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EFFECT OF WEIGHT PERCENTAGE ON PHYSICAL AND MECHANICAL PROPERTIES OF COCONUT SHELL REINFORCED POLYMER COMPOSITE

K. A. Zakaria[1], V. T. Singh[1], M. B. Ali[2], M. A. Yusuff[1], R. Adnan[1] and A. M. T. Ariffin[3]
[1]Fakulti Teknologi Dan Kejuruteraan Mekanikal, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, Durian Tunggal, Melaka, Malaysia
[2]Fakulti Teknologi Dan Kejuruteraan Industri dan Pembuatan, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, Durian Tunggal, Melaka, Malaysia
[3]Fakulti Kejuruteraan Mekanikal dan Pembuatan, Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, Johor, Malaysia
Email: kamarul@utem.edu.my

ABSTRACT

The utilization of natural fibers in composites has been increasing and developed to save the environment by using biodegradable materials. Synthetic fiber has many disadvantages than natural fiber such as lower mechanical properties, high cost, and higher environmental risk. Therefore, this study aims to develop natural fiber composites that are reinforced with coconut shell waste and study the effect of weight percentage (wt%) on their physical and mechanical properties. Testing samples were produced from coconut shell reinforced and polyester resin matrix. Coconut shell powder with a particle size of 500 μm and below is randomly distributed into polyster resin matrix. The coconut shell wt% varies from 10% to 30%. The physical and mechanical properties of the composite are determined by collecting data from the density test, hardness test, and tensile test performed based on ASTM standards. The finding results showed that the physical and mechanical properties of coconut shell reinforced polymer composite are influenced significantly by the wt% of coconut shell. The maximum tensile strength was achieved at 15% wt% of the coconut shell.

Keywords: coconut shell, composites, mechanical properties, natural fibers, polymer.

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INTRODUCTION

The studies in natural fibers have increased insignificantly around the globe. Coconut shell is an organic natural plant fiber that is widely found nowadays in many industries such as building structures, furniture, and packaging [1]. Natural fiber is also a renewable source that can be extracted from leaves, seeds, and grass. Coconut also has unlimited availability in many countries, it can be found abundantly in many countries such as India, Thailand, Indonesia, Malaysia, Sri Lanka, and also Bangladesh. Lately, there has been an escalation of interest and demand for natural fibers in many industries. The renewability of the biodegradable bio-composite makes it a highly interesting attribute. The increase in environmental awareness and consciousness raises the interest in using natural fibre as reinforcement in composites. Environmental friendliness and low cost production are among the most highlighted advantages offered by natural fibres [2-5]. It is also known that natural fibers show better mechanical properties compared to conventional synthetic fibres [6].

Other natural fibres are additionally frequently utilized as reinforcements. For example, jute, hemp, and flax are commonly utilized as reinforcing materials in composites. The composite can be relegated as a thermosetting or thermoplastic polymer to compose a composite that has propitious properties like low energy engendered, biodegradable, and low manufacturing hazard [7]. However, composite with natural fiber consists of intrinsic vigor that this potential can be enforced in many sectors and industries as long as we understand to analyse the mechanical deportment.

Composite materials are defined as materials that consist of a combination of two or more materials that result in better properties than those of the individual components used alone [8-9]. Composite consists of a discontinuous phase, which is additionally kenned as reinforcing material, and a perpetual phase, which is kenned as a matrix. The parameters of a composite such as shape, size, and size distribution of reinforcement are consequential in determining the mechanical properties of the composite [10]. Anteriorly, ceramics, metals, and plastics control the composite industry. The high ebullience to supersede metals in the industry is due to attribute that is light, vigorous, and corrosion resistant. The cull of matrix and reinforcing material of a composite must be opportune cumulation to engender efficient composite.

Conventional synthetic fibers that are utilized these days have few disadvantages. Utilizing lignocellulose fibers provides a more salubrious working environment than synthetic fibers. The glass fiber dust from the trimming and mounting of glass fiber components causes skin vexation and respiratory diseases among workers. For example, there was some evidence of an ‘asbestos type’ condition arising from handling fiber [11]. As an alternative to conventional reinforcing fiber, lignocellulosic natural fiber is utilized since it is costefficacious and environmentally cordial through the utilization of natural fillers or reinforcement in polymer composite [12].

Coconut shell is additionally incrementing in agro waste. This designates that coconut shells will be discarded after it was utilized in agriculture. Therefore, this study's aim to fabricate a sample set of composites is consequential to analyze the mechanical properties using coconut shells as an agro waste, which is to ensure a healthy environment by using agro waste in composite in the future. In this study, the powder particle size is 500 µm and below which is randomly distributed, and coconut shell concentration varies from 10% to 30% in the polyester matrix. The characterization of the composites is determined by collecting data from the density test, hardness test, and tensile. It is expected that the physical and mechanical properties of this composite are influenced significantly by the coconut shell contents. The results finding is indispensable for the future development of composites that will be utilized in the future in many fields such as building materials, furniture, and other household appliances.

METHODOLOGY

The raw materials used for the fabrication of the composites are coconut shell, unsaturated polyester, and hardener. In this study, coconut shell powder particles with a size of 500 µm and below were randomly distributed in polyster resin matrix. The weight percentage (wt%) of coconut shells used in the study varies by 10%, 15%, 20%, 25%, and 30% as shown in Table-1, to determine their optimum mechanical properties.

Table-1. Composition of coconut shell and polyster.

	wt% of the coconut shell				
Element	**10%**	**15%**	**20%**	**25%**	**30%**
Coconut (g) shell	2.66 g	3.99 g	5.32 g	6.65 g	7.98
Polyester (g) resin	23.95 g	22.61 g	21.29 g	19.96 g	18.63

The coconut shell was broken with a hammer to remove coconut milk and flesh inside the shell. After removing the coir, coconut milk, and flesh from the coconut shell, rinse the coconut shell and leave it to dry. Next, rinse the crushed coconut shell with distilled water to remove dust and foreign particles. The crushed coconut shell was then dried at room temperature for 24 hours. The crushed coconut shell was ground by using the crushing machine to produce tiny coconut shell pieces as shown in Figure-1. The crushed coconut shell was then sieved using a Vibratory Shaker Machine with 0.7mm amplitude to separate larger coconut shell tiny pieces from the powder size less than 500µm as shown in Figure-2.

Figure-1. Pieces of tiny coconut shells.

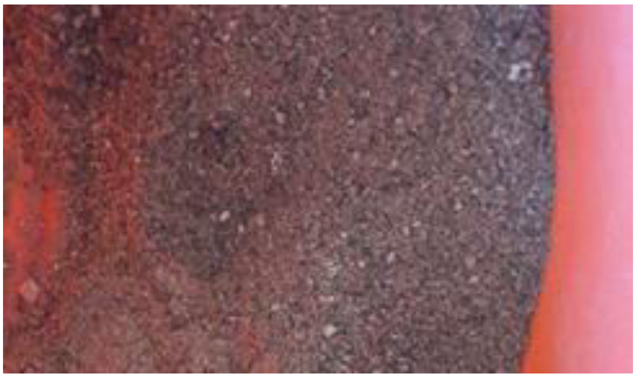


Figure-2. Coconut shell powder after sieved.

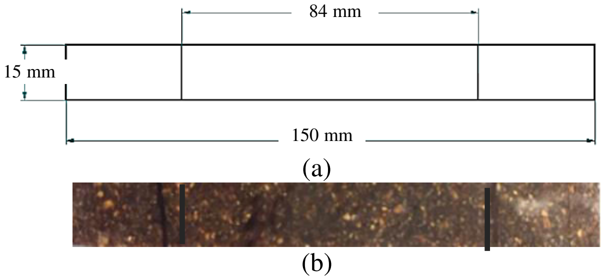
The coconut shell powder is then mixed with polyester resin after measuring the mass of each constituents in the composite until it is homogeneously mixed. The mixed polyester and powder are stirred well for at least 10 minutes to allow the polymerization reaction to be initiated at 250 rpm using a stirrer machine. Then the hardener is added to the mixture which acts as a catalyst. The mixture with catalyst is poured into a mold and left to harden for about 1 hour to produce the composite plate as shown in Figure-3.

Figure-3. Coconut shell-reinforced polymer composite plate.

The density test was performed to determine the specific gravity of the composite using Electronic Densimeter MD-300S. In the testing, the mass of the composite specimen was measured and put into the liquid medium. The composite surface hardness was measured analogue Shore scale “D” type Durometer CV-DSA 001 TM based on ASTM D2240. The surface hardness was measured at six points on the composite surface and then averaged for each sample.

The tensile strength can be expressed as the ability of a composite material to withstand forces that pull it apart as well as the capability of the material to stretch before failure [13]. The tensile tests were performed to determine the mechanical properties of the composite material such as tensile strength and modulus of elasticity [14]. The tensile test was performed according to the ASTM D3039. The specimens were cut to meet the specifications of 150 mm length, 15 mm width, and 3 mm thickness as shown in

Figure-4 the test is conducted using a Universal Testing Machine, Model Instron 8872 with a maximum load capacity of 25 kN as shown in Figure-5. The crosshead speed was set at 2.0 mm/min. While the testing was conducted, the uni-axial load was enforced through both ends of the specimen to produce the tensile properties of the specimens.



(a)

(b)

Figure-4. Tensile test specimen dimensions, (a) as per ASTM 3039 and (b) coconut shell reinforced polymer composite.

Figure-5. Universal Tensile Testing Machine with a load capacity of 25 kN.

RESULTS AND DISCUSSIONS

Table-2 shows the coconut shell reinforced polymer composite density with different wt%. It can be observed that the density of the composites decreases slightly as the wt% of coconut shell increases. Recorded data showed that the density of composite decreased a total of 0.58 % when the coconut shell wt% increased from 10% to 30%. This density increase can be related to the fact that the coconut powder particles are light in weight but occupy a substantial amount of space. Particles are not closely bonded to each other due to the open mould casting method. The weight ratio over composite volume is decreased as the coconut shell increases. A similar result is obtained from previous studies performed by Agunsosoye [15].

Table-2. Composite density with different wt% of coconut shell.

Weight %	wt% of coconut shell				
	10%	15%	20%	25%	30%
Density (g/cm^3)	1.201 g	1.200 g	1.198 g	1.195 g	1.194 g

The surface hardness was measured at six points on the composite surface and then averaged for each sample. Figure-6 shows the graph of average surface hardness values of composite obtained from the durometer gauge for each wt% coconut shell. The graph trend shows that average hardness increases gradually as the weight fraction of coconut shells increases. The average hardness is 67.5 at 10 % compared to 86.0 at 30% wt% of coconut shell. This indicated that the average surface hardness of the composite was increased by 21.51% as the wt% of coconut shell increased from 10% to 30%. This shows an increase of the hardness of composite 21.51 % from 10% to 30% weight percentage of filler. A similar trend of increase in hardness of the composites with coconut shell content has also been reported by Geetanjali [16].

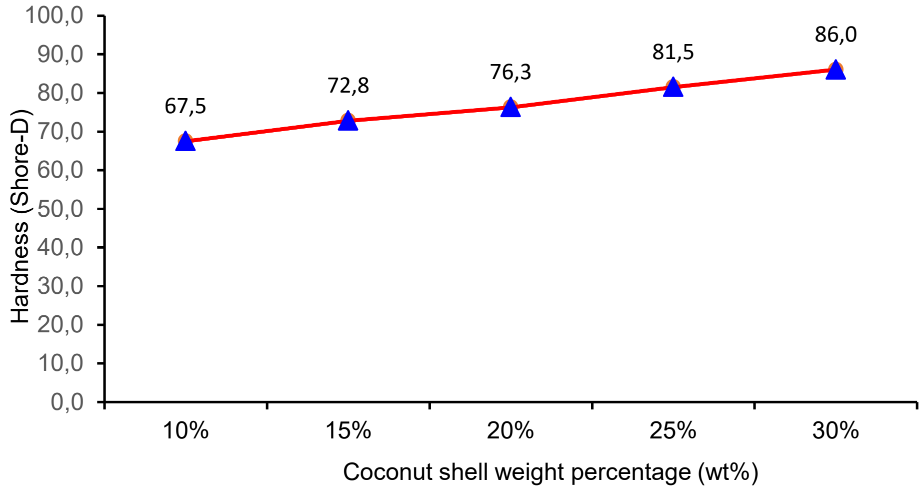


Figure-6. Average surface hardness of composite with different wt% of coconut shell.

Tensile tests were performed to provide information on the mechanical properties in terms of the strength and ductility of the materials under uniaxial loading. These properties were useful for determining the characteristics of materials, alloy development, and design under certain circumstances [17]. Figure-7 shows the typical stress–strain curve of composite samples for different wt% of coconut shells. The plotted stress-strain curve showed that the tensile stress increases gradually with tensile strain before sudden breaks. The sudden break of the composite specimen at the maximum load indicates brittle fracture occurred on the composite specimens.

The maximum tensile strength of the composite obtained from tensile tests was plotted on the graph shown in Figure 8. The tensile strength varies from 13.7 MPa to 18.3 MPa for different weight composition of the coconut shell. Tensile strength increased by about 15.9% which is from 15.432 MPa to 18.352 MPa when the wt% of coconut shells increased from 10% to 15%. This increment can be obtained from the increase in surface area, good distribution, and dispersion of the reinforcement in the matrix that results in a greater ability to restrain deformation [18]. When the wt% of coconut shell further increased from 15% to 30%, the tensile strength was about 25.5%, which is from 18.3 MPa to 13.7 MPa. The reduction of tensile strength may be caused by poor adhesion of filler within the matrix and poor dispersion [12]. The result exhibits that 15% filler content produced the best tensile strength performance of coconut shell-reinforced polymer composites to withstand the load.

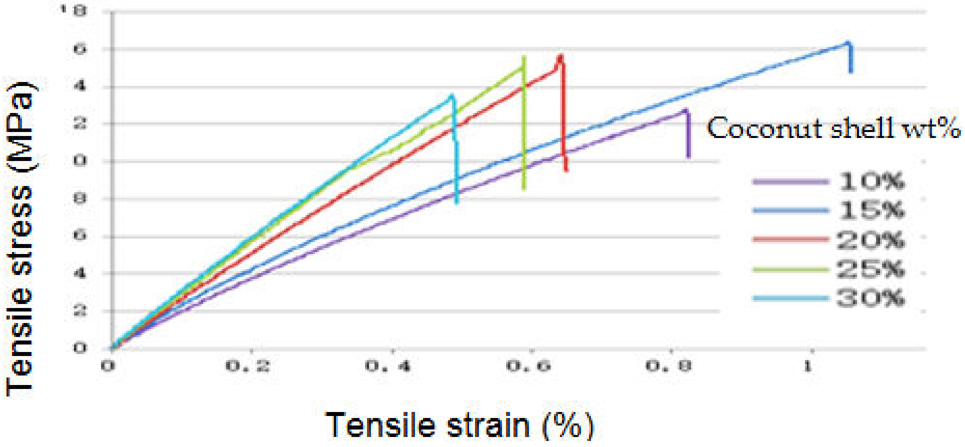


Figure-7. Typical stress-strain curve of coconut shell reinforced polymer composites.

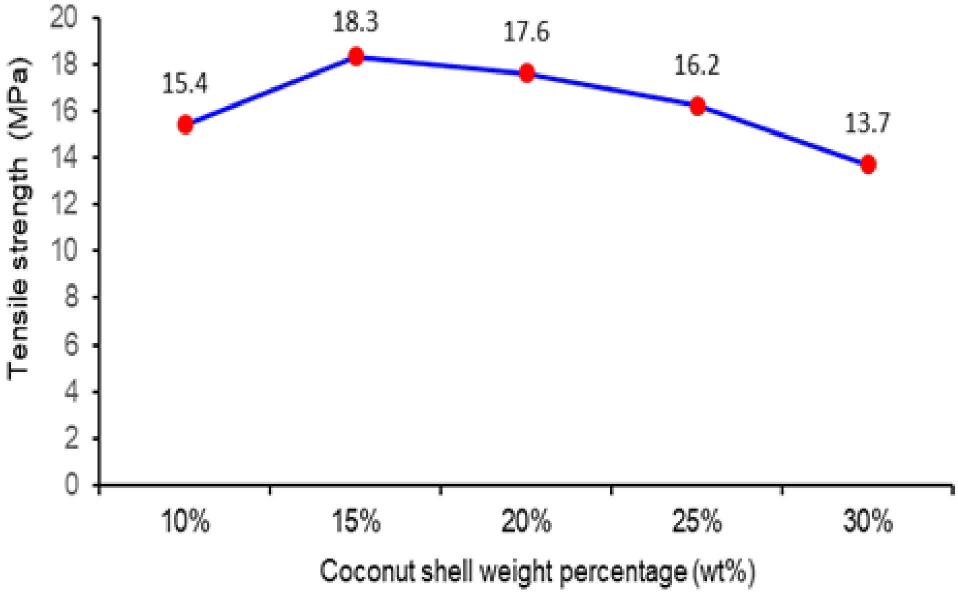


Figure-8. Tensile strength of composite with different wt% of coconut shell.

Figure-9 shows the effect of increasing the wt% of coconut shell on the modulus elasticity. The modulus elasticity increased linearly with the wt% of the coconut shell. The magnitude of modulus elasticity is 2.7 GPa at 10% compared to 3.9 GPa at 30% weight fraction of the coconut shell. The increase is about 33.3%. The increment weight percentage of the coconut shell is the incorporation of filler restrains the motion of the matrix phase in the proximity of each particle which consequently contributes to the enhancement in modulus and stiffness [12].

Figure-10 shows the effect of increasing the wt% of coconut shell to the extension at break. The extension at break varies from 0.28 mm to 0.62 mm for different weight compositions of the coconut shell. Extension at break increased about 6.5% which is from 0.62 mm to 0.66 mm when the wt% of coconut shell increased from 10% to 15%. Then, the extension at break decreased 57.6% which was from 0.66 mm to 0.28 mm when the coconut shell wt% increased from 15% to 30%. This is due to lower elastic behavior for the coconut shell reinforced polymer composites above the 15 % wt%. The lower elasticity nature of the coconut shell reinforced results in lower extension at the break as the coconut shell weight content increases within the composite.

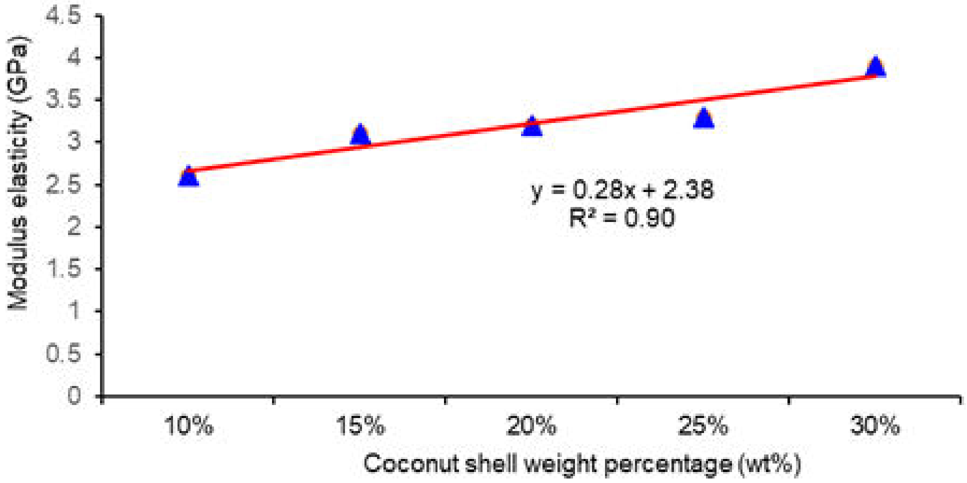


Figure-9. Effects of coconut shell wt% to Modulus of elasticity.

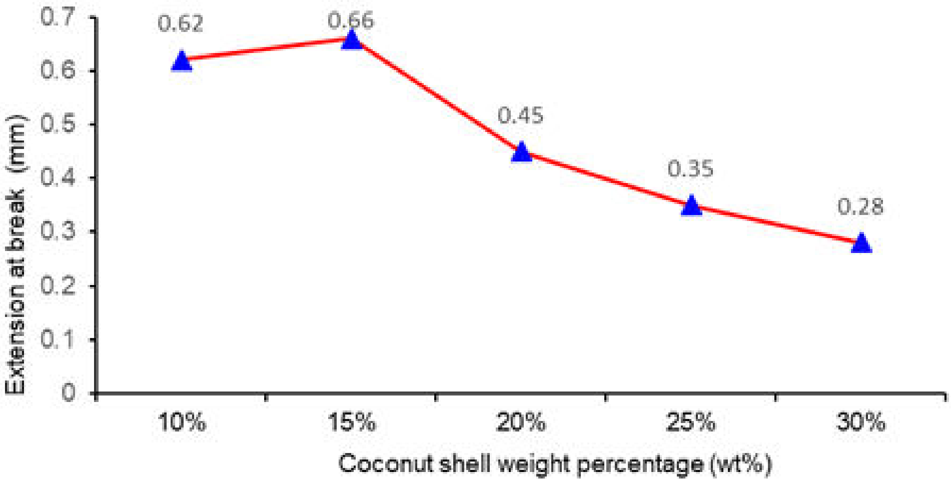


Figure-10. Effects of coconut shell wt% to extension at the break.

CONCLUSIONS

In this study, the natural fibers composite is successfully developed from the coconut shell, which can be used as an alternative material to synthetic composites. The composite material from coconut shell waste is a biodegradable material that can contribute to a better environment. Experimental results showed that the physical and mechanical properties of this composite are influenced significantly by the wt% of the coconut shell. Higher wt% of coconut shell produced lower density and higher surface hardness. The tensile strength increased with coconut shell wt% (up to 15% weight fraction). Beyond that, the tensile strength gradually reduced. Therefore, the best wt% of coconut shell for this composite specimen is 15%. The findings and results obtained from this study can be used as a reference for the application of coconut shell-reinforced polymer composites and further improvement in the future.

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