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PRODUCTION AND MECHANICAL EVALUATION OF BIO-COMPOSITE MATERIAL FROM COCONUT (COCOS NUCIFERA) SHELLS, PALM KERNEL (ELAEIS GUINEENSIS) SHELLS, PERIWINKLE (LITTORINA LITTOREA) SHELLS AS AN ALTERNATIVE TO GRINDING WHEEL PRODUCTION

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Abstract

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Introduction

The production of non-degradable grinding wheels with materials like glass powder, steel abrasive, silicon carbide, diamond dust, Zirconia alumina, Boron carbide, Slags and other special grits of grinding wheels are imported on daily basis to meet the demand of the market. The cost of these non-biodegradable conventional abrasive grinding wheels is on the high side and it also poses a pollution challenge to its users and their environment. However, there are available degradable raw materials such as coconut, palm kernel and periwinkle shells that can be used for their products locally but are being considered residues

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and discarded unhealthily. Therefore, this study seeks to develop abrasive grinding wheels produced from coconut, palm kernel and periwinkle shells. This study aims to develop abrasive grinding wheels from a mix of coconut, palm kernel and periwinkles shells and determine the mechanical properties of the composite grinding wheels. First, we design and fabricate the mould for the production of abrasive grinding wheels and then the mixing and production of abrasive grinding wheel composite material.

The production of abrasive grinding wheels from the composite of degradable waste materials will meet the high demand, thereby reducing the high effect of environmental pollution and equally creating job opportunities which will improve the economic state of the nation.

Palm kernel shell (PKS), coconut shell (CNS) and periwinkle shell (PWS) are agricultural residues obtained in the processing of palm oil, coconut oil and seafood respectively, and are available in large quantities in the tropical regions of the world. The development of abrasives from the huge amount of coconut and palm kernel shells available in Nigeria to manufacture tools and equipment is a suitable alternative to reduce cost, utilize and place economic values on these agricultural residues.

Grinding Wheel

A grinding wheel often called a grinding disc is a wheel composed of an abrasive compound used for various grinding, abrasive cutting and abrasive machining operations. The wheels are generally made from a composite material consisting of coarse-particle aggregate pressed and bonded together by a cementing matrix (bond in grinding wheel) to form a solid, circular shape. Various profiles and cross sections are available depending on the intended usage of the wheel. They may also be formed from a solid steel or aluminium disc with particles bonded to the surface. Surface finish, which is also known as surface texture or surface topography, is the nature of a surface as defined by the three characteristics such as lay, surface roughness and waviness (Obot et al., 2015). It comprises small, local deviations of a surface from the perfectly flat ideal plane



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materials such as metal sheets and woods. Surface texture is one of the main factors that control aesthetics in engineering. The grinding process is constantly adapting to new requirements in the industry, with a particular focus on the production of high-quality surface finish while increasing process efficiency (Godino et al., 2018). Figure 1. Grinding wheel.

Grit number

Some of the important physical properties of abrasive materials are hardness, brittleness, toughness, grain size and grain shape, purity and uniformity of the grains (grit). The grinding wheel is made from large numbers of abrasive grain particles. The grit number, shown in Table 1 implies the size of the abrasive grains used in making a wheel or the size of the cutting teeth. The grits number determines stock removal rate and generates surface finish, coarser grits remove stock more rapidly, but do not leave a good finish. Conversely, finer grits give a better finish, but slower stock removal rates. The selection of grits number is determined by the nature of the grinding operation, material to be ground, material removal rate and surface finish required.

Table 1 Particle grits numbers and applications

S/N	Size	Type	Applications
1	10, 12, 14, 16, 20, 24	Coarse	Rapid material removal
2	30, 36, 46, 54, 60	Medium	Stock removal and surface finish
3	80, 100, 120, 150, 180	Fine	Less stock removal high surface finish
4	220, 240, 280, 320	Very fine	Very high surface finish grinding hard material

Materials

The materials that were used in this study are agricultural residues such as coconut (Cocos nucifera) shells, palm kernel (Elaeis guineensis) shells, periwinkle (Littorina

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littorea) shells, polyester resin bond, cobalt octoate (accelerator) and methyl ethyl ketone peroxide (hardener).



Figure 2 Agricultural residues for bio-composite; (a) Coconut shell (b) Palm kernel shell (c) Periwinkle shell

Polyester resin

Polyester resins are the most economical resin formula used, but not much in high-performance composites. They can be used for large variety of properties, stating from soft-ductile-hard-brittle. Polyesters are low cost, low viscosity and a relatively short curing period. However, the have lower mechanical properties than other thermosets, poor weathering resistance and high shrinkage. The effect of shrinkage can be reduced by adding a thermoplastic component. It has advantages of adequate resistance to water, a variety of chemicals, adequate resistance to weathering and ageing, can withstand a temperature up to 80°C, good wetting to glass fibres and relatively low shrinkage at between 4-8% during curing. It cures exothermically as a thermosetting agent, and the use of an excessive initiator such can cause charring or ignition during the process. This excessive initiator may also cause the product to fracture or form rubbery material. Two principal types of resin use in the composite industry are the Orthophthalic polyester resin which is the standard economic resin used in many industries while Isophthalic polyester resin is now becoming the preferred material in industries such as marines where high water resistance is required. There are other types of bonds like Vitrified (V) or Ceramic bonds, Resinoid or Organic (B) bonds, Rubber (R) bonds, Silicate (C) bonds, Shellac (E) bonds and Magnesite (O) bond, and Metal bonds which are binders used for various kinds of grinding and cutting wheels for different applications.

Methyl ethyl ketone peroxide

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Methyl ethyl ketone peroxide (MEKP), is organic peroxide, a colourless liquid with a strong irritant to skin and tissue. It is an initiator used for curing of unsaturated polyester resins under room temperature. It is an oily liquid and is slightly less sensitive to shock, good temperature, high explosive and more stable in storage. Table 2 shows the chemical and physical properties of Methyl Ethyl Ketone Peroxide.

Table 2 Chemical and Physical Properties of Methyl Ethyl Ketone Peroxide (Johnson, 2017)

Chemical name	Methyl ethyl ketone peroxide
Compound formula	$C_8H_{16}O_4$
Molecular weight	210.22 g/mol
Appearance	Colourless liquid
Density	1.170 kg/m^3
Boiling point	80 °C

Cobalt Octoate

Cobalt octoate (Cobalt 2-ethylhexoate) is one of the most active major driers and is used alongside with auxiliary drier to stimulate an even surface through drying. Care needs to be applied when measuring Cobalt to prevent an excess of it which could cause fast drying that would result in surface wrinkling. It speeds up the catalytic action of Methyl ethyl ketone peroxide (MEKP) to polymerize unsaturated polyester resin. It is an accelerator for polymerization of unsaturated polyester resins. It is better compared to cobalt naphthenate. It has a pale colour, low toxicity and low odour. The sample of Cobalt octoate is shown in Table 3.

Table 3 shows the chemical and physical properties of Cobalt octoate (European Chemicals Agency (ECHA), 2019

Chemical name	Cobalt octoate (Cobalt 2-ethylhexoate)
Compound formula	$C_{16}H_{10}CoO_4$
Molecular weight	345.34 g/mol
Appearance	Purple Liquid
Density	1.01 kg/m^3
Exact mass	345.147603 g/mol
Mono isotopic mass	345.147603 g/mol

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Figure 3 Samples of the polyester resin, methyl ethyl ketone peroxide and cobalt octoate

Equipment

The equipment that was used during this research study is a 3,730 W hammer mill, a set of mechanical sieves, Electronic weighing balance (Model: SF-400 with 0.001 g resolution), Universal Testing Machines (Testometric M500-100AT), Universal Testing Machine (Testometric FS5080) capacity 50 KN and electric handheld grinder. The laboratory tools to be used include a manual stirrer, bowls and scrapper.



Figure 4a Standard sieve test apparatus



Figure 4b. 30 Tons Hydraulic press

Material Preparation

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A quantity of 10 kg of palm kernel shell (PKS), 10 kg of coconut shells (CNS) and 10 kg of periwinkle shell (PWS) samples were obtained and sorted to remove dirt and other unwanted materials such as palm fibres, uncrushed palm fruits, stones and other plant residues. The sorted samples were sun-dried for days. The samples were grinded separately using a 3,730 W hammer mill. After then were pulverized with different sieve sizes of 250, 500, and 850 (ASTM E11) to categorize the (CNS/PKS/PWS) grains into FEPA abrasive grits numbers (FEPA Abrasives, 2013). The mass of each sample were measured using an Electronic weighing balance (Model SF-400) weighing out 75/0/0, 0/75/0, 0/0/75, 40/20/15, 20/40/15 and 30/30/15g of CNS/PKS/PWS abrasive particles. This is shown in Table 4. The weighed samples were poured into separate plastic containers adding 23 g of polyester resin and 2g of cobalt octoate and methyl ethyl ketone peroxide to cause binding and blending effect on the samples thoroughly mixed. The masses of polyester resin, cobalt octoate and methyl ethyl ketone peroxide were kept constant throughout the sample composition.

Table 1 Mass composition of CNS/PKS/PWS/resin bond/Cobalt/MEEK of the samples

	CNS (g)	PKS (g)	PWS (g)	Resin (g)	Cobalt/MEKP	Total Mass (g)
Sample A	75.0	0.00	0.00	23.0	2.00	100
Sample B	0.00	75.0	0.00	23.0	2.00	100
Sample C	0.00	0.00	75.0	23.0	2.00	100
Sample D	40.0	20.0	15.0	23.0	2.00	100
Sample E	20.0	40.0	15.0	23.0	2.00	100
Sample F	30.0	30.0	15.0	23.0	2.00	100

Formulation and production of bio-composite for grinding wheel

The samples of coconut, palm kernel and periwinkle shells were manually mixed before addition of polyester resin, cobalt octoate accelerator and methyl ethyl ketone peroxide hardener were added and stirred thoroughly using a manual stirrer to ensure homogeneity of the mixture and allowed to stay for 2 to 5 mins. The prepared samples is then poured into the prepared mould and compressed with a force of 180 kN using a manual compression machine, by placing the mould in between the compressive plates of the machine before releasing the piston which exerted force on the blend to produce the abrasive wheel. The same process was repeated to produce other abrasive samples. The samples produced

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were allowed to cure properly for 2-3 weeks under open space. The methods of Odior& Oyawale 2013 and Shehu et al. (2014) were adopted in this research.

Results and Discussion

The physical mechanical properties such as shattering index, tensile strength and compressive strength of the composites were evaluated.



Figure 5. Samples of the grinding wheel produced with different blending ratio of CNS, PKS and PWS.

Shattering index (%)

Figure 6, Shows how particle size variation and blending affected the composite grinding wheel's ability withstand tension or fracture.

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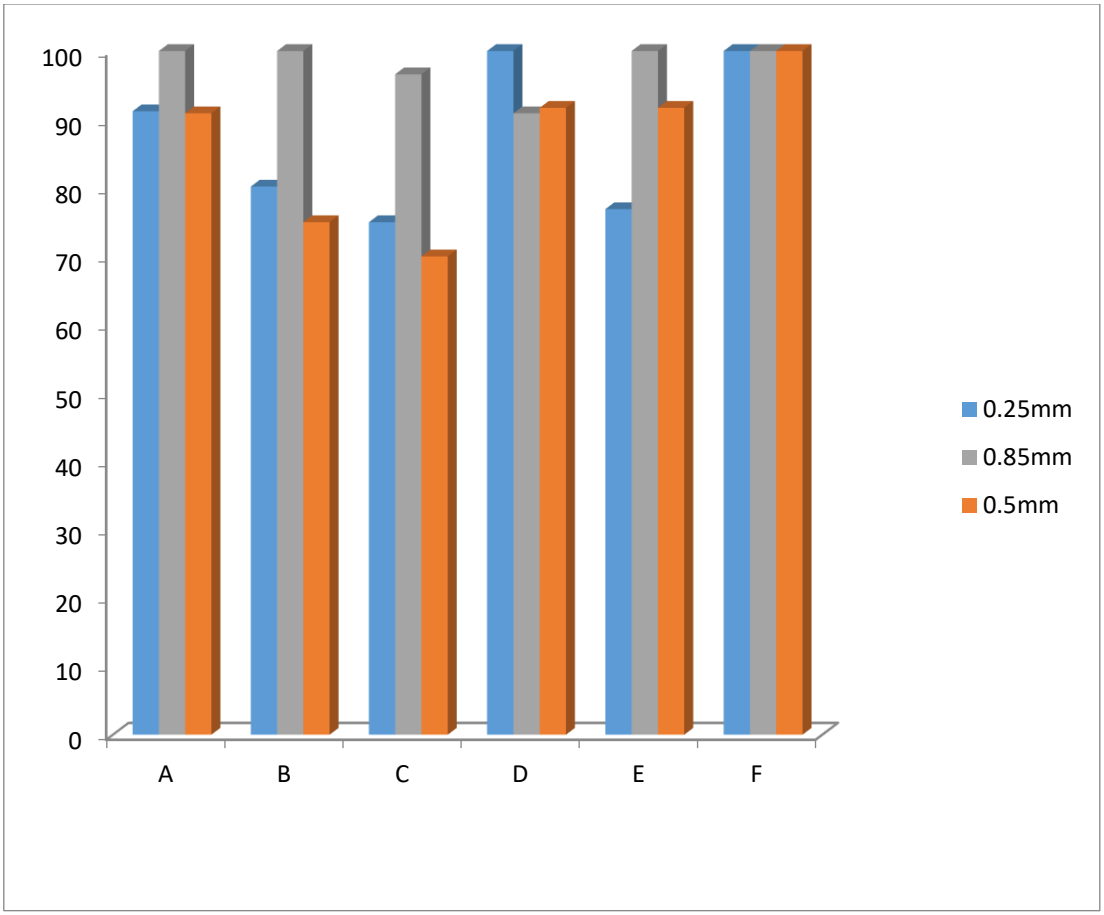


Figure 6. Percentage shattering index plot against particle size with different blending ratio

From figure 6, the result shows that there was a significant effect of shattering index on the particle size and blending ratio. Sample F shows that despite the sieve size, there was no significant change in the shattering index plot against the blending ratio as could be as a result of the balanced constituent of the mixture. Sample C shows the highest significant change in the shattering index plot with 0.5mm sieve size. The increase in particle size has a positive impact on the shattering index which could be as a result of intermolecular interaction and bonding effect of the blend.

Compressive strength (kN/mm²)

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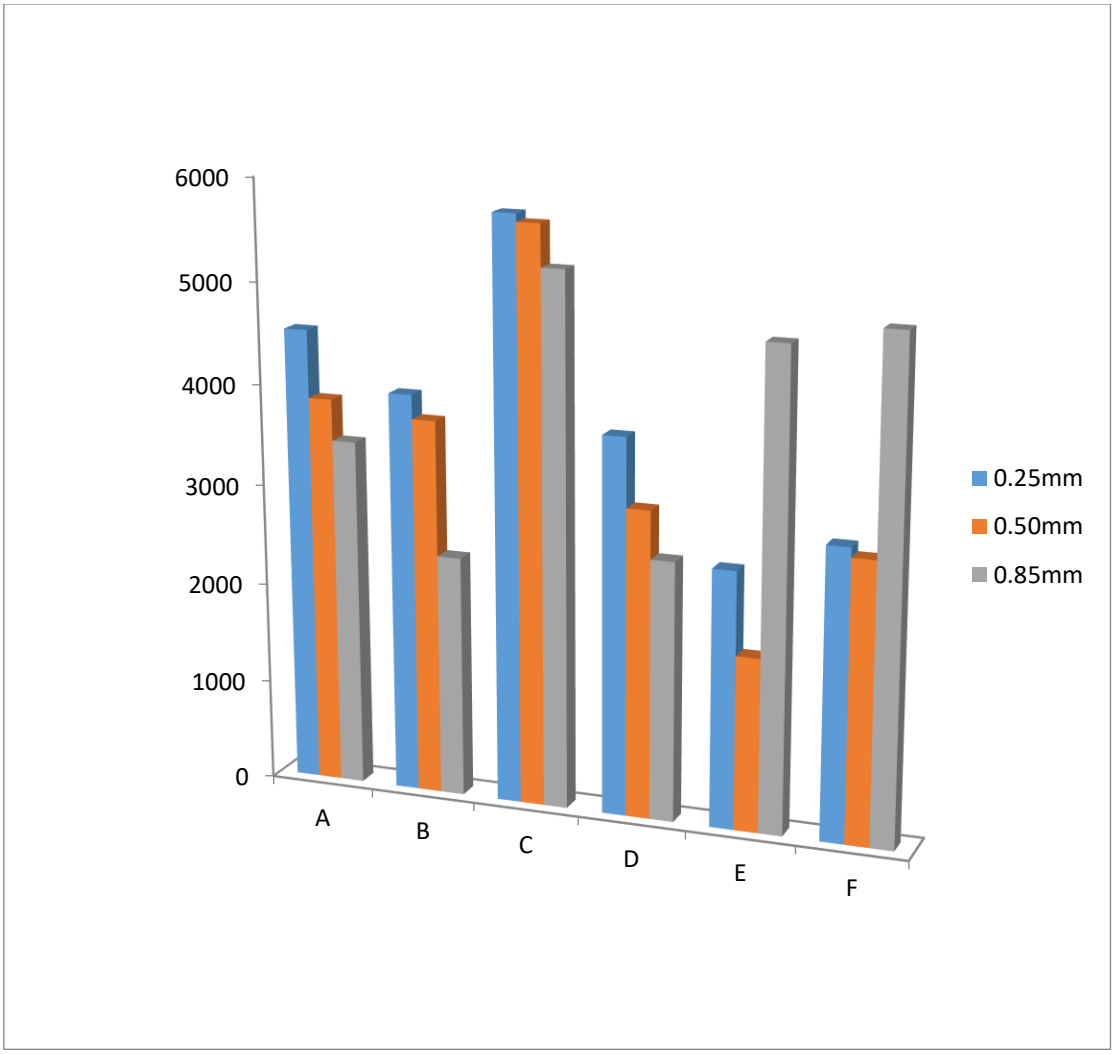


Figure 7. Compressive strength against particle sizes

From Figure 7 above, the result shows that sample C has the highest compressive strength in the particle size of 0.25mm, 0.50mm and 0.85mm respectively, with the strengths over 5000N/mm^2. In sample D, 0.25mm particle size has the highest compressive strength of 3740N/mm^2 compare to 0.50mm and 0.85mm and might be the effect of grain size and compacting pressure during molding.

Tensile strength

The chart below shows the effect of blending ratio and particle size on tensile strength.

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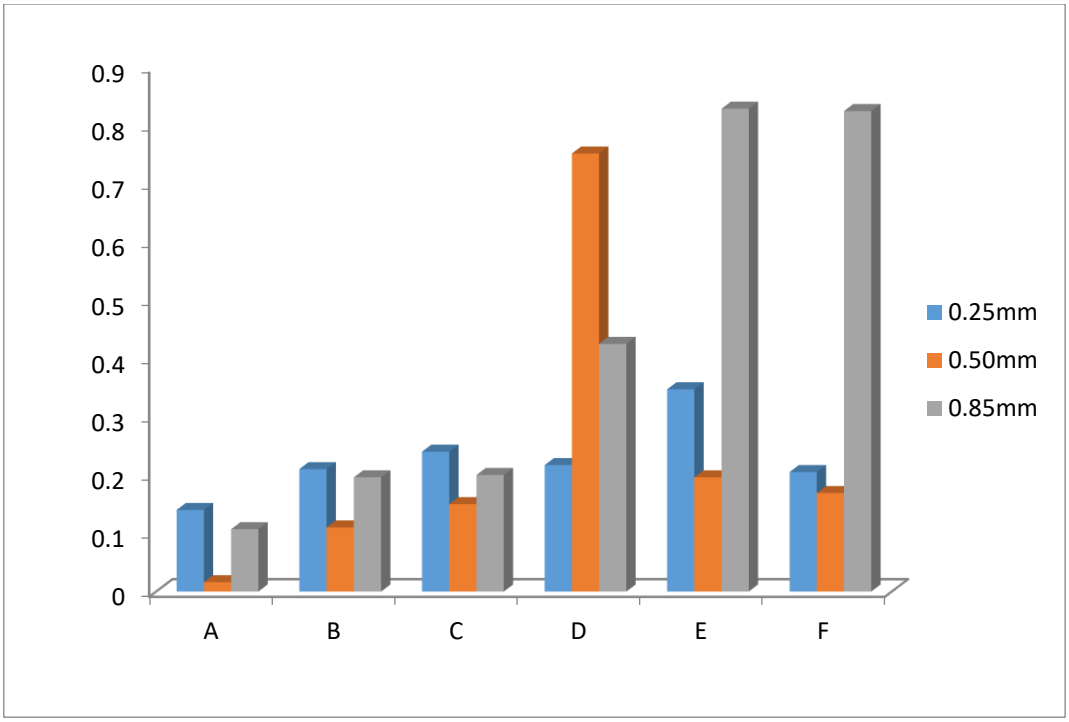


Figure 8. Tensile strength against particles size

The highest value of tensile strength is seen in sample E of 0.85mm particle size with 0.829 N/mm^2 while the lowest tensile strength is seen in is as result of higher particle size and increase in PKS in the blend. The intermolecular interaction and bonding effect is high and this means, increase in the particle size and increase in the quantity of PKS present increases the tensile strength.

CONCLUSION

In answer to the challenge of high rate importation non-biodegradable product and high risk of environmental pollution, the study described the production of biodegradable composite abrasive grinding wheels constructed from coconut shell, palm kernel shell, and periwinkle shell with polyester resin, some physical and mechanical properties such as shattering index, compressive strength and tensile strength.

Sample F shows that despite the sieve size, there was no significant change in the shattering index plot against the blending ratio as could be as a result of the balanced constituent of the mixture. Sample C shows the highest significant change in the shattering index plot with 0.5mm sieve size. The increase in particle

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size has a positive impact on the shattering index which could be as a result of intermolecular interaction and bonding effect of the blend. sample D, 0.25mm particle size has the highest compressive strength of 3740N/mm^2 compare to 0.50mm and 0.85mm and might be the effect of grain size and compacting pressure during molding. The highest value of tensile strength is seen in sample E of 0.85mm particle size with 0.829 N/mm^2 while the lowest tensile strength is seen in is as result of higher particle size and increase in PKS in the blend. The results and the analysis shows that the production of abrasive grinding wheels from the blend of palm kernel shell, coconut shell, and periwinkle shell is possible and recommendable.

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