and Palm Fruit Polyester Composites", International Journal of Materials Engineering 2014; 4(4):141-147.
6. Hamidah mohd, saman, Madya, Azmi Ibrahim, Rohana Hassan, Coconut Shell and its Ash as a Replacement of Aggregate or Cement in Producing Concrete and Particleboard, Universiti Teknologi Mara 40450 Shah Alam, Selangor, Malaysia, 2002.
7. Husseinsyah S, Mostapha M, the Effect of Filler Content on Properties of Coconut Shell Filled Polyester Composites," Malasian Polymer Journal. 2011; 6(1)87-97.
8. Sapuan M. Harimi M, Mechanical Properties of Epoxy/Coconut Shell Filler Particle Composites the Arabian Journal for Science and Engineering 2003; 28, 2B, 171-181.
9. Mariana Etcheverry and Silvia E. Barbosa Glass Fiber Reinforced Polypropylene Mechanical Properties Enhancement by Adhesion Improvement. Materials 2012, 5. 1084-1113.ISSN:1996-1944.www.mdpi.com/journal/materials.
10. Monteiro SN, Terrones LAH, D'Almei JRM. "Mechanical Performance of Coir Fiber/Polyester Composites," Polymer Testing, 2008; 27(5):591-595. doi:10.1016/j.polymertesting. 2008.03.003.
11. Odewale JO, Odiowaya G, Agho Collins, Enaberue L. Okoye MN, 'Relationship between Canopy Sizes and Shapes and the Productivity and Yield of Coconut (Cocos nucifera L.) Varieties in Nigeria', Greener Journal of Agricultural Sciences ISSN: 2012; 2(8):2276-7770. 378-380.
12. Olumuyiwa J, Agunsoye Talabi, Isaac S, Sanni O, Samuel, "Study of Mechanical Behaviour of Coconut Shell Reinforced Polymer Matrix Composite" Journal of Minerals and Materials Characterization and Engineering, 2012; 11:774-779.
13. Adeosun SSO, Akpan EIO, Akanegbu HA. Thermo-Mechanical Properties of Unsaturated Polyester Reinforced with Coconut and Snail Shells International Journal of Composite Materials 2015; 5(3):52-64.
14. Salmah H, Marliza M, Teh PL. Treated Coconut Shell Reinforced Unsaturated Polyester Composites .International Journalof Engineering & Sciences.http://www.ijens.org/Vol_13_I_02/1310202-8383-IJET-IJENS.pdf.
15. Sarki JSB. Hassan VS, Aigbodion JE, Oghenevwetaa, 2010, "Potential of Using Coconut Shell Parti-cle Fillers in Eco-Composite Materials," Journal of Alloys and Compounds, 2011; 509(5):2381-2385. doi:10.1016/j.jallcom.2010.11.025.
16. Teipel EG. Polymeric Composites Reinforced with CSP: Coconut Shell Powder Technology, Young Persons' World Lecture Competition (YPWLC) 2011.
17. Vinay K Singh. Jitendra Bhaskar. 2013 "Water Absorption and Compressive Properties of Coconut Shell Particle Reinforced-Epoxy Composite", J. Mater. Environ. Sci. 2013; 4(1):113-118. ISSN: 2028-2508CODEN: JMESCN.
18. W. Wang and G. Huang, Characterization and Utilization of Natural Coconut Fibers Composites, Materials & Design. 2009; 30(7):2741-2744.