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STUDY OF THE MECHANICAL PROPERTIES OF POLYESTER/COCONUT SHELL /WOOD DUST PARTICLES HYBRID COMPOSITE

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ABSTRACT

This research developed two hybrid composites consisting of unsaturated polyester resin (UPR) as matrix and different weight fractions (0 to 25wt %) at 5 wt% interval, of both fresh and ashed coconut shell and wood dust particles as fillers. The fresh and ashed (having sieve sizes of 300µm) fillers reinforced polyester hybrid composites were prepared using hand layup method and subjected to a number of tests; physical (density) and mechanical (tensile, flexural, hardness test, impact tests). It was observed that tensile strength decreased with filler loading with peak value at 5 wt% composition. Percentage elongation and flexural strength decreased with fillers content. The fresh filler reinforced samples have maximum value of percentage elongation and flexural strength of 18% and 86 N/mm^2 respectively at 5wt% composition. On the hand, unsaturated Polyester Resin (UPR) recorded 19% and 68 N/mm^2 for the respective percentage elongation and flexural strength. Young's modulus Modulus of elasticity followed a regular trend of increase with filler contents reaching peak at 25 wt% additions. The results further revealed that with increase in fillers additions, agradual rise gradualrise in hardness accompanied with a significant improvement in impactenergy except at 20 and 25 wt% addition was achieved.

Keywords: Polyesterresin, Hybrid composite, Coconut shell, Wood dust, Fillers

1.0 INTRODUCTION

In recent years, the interest in composite materials is increasing due to its advantages as compared to monolithic materials. Composites can be defined as engineered materials which exist as a combination of two or more materials that result in better properties than when the individual components are used alone (Chowdhury, 2010). Among the possible alternatives, the development of composites using agricultural residues (including stalks of most cereal crops, rice husks, coconut fibres, bagasse, maize cobs, peanut shells, and other wastes) is currently at the center of attention (Ashori and Nourbakhsh, 2010). Natural fibres, such as wood fibre, wheat straw, jute fibre and bagasse fibre have several benefits which include low cost, low density, high toughness, enhanced energy recovery and biodegradability (Zheng et al, 2007). A pressing issue in Nigeria today, is the recycling of waste products and other agricultural by-products suitable for the invention and characterization of new materials. Annually, approximately 33 billion coconuts are harvested worldwide with only 15% of its waste being utilized (Monteiro*et al*., 2008; Wang and Huang, 2009) which suggests the need to enhance the utilization of natural resources of these types. Natural lignocellulosics such as coconut shell powder (*cocosnucifera*) has outstanding potentials as reinforcement in plastics. Coconut shell is an important filler for the development of new composites as a result of its inherent properties such as high strength and high modulus (Sapuan and Harimi, 2003). The use of natural fibres in plastic matrices includes many benefits such as low volumetric cost, increase of heat deflection temperature, increase of stiffness of thermoplastics and improvement of surface appearance. According to scholars, natural fibers reinforced plastic composites have achieved applications in decking, furniture components, door mouldings, packing pallets and interior panels of automobiles (Zheng*et al*, 2007). Many researchers have been exploring the use of lignocellulosic fillers in place of synthetic fillers. *Sapuanet al., (2003)* studied the mechanical properties of epoxy/coconut*shell filler* particle composite. They concluded that the tensile and flexural strengths of the composites were affected by the amount of fillers in the composites. The more the filler content, the higher the strength. In tensile testing, filler composites demonstrated linear behaviour with sharp fracture whereas in flexural testing, filler composite demonstrates slightly nonlinear behaviour prior to sharp fracture. Michael *et al.*, (2012) studied the mechanical properties of hybrid periwinkle and rice husk filled Cashew nut seed liquid composite. They reported that the highest tensile and flexural strengths were obtained at 30wt% filler content and 400µm particle sizes, and the highest tensile modulus and impact strength were obtained at 800µm and 400µm particle sizes, respectively, for some percentage of filler content. The flexural strength from the result converges at 30wt% filler content. The present study focuses on the development of hybrid composites with unsaturated polyester resin (UPR) as matrix and fresh and ashedcoconut shell and wood dust as fillers.

2.0 MATERIALS AND METHODS

The materials used in this research include unsaturated polyester resin (UPR), cobaltnaphthenate as accelerator, Methyl Ethyl Ketone Peroxide (MEKP) as catalyst, coconut shell, wood dust, wooden mould and release agent.

The tensile specimens were prepared according to ASTM D 638 standard. Similarly, other properties of the prepared polyester composites were determined using ASTM standard methods as follow; Flexural strength ASTM D 790-97, Hardness ASTM D 2240, Impact strength ASTM D256.

2.1 Sample preparation

2.1.1 Wood dust

Wood dust used in this work was obtained from mahogany tree which was obtained from a local vendor in considerable amount in which part of it was converted to ash by packing it in a furnace and heating to 1000 ^{o}C and held for 3 hours. After the ashing process, it was then sieved to particle size of 300 µm-300 µmand stored for further process.

2.1.2 Coconut shell fresh and ash

The coconut shell used in this work was sourced locally at Samaru central market, Zaria, Kaduna State, Nigeria. The coconut shell was dried in open air and ground with the aid of a laboratory grinding mill in considerable amount in which part of it was ashed in line with the procedure of 2.1.1. The produced ash and the fresh coconut shell particles were then sieved to obtain300 µm-300 µm particle sizes.

2.1.3 Unsaturated polyester resin (UPR)

A clean disposable plastic container was placed on a sensitive electronic balance and the required amount of unsaturated polyester resin was poured. For 100 g of unsaturated Polyester resin, 0.5 g of cobalt naphthenate as accelerator and 2 g of Methyl Ethyl Ketone Peroxide (MEKP) as hardener were added and mixed until a homogeneous mixture was obtained using a fabricated stirring spoon. The mixture was thereafter poured into a wooden mould of specific dimensions of sample sizes to set. After the samples had set, they were removed from the mould and heated in the oven at 300 ^{o}C for 3 hours for curing to take place. These served as the control samples.

2.1.4 Hybrid composite fabrication

Two hybrid composites of polyester resin and both fresh and ashed coconut shell (CSP) as well as wood dust (WDP) particles were produced. The first hybrid composite produced was reinforced with a combination of fresh wood dust and coconut shell powders with unsaturated polyester resin as matrix while the second was reinforced with a combination of ashed wood dust and coconut shell particles with unsaturated polyester resin as matrix. The weight percentages of the fillers were regularly varied to study the effect of the reinforcement additions on the physical and mechanical properties of the composite. A mould release agent was thoroughly applied over the surface of the mould for easy removal of the polyester composite specimens. The catalyst hardener (methyl ethyl ketone peroxide) and the accelerator (cobalt naphthenate) were mixed with unsaturated polyester resin and stirred slowly. The fresh and ashed reinforcement of wood dust and coconut shell particles used for the fabrication of the two hybrid composites were taken in appropriate weight ratios and slowly poured in the polyester resin and the mixture was stirred to properly disperse them in the matrix. The gel like solution consisting of polyester resin with the WDP and CSP was then filled into a pre-cleaned mould. The polyester composite was left to set for few minutes in the mould. Subsequently, it was post cured in the oven for another 3 hoursat300 ^{o}Cafter removal from the mould. The weight percentages of the fillers were varied from 0 to 25 wt% (0, 5, 10, 15, 20 and 25 wt%). Equal amounts of WDP and CSP were added in order to achieve each filler additions. For example, in 5w% filler content, there is 2.5w% of WDP and 2.5wt% of CSP in each sample of both fresh and ash hybrid composite produced.

3.0 RESULTS AND DISCUSSION

Density

Figure 1 shows the relationship between the densities of the hybrid composites which increases with increase in fillerloadings for both fresh and ashed composite from 0%wt to 15%wt filler contents. This may be attributed to the increase in weights of the fillers due to higher density than unsaturated polyester (matrix). The density values of the fresh filler composites were higher than those of the ashed up to 25%wt content.

This increase is simply due to the fact that the ashed filler content had lost most of its mass to the ashing processes, in which over 70% of its weight was lost through the evolution of its volatile matter and this could also translate to abrupt decrease in density for the ashed filler reinforced polyester composites at 20 and 25wt%. The results obtained in this research are in line with the existing literature (Kandachar and Brouwer, 2002).

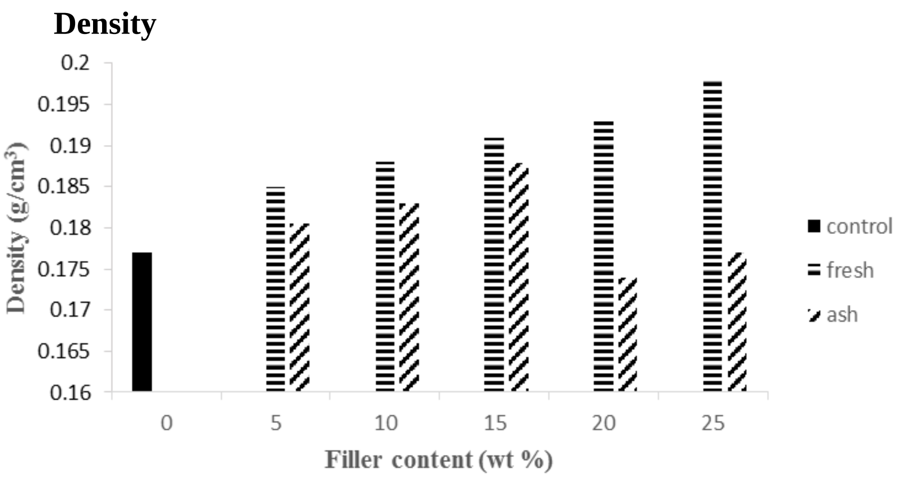

Figure 1: Variation of density with fresh and ashed filler contents (wt%)

Tensile Strength

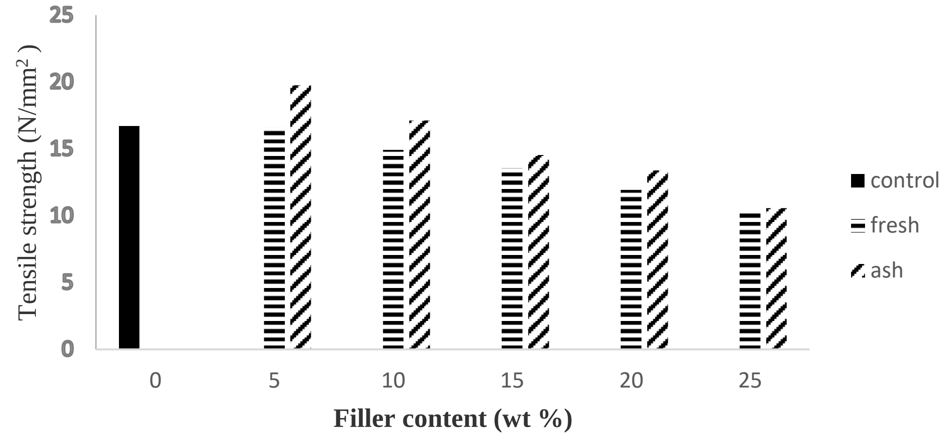

Figure 2: Variation of tensile strength with %wt of fresh and ashed hybrid composites

Young's modulus

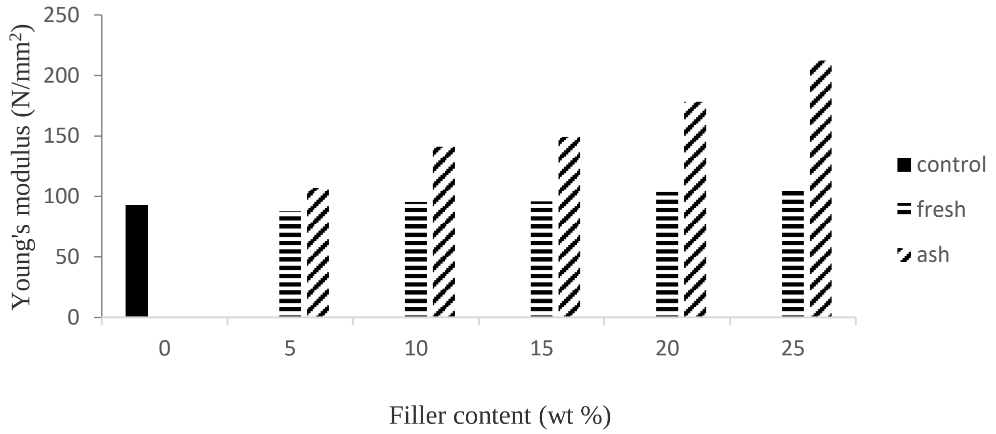

Figure 3: Variation of Young's modulus with %wt of fresh and ash hybrid composite

Percentage Elongation

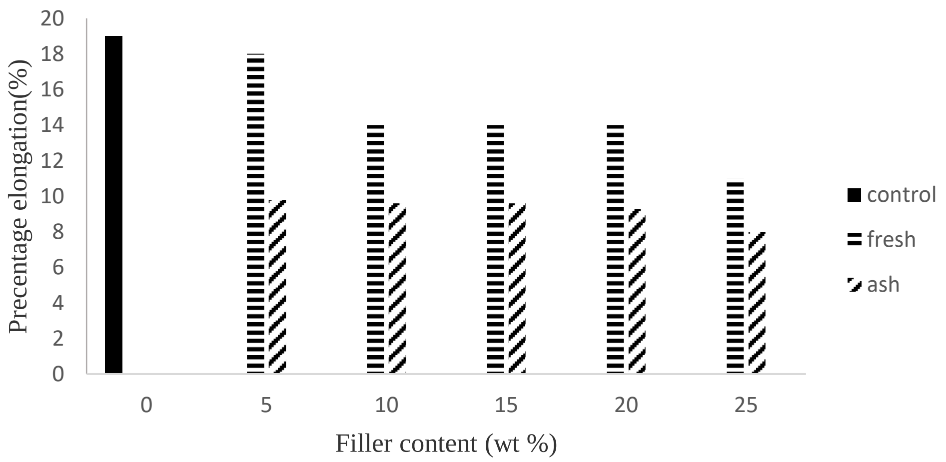

Figure 4: Variation of percentage elongation with %wt of fresh and ash hybrid composite

Figure 2presents variation of tensile strength with filler contents. For both fresh and ashed fillers, there is steady decrease in tensile strength as filler with loadings. Rosa *et al*., (2009)and Yang *et al*., (2007) reported reduction in the tensile strengths of composites as compared to the matrices but they remained within acceptable limits (Imoisili *et al*.,2012; Yang *et al*., 2004 and 2006). At 5 and 10% ash filler additions, the tensile strength of the hybrid increases considerably because the stress transferred by the matrix is effectively supported by the fillers. A similar trend was reported with coconut shell loading (Agunsoye*et al.,* 2012). Similarly, composites reinforced with ash fillers exhibit higher tensile strength than their fresh counterpart. Perhaps, the bonding between the ash fillers and the matrix is much stronger due to their small size fraction sand so offer stronger support to the matrix compared to fresh fillers.

Decrease in tensile strengths of lignocellulosic particle-filled composites is a general trend that have been reported by various investigators (Baek *et al*., 2013; Eze *et al*., 2013; Koutsomitopoulou*et al*., 2014) although some other reports have shown increase in tensile strengths with filler loading (Onuegbu and Igwe, 2011; Ojha *et al*., 2014).

Thamae *et al*., (2009); Ewulonu and Igwe (2011); Chun *et al*., (2012) and Viet *et al*., (2012) gave the reason for general decrease of tensile strength with filler loading for particle filled composites as probably due to the irregular shape exhibited by the fillers which may not be able to maximize the interfacial surface area and are rather poor in their ability to support the stress transfer from the matrix leading to weak bond between the flour and matrix which subsequently leads to reduction in tensile strength with filler loading. This is unlike the reinforcing fillers such as glass, carbon and Aramid fibres which confer improvement in mechanical properties of the resulting composites.

Figure 3 depicts the results of the Young's modulus of the fresh and ashed hybrid composites produced. As seen, there is an increase in the rigidity of the samples with filler loading within the matrix of the hybrid composites. Further, a significant increase in the Young's modulus is observed with ashed filler additions whereas the modulus of elasticity of the composites with fresh fillers experienced a modest improvement as the additions increases.

The results obtained are in agreement with findings of other researchers (Ibrahim *et al*., 2012; Imoisili *et al*., 2012; Fakhrul *et al*., 2013) that reported increase in modulus with filler loadings.

The general increase in Young's modulus with filler loading is commonly attributed to the inherent rigidity of fillers which exhibit higher stiffness than the polymer matrices (Rosa *et al*., 2009; Salmah *et al*., 2012; Eze *et al*., 2013).

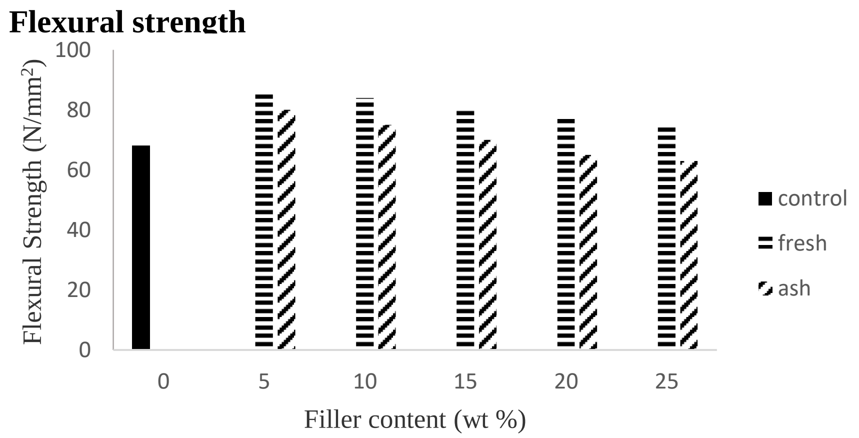

Figure 5: Variation of flexural strength with %wt of fresh and ash hybrid Composites

Hardness

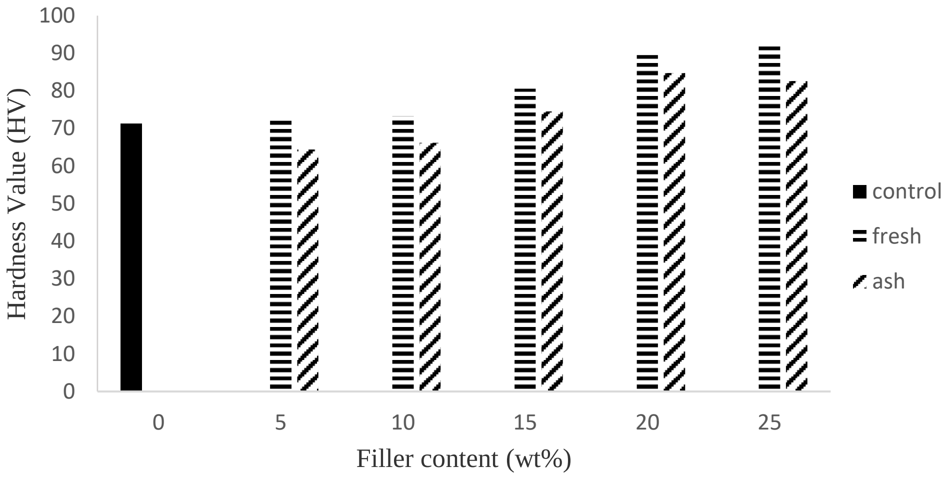

Figure 5: Variation of flexural strength with %wt of fresh and ash hybrid Composites

Impact Energy

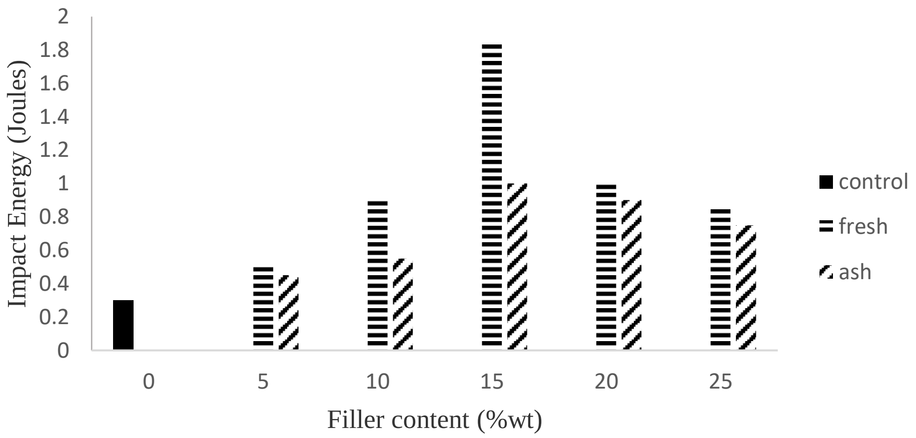

Figure 7: Variation of Impact Energy with %wt of fresh and ash hybrid composites

From Figure 4, the ductility of the composites decreases gradually with increase in filler contents. The reduction in elongation at break could as a result of the fact that fillers cause polymer matrices to lose their elastic properties due to stiffening effect which leads to restriction of polymer chain mobility. Also, with increase in filler content, there is the matrix reduction in quantity that may lead to reduction of the effect of the matrix as compared to that of the filler which then leads to an increase in modulus of composites but reduction of EB (Ahmad *et al*., 2007; Chun *et al*., 2012; Ibrahim *et al*., 2012; Eze *et al*., 2013).Additionally, Samples with 5, 15 and 20% reinforcement additions exhibited nearly the same ductility.

Figure 5: Variation of flexural strength with %wt of fresh and ash hybrid Composites

Effect of flexural strength with filler content is shown in Figure 5. It is evident from the figure that increase in filler loading led to a mild decline in flexural strength. The decline in flexural strengths is attributable to voids and weak interfacial bonding as the fillers increased which resulted to weak bending load carrying capacity by the polyester matrix. Similar submissions were made on

UPR/CS/Groundnut shell particles and Epoxy/CS composites (Muthukumar and Lingadurai, 2014; Singh *et al.*, 2013). In the same vein, fresh fillers proved to have higher flexural strength than ash fillers. This is might be due to improper wetting of the ash fillers.

Figure 6 depicts variation of the hardness values with the reinforcement loading. Except at 25 %wt addition of ash fillers, the general trend showed increase in hardness values with increased addition of the fillers. Decrease in voids and micro-cracks with filler loading must have made it difficult for the indenter to make bigger impressions on the produced hybrid composite. The trend is supported by a report of Sandesh*et al.*(2014). Similarly, composites with fresh fillers exhibit higher hardness than those with ash fillers. Perhaps, the fresh fillers offer higher resistance to indentation

Figure 7 illustrates the effect of fillers content on the impact energy of the produced hybrid composite. As seen, impact energy absorbed prior to fracture by the composites increase with the filler loadings. A marked rise is noted for the addition of fresh fillers while ash fillers loading led to a gradual improvement. However, after attaining a value of 1.85 J (fresh fillers) at 15 %wt addition, the impact energy declined significantly on the increase in the filler contents. The decrease might be due to the fact that fillers are no longer isolated by the ductile UPR matrix; therefore crack propagation is likely to be high. As a result, gaps propagate easily between particles which probably led to lower toughness. Hence, this contributes to the brittle nature of the composites. Similar occurrences have been reported(Ameh, *et al.,* 2015; Dodo *et al.,* 2018).

4.0 CONCLUSIONS

Hybrid composites using fresh and ashed coconut shell and wood dust as fillers and unsaturated polyester matrix have been developed. At the end of the study, the following conclusions are drawn:

1. There was a gradual decrease in tensile strength of the hybrid composites with filler loading.
2. The hybrid composite with ashed filler exhibited higher tensile strength than those with fresh fillers for all composition of the fillers.
3. The density of the hybrid composites increased with filler contents. However, at 20 and 25wt% ashed filler contents, lower density values were obtained.
4. Young’s modulus of the hybrid composites increased with increase in filler contents.Also the values for the ashed filler were higher than those containing fresh fillers.
5. There was decrease in percentage elongation of both hybrid composites with those containing fresh fillers being higher than their ashed counterparts.
6. Hardness of the composites increased with filler loadings while the impact energy for the fresh filler rose up till 15% content before decreasing with further increase in filler contents.
7. The hybrid composites exhibited mechanical properties within acceptable limits as compared with values of other materials as cited from literatures. It was observed that filler loading has stronger influence on the mechanical properties of the composite than the nature of the fillers. However, the nature of the fillers has more impact on the density of the composites than the fillers addition. After a significant improvement at 5 %wt fillers addition, tensile and flexural strengths decrease with filler content. Further, the strengths are slightly affected by the nature of the fillers. There is an increase in the rigidity of the composites with the filler loading. Additionally, a significant increase in the Young’s modulus was observed with ash filler additions. The ductility of the produced hybrid composites were markedly more affected by the fresh fillers than ash fillers. It was noticed that an increase in the fillers addition caused a

decrease in the percentage elongation. Hardness values of the fresh fillers reinforced composites were slightly higher compared to those reinforced with ashed fillers. Impact test recorded the highest values at 15 %wt additions for both composites reinforced with fresh and ashed fillers. On the basis of nature of the fillers, hybrid composites with ash fillers gave lower density, ductility, flexural strength, hardness and impact energy. Based on the mechanical properties tested, fresh fillers gave optimum properties compared to ash fillers. The fabricated hybrid fresh fillers composites with 15 %wt addition can be recommended to be a promising material for an application where high hardness and impact energy is required.

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