# DEVELOPMENT AND ASSESSMENT OF PARTICLE REINFORCED ABRASIVE GRINDING DISCS FROM LOCALLY SOURCED MATERIALS

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## ABSTRACT

*Management of waste materials is a serious concern to researchers and scientists. Waste materials cause health and environmental hazards. Hence, they should be properly managed. The aim of this study is to develop a grinding disc using agricultural wastes (palm kernel shell and snail shell), granite, aluminium oxide, and polyester resin. The particles of snail shell, palm kernel shell, aluminium oxide (abrasive) and granite (friction modifier) were measured in percentages varying between 8 - 29 wt. % and were mixed with 27 wt. % polyester resin (binder), 3 wt. % methyl ethyl ketone peroxide (hardener) and 3 wt. % cobalt naphthalene (accelerator) to produce a grinding disc. The micrograph, hardness, wear rate, and water absorption tests were carried out on the grinding disc samples. The result showed that the composition with the highest palm kernel shell particle content (29 wt. %) had the best values for hardness and wear resistance, making it the most suitable material for grinding discs. The environmentally-friendly palm kernel shell-based discs could be used for soft metals, wood grinding and finishing processes.*

*Keywords: abrasives; grinding disc; strengths; agro-residue; environmentally friendly.*

## INTRODUCTION

The employment of synthetic and natural fibers in the production of various products has demonstrated exceptional applications in a variety of fields [1]. The use of locally derived resources in the creation, invention, and production of commodities has attracted the attention of numerous scholars in recent years. For instance, an abrasive material was developed from periwinkle shell [2], while an asbestos-free brake pad was developed using bagasse [3]. Locally derived materials have been utilized to produce other products as reported [4 - 8]. Application of wastes for various utilizations is economical, and it may also improve foreign exchange and lead to environmental control [9]. An essential component of these wastes is agricultural waste. Agricultural wastes are essential in production since they are not only economical but also the only means of reducing environmental contamination [10 - 12]. The most sustainable, cost-effective, and environmentally friendly method of waste management appears to be the conversion of agricultural waste into usable forms to promote clean environment, industrialization, resource conservation, and regeneration [13, 14].

Abrasives are small, hard particles with irregular forms and sharp edges. They are often referred to as grits [2]. An abrasive is used to shape or finish a product made of wood, metal, or another material through rubbing, which causes some of the workpiece to be removed due to friction. The formation of grits involves the treatment of the abrasive materials in furnace, pulverizing the materials before sifting the materials into various sizes of grain [15, 16].

The abrasives industry mostly depends on five abrasive materials: aluminum oxide (alumina, $Al_2O_3$), garnet, and silicon carbide (SiC). The other two are cubic boron nitride (CBN) and diamond are known as super abrasives [17]. Environmental and health hazards concerning the use of conventional abrasives particles as well as their rising costs have stirred up interest in a number of scientists developing abrasive particles from agricultural waste or residue [18, 19].

Some researchers have provided alternatives to conventional abrasives by developing abrasive materials using locally sourced materials. In a study, abrasive wheels were produced for chip removal using locally sourced materials which include: snail shells, palm kernel shells, granite, bottle pellets, gravel, and metal chips [20]. More so, abrasive sandpaper was produced for polishing and smoothening wood surfaces by mixing coconut shells (agricultural waste) with polyester resin [21]. Locally sourced materials were utilized in developing emery cloth/sandpaper [22] while some locally sourced materials were employed in the synthesis of silicon carbide abrasives [23]. Walnut shells were used to produce abrasive sandpaper for utilization in woodwork industry [1], while palm kernel and periwinkle shells were combined to produce sandpaper models using hand spray method. The produced sandpaper was compared with the imported abrasive sandpaper [24]. They confirmed the ability of agricultural waste materials to be used in the production of abrasive materials for both residential and industrial usage.

With the continuous abundance of environmental, agricultural and industrial wastes that require proper management and utilization, an eco-friendly answer to the waste management problems is required and tailored towards a particular product. In this study, agricultural waste materials (snail shells (SS) and palm kernel shells (PKS)) are used to produce abrasive discs for utilization in woodwork industry. The synthesized abrasive discs were subjected to various mechanical tests to determine their hardness, wear rate, water absorption, and an optical microscopy examination was done.

## EXPERIMENTAL

### Experimental materials

The experimental materials utilized were snail shells (SS) and palm kernel shells (PKS) obtained from Oja-Oba market in Ilorin metropolis. The granite was obtained from a construction site in a university environment at Ilorin, having a particle size of 420 μm while the aluminium oxide was obtained from a local chemical vendor with a particle size of 25 μm. Polyester resin (binder), cobalt naphthalene (accelerator), methyl ethyl ketone peroxide (MEKP (hardener)), water, and containers were purchased.

### Preparation of Abrasive grains

To remove impurities that might prevent the solid creation of abrasive grinding discs, experimental specimens were carefully prepared according to recognized techniques adopted [2, 16, 21]. The snail shells and palm kernel shells for sample preparation were thoroughly washed in detergent water and rinsed in clean water to remove traces of oil and dirt on them. These materials were sun-dried for 3 days (7 h $day^{-1}$) to remove the moisture or water content present as a result of the initial washing. After, they were subjected to a temperature of $100^oC$ for 3 h in an electric oven to eliminate the residual moisture. The SS and PKS were later pulverized using a ball milling machine and sieved by a vibrating sieving machine using a 420 μm sieve mesh according to ASTM E11 guidelines. This is to allow the sorting of the SS and PKS grains into Federation of European Producers of Abrasives (FEPA) abrasive grits of P40 standard grits [25]. The granite was milled into a particle size of 420 μm while the aluminium oxide was obtained in a particle size of 25 μm. Other constituent elements of the abrasive composites (including MEKP, polyester resin, and cobalt naphthalene) were identified. For ease of identification, the chemicals are put in confined but well-labelled transparent glass bottles.

### Synthesizing of Abrasives Specimen

The powder metallurgy technique was the production route for the abrasive specimen adopting the procedure reported [20, 24]. The experimental mass composition of the various composite grinding discs and their equivalent percentage weight are presented in Table 1.

Fig. 1a - d display the PKS, granite and SS pulverized to 420 μm size, while the particle size for $Al_2O_3$ was 25 μm.

Using an electronic weighing machine, the appropriate measured amount of milled PKS and SS samples were emptied into a clean, separate

Table 1. Mass composition of composites grinding disc and their equivalent percentage weight.

| Sample | | PKS | SS | Granite | $Al_2O_3$ | Polyester Resin | MEKP | Cobalt Naphthalene | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Mass, g | 7.8 (13 %) | 4.8 (8 %) | 17.4 (29 %) | 10.2 (17 %) | 16.2 (27 %) | 1.8 (3 %) | 1.8 (3 %) | 60 |
| 2 | Mass, g | 17.4 (29 %) | 10.2 (17 %) | 4.8 (8 %) | 7.8 (13 %) | 16.2 (27 %) | 1.8 (3 %) | 1.8 (3 %) | 60 |
| 3 | Mass, g | 10.2 (17 %) | 17.4 (29 %) | 7.8 (13 %) | 4.8 (8 %) | 16.2 (27 %) | 1.8 (3 %) | 1.8 (3 %) | 60 |
| 4 | Mass, g | 4.8 (8 %) | 7.8 (13 %) | 10.2 (17 %) | 17.4 (29 %) | 16.2 (27 %) | 1.8 (3 %) | 1.8 (3 %) | 60 |

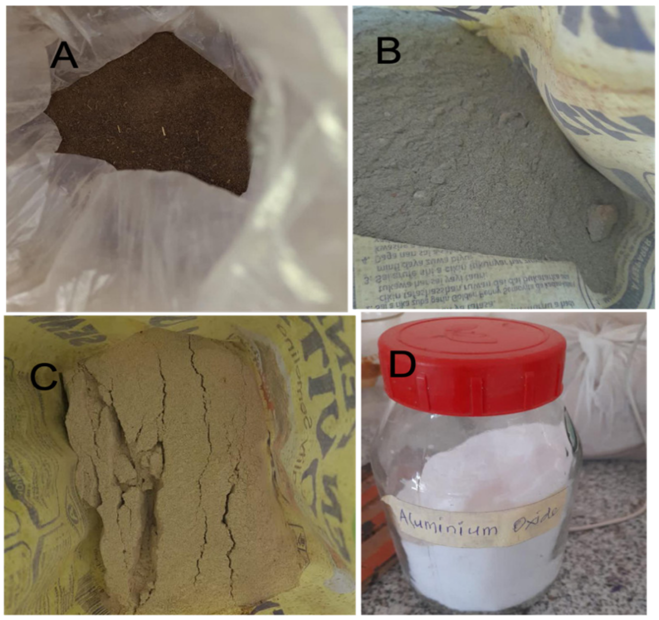


Fig. 1. Raw materials used in this study (a) PKS (b) granite dust (c) Snail shell (d) Aluminium oxide.

plastic container. The appropriate amounts of granite, aluminium oxide, polyester resin (a binder), cobalt naphthalene (an accelerator), and MEKP (a hardener) as displayed in Table 1, were successively added to the PKS and SS samples. The combined raw materials mixtures were sequentially mixed for 5 min in a mechanized mixer into a homogeneous, thick paste-like consistency at 400 rpm speed. The cavities of the steel mould (40 mm height and 60 mm diameter) were subsequently filled with the obtained paste from the mixture. Talc is used to powder the mould to make it easier to remove the components after casting. The compression process involved compressing the samples at room temperature under a constant pressure of 13.5 N mm$^{-2}$.

For the creation of each grinding disc sample and experimental test specimen, the procedure was repeated. The produced abrasive grinding discs were allowed to cure for about 2 h. After the curing, the samples were dried at 70$^{o}$C in an electric oven for 7 h [25]. Prior to conducting the analytical tests, the samples obtained, as shown in Fig. 2 were examined for shape and size distortion and then stored for 7 days in a well-ventilated condition to reach full strength. In addition, the specimens were held for another 7 days for strengthening before the mechanical tests were done [1]. The dried samples were gathered and put through various tests, such as stereo microscopy analysis, hardness testing, water absorption testing, and wear (abrasion) resistance

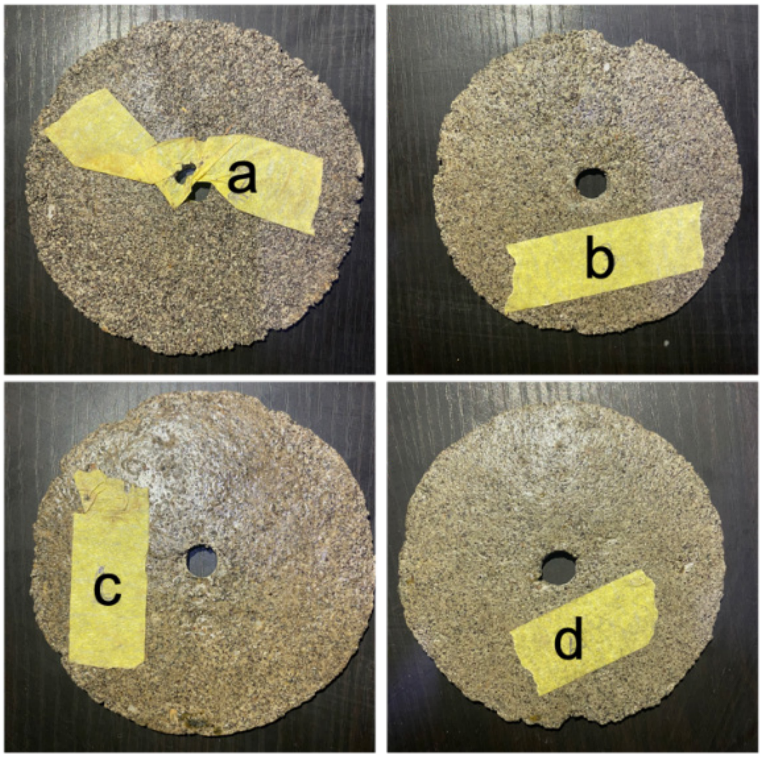


Fig. 2. Abrasive grinding disc samples made from SS and PKS grains with a sieve size of 420 microns.

testing, to determine their suitability for making grinding discs [26, 27].

**Microstructural examination**

Before the microstructural examination, the grinding disc samples were not polished due to their non-shiny surface. An optical microscope could not give the surface structure but a stereo microscope of model MSC-ST40 was used at a material science and engineering laboratory. Snapshots seen in Fig. 3 were taken with the aid of an external camera. The developed grinding discs' grain distribution and homogeneity were assessed.

**Physical Properties**

***Water absorption test***

The initial weight ($W_1$) was noted before each sample was drenched in distilled water. After 24 h, the immersed samples were removed and meticulously drained and cleaned to eliminate any remaining water from the surfaces, reweighed, and recorded as $W_2$. Then, using Equation (1), the difference between each specimen's initial and final weights was utilized to calculate the water absorption percentage [12, 27].

$$\%\ \text{Water absorption} = \frac{W_2 - W_1}{W_1} \times 100 \quad (1)$$

where $W_1$ and $W_2$ are the initial and final weights of the sample.

**Mechanical Properties Tests**

The manufactured abrasive grinding discs were subjected to mechanical properties testing, such as hardness and wear (abrasion) resistance tests, which were carried out in accordance with previous literatures [12, 24].

***Hardness test***

The hardness value of the sample was done using a Rockwell hardness tester of model number 7005 RHT-M in accordance to ASTM E18-79 standard. The steel ball indenter used was 1.56 mm at 10 kg load. The difference between the baseline and final depth measurements was used to calculate the Rockwell hardness value.

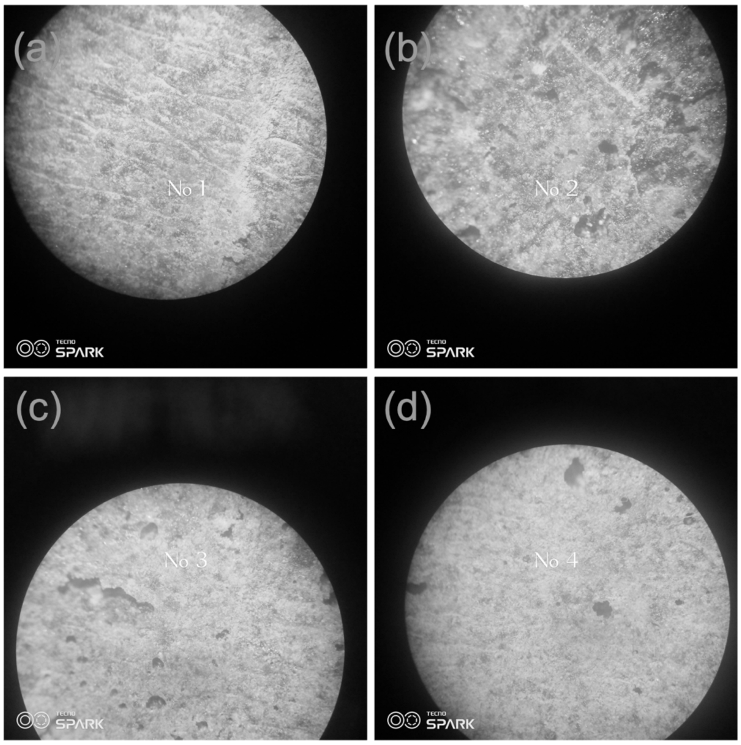


Fig. 3. Grinding disc (a) sample 1 (b) sample 2 (c) sample 3 (d) sample 4.

***Wear resistance measurement***

The Taber abrasion machine of model 1700 (115/230V; 60/50Hz) was employed for the wear experimentation. The experiment was carried out in accordance with ASTM D4060-14 standard [28]. Test sample discs (100 mm outer diameter, 6 mm inner diameter, and 3 mm thickness) were placed on a turntable platform which revolves on a vertical axis at a fixed speed of 1000 rpm [29]. The turntable includes two precisely balanced abrasive arms. Each arm was loaded twice - once with a 250 g wheel and once with a 500 g wheel - against the test samples before being lowered onto the sample surface. The test sample comes into contact with the sliding rotation of the two abrasive wheels, causing the distinctive rub-wear motion. The wheels on the turntable are moved in opposition to one another as the turntable revolves around a horizontal axis that is offset tangentially from the axis of the sample. During the test, a vacuum system eliminates the debris while one abrading wheel rubs the sample outward toward the periphery and the other inward toward the core. Each test sample was subjected to the examination for 10 min. Abrasion resistance is visible at all angles in relation to the weave or grain of the material when the wheels go around the whole circumference of the sample surface. Using the relationships in Eq. (2), the weight loss of the materials due to abrasion and their wear indices were calculated [30]. To guarantee the correctness and reliability of test results, four tests were carried out for each sample, and their means were employed in this study.

$$\text{Wear Index} = \frac{initial\ weight - final\ weight}{\text{number of cycles}} \times 1000 \quad (2)$$

## RESULTS AND DISCUSSION

**Micrograph of composite grinding disc**

The micrographs of the grinding disc samples are shown in Fig. 3a - d. The surfaces of the grinding discs were examined using the stereomicroscope. The micrographs of the particle-reinforced grinding discs at 420 μm grit size are shown in Fig. 3a - d. The largest and most evenly distributed pores are found in sample

2 (Fig. 3b), which causes the grinding disc to become loose. Because of the uneven distribution of PKS particle sizes, mixtures were filled with air, which led to the formation of pores when the sample was dried. The pores in the various samples are also caused by the resin's water content [30]. The structure of sample 1 (Fig. 3a) appears to have the fewest pores and a consistent distribution of binder and abrasive particles, which is ideal for achieving uniform mechanical properties throughout the material. The result of the micrograph in Fig. 3d demonstrates that the bonding between the abrasive particles and the binder is quite homogeneous with little pore appearing in sample 4 (the composition containing most aluminium oxide particles).

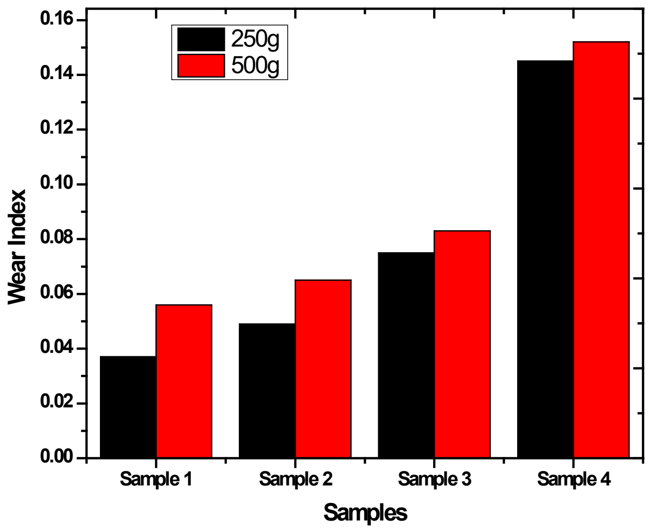


Fig. 4. Wear index for the samples.

**Wear resistance**

The wear index values for 250 g and 500 g loads are shown in Fig. 4. Samples 1 and 4 exhibit the best and worst wear resistance, respectively. The wear index decreases as the aluminium oxide content increases. Yet, the increased interfacial interaction between the abrasive particles and polyester resin has led to a higher concentration of granite particles in the composite grinding disc, which is the reason for the improvement of the wear resistance. With the value of the wear resistance obtained in this study, the manufactured grinding disc would be suitable to grind soft metals like copper and aluminium that have a low wear resistance.

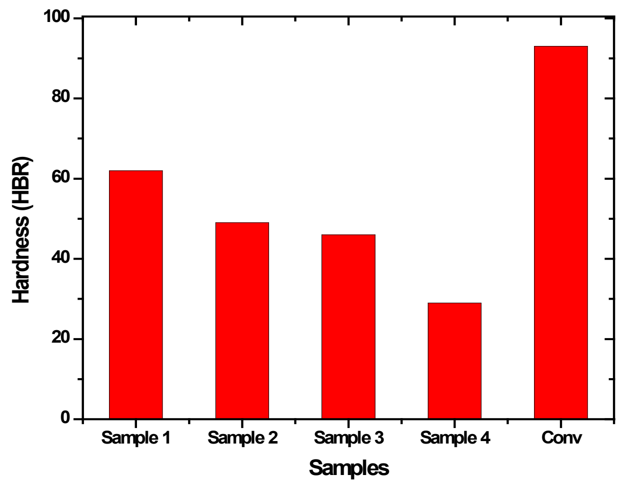


Fig. 5. Hardness values for the produced grinding disc.

**Rockwell hardness**

The yield strength of a material is related to its hardness. The hardness values of the produced grinding discs are represented in Fig. 5. The obtained values were compared with commercially available grinding disc. It can be observed that the results were different from the hardness values of the commercial grinding discs [31]. This is because the standard grinding disc is produced using silicon carbide abrasive and vitrified bonding [31], as opposed to the locally sourced abrasives and resin bond used in this study. From sample 4 (lowest PKS concentration) to sample 2 (highest PKS concentration), the hardness increased. The hardest sample 1 has an enhanced granite content of 29 weight percent; this sample's increased hardness value may be due to the individual hardness of granite particles, which are the hardest particles in the matrix, as illustrated in Table 1 (Fig. 6). More so, the percentage combination of the two hardest materials of PKS and granite could have accounted for the gradual increase in hardness as both percentages increased. A superior hardness result was obtained in this present study due to the presence of granite, a harder material. The highest hardness obtained when PKS based abrasive sandpaper produced was 9 HRB at 250 μm sieve size. However, this hardness value (8.4 HRB) decreased at 420 μm sieve size. With similar trends shown by the coconut shell based abrasive sandpaper, the 250 μm sieve size had 8.75 HRB while 420 μm sieve size had 7.92 HRB [16].

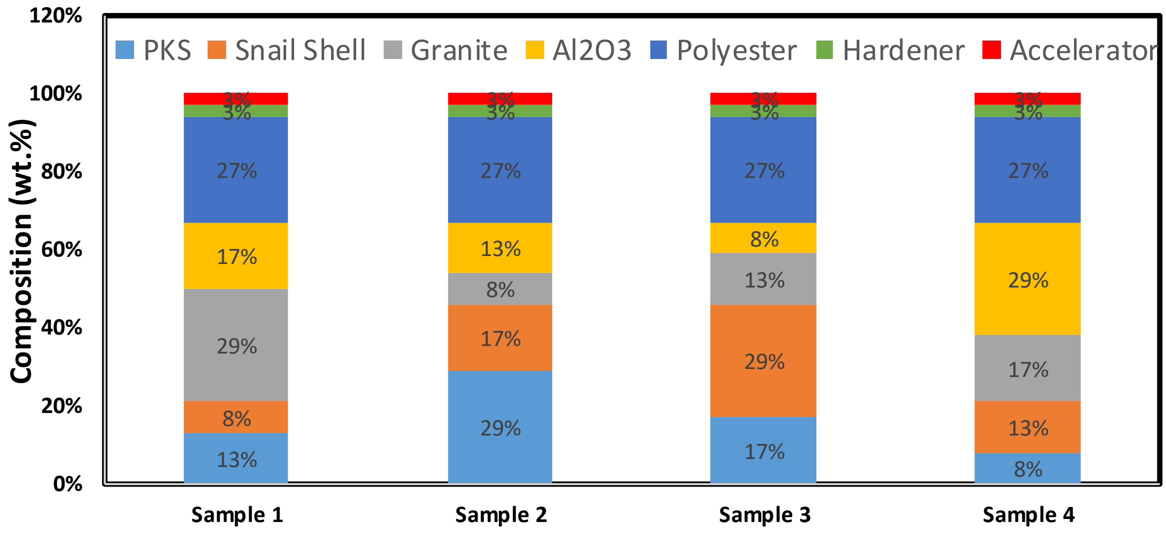


Fig. 6. Composition (wt. %) for each grinding disc sample.

Table 2 .Hardness values of some metals [33].

| Metal | Alloy & Temper | Hardness Rockwell B-Scale (HRB) |
|---|---|---|
| Aluminium | 3003-H14 | 20 - 25 |
| Aluminium | 3003-H34 | 35 - 40 |
| Aluminium | 6061-T6 | 60 |
| Copper | 1/8 hard (cold roll) | 10 |
| Commercial Bronze | 1/4 hard | 42 |
| Yellow Brass | 1/4 hard | 55 |
| Steel (Low Carbon) | Cold-rolled | 60 |
| Zinc-Cu-Tn Alloy | Rolled | 40 |
| Lead | Sheet lead | 5 |

The produced sample 1 grinding disc can grind/polish all the metals listed in Table 2 due to its higher hardness value. Theoretically, harder wheels can grind softer metals because harder materials tend to break into little fragments, whereas softer materials would plastically flex and exert greater force on the grains [32].

**Water absorption**

The water absorption of the samples in Fig. 7 demonstrates that as the PKS composition increases, the water absorption of the samples increases as well. Moreover, as the porosity of the grinding discs rises, so does the water absorption. The micrograph in Fig. 3b showed that sample 2 had the largest and

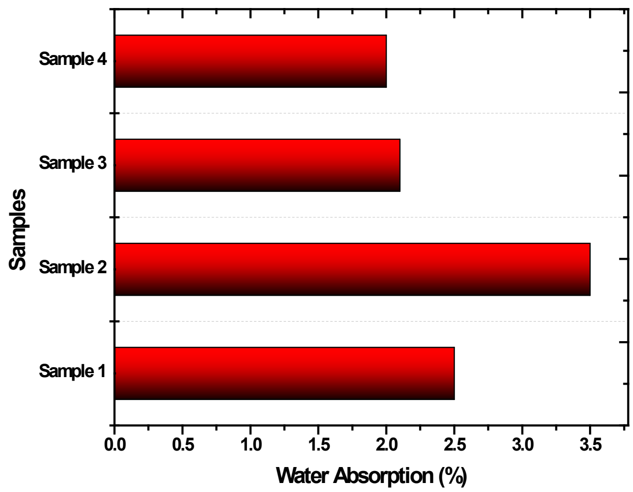


Fig. 7. Water absorption of the samples.

most evenly distributed pores, which made it more permeable to water than samples 1, 3, and 4. Due to PKS's hydrophilicity, which draws water molecules to itself [16, 24], sample 2 absorbs more water. Since fewer water molecules may flow through the matrix due to the strong link between the particles and resin in sample 1, which has reduced porosity as seen in the micrograph in Fig. 3a. It tends to be more water resistant and has the lowest value for water absorption in this investigation. Increased in water absorption rate could be linked to reduction in the interfacial bonding between the filler materials and the binder; thereby, increasing the porosity [16]. The highest water absorption recorded in this study was 3.5 % (sample 2) and the lowest was 2.0 % (sample 4) compared to 7.76 % highest water absorption rate reported by [16]. This disparity could be due to the utilization of biomass material that was capable of absorbing water due to porosity attained because of interfacial bonding reduction. Samples 2 and 4 have the highest and lowest percentage of PKS in this study, which can absorb more water as it increases in the constituents.

## CONCLUSIONS

In this study, locally available materials have been used to produce a grinding disc. Sample 1 has the highest hardness value and hardness improves as the percentage weight composition of the PKS increases in the sample. The manufactured grinding discs have lower hardness values than the conventional ones. Sample1 have fewest pores and its binder is evenly distributed based on microstructure. Increase in PKS improved the wear resistance of the composite grinding disc. The wear rate and hardness decreased as the amount of aluminum oxide increase in the sample. Sample 1 had the best abrasive qualities in terms of hardness and wear resistance (high granite content). Only light weighted metals such as aluminium, copper, commercial bronze, yellow brass, steel (low carbon), zinc-cobalt-tin alloy, and lead are suitable to be polished or grounded using the manufactured grinding disc.

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