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# Production and characterization of asbestos-free brake lining material using agro wastes

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**Abstract**

The health problems associated with the use of asbestos based brake linings have motivated research on the use of ecofriendly-agro based biomaterials as reinforcing agents in composite materials used for brake pad lining production. This research work studies the possibilities of using palm kernel shell (PKS), coconut shell (CNS), and canarium sweinfurthii shell (CSS) powder for asbestos-free brake lining materials production. The powders alongside the relevant fillers were used in the production of the brake lining. Compositions of the reinforcing powders were varied from 25% to 40% that of resin binder was varied from 58% to 43%, while those of filler metal and curing agents were kept constant. These materials were weighed, formulated, mixed, cured, and moulded. The developed composite materials were characterized and subjected to water and oil absorption, compressive strength, hardness, and wear tests. Results of the analysis revealed that increase in reinforcing materials results in an increase in the water and oil absorption of the samples. The composite's compressive strength equally increased with the introduction of up to 35% composition. The measured value of coefficient of friction was found to be within an acceptable range. Also, when mixed with other fillers and bounded, CSS powder proved to be a very promising material for brake lining production.

**Keywords:** CSS, PKS, CNS, Brake linings, Compression moulding

## 1. Introduction

Most motor vehicles make use of hydraulic disc brakes [1]. Brake pads are plates with steel backing bound with friction materials. They are made up of two main parts; the friction material and the backing. The backing main importance is to serve as a support for the friction material, as the stoppage of the vehicle is mainly carried out by the friction materials [2]. Modern friction materials development span over 110 years. The pioneer invention of brake lining materials was in 1897 by Herbert Frood [3]. In 1901, Herbert patented a cotton material block impregnated with rubber, and the cotton was replaced with asbestos in 1908 because of the limitations of using textile materials. As a common base material for brake lining production, asbestos has been for close to 100 years. Asbestos is mostly termed a "God given" material with great and stable chemical and physical properties, irrespective of the changing temperature conditions, as such commonly included in friction linings [4]. However, it has been reported that asbestos is harmful to the human health. Reports have linked asbestos with diseases such as mesothelioma, asbestosis, and various types of cancer including lung cancer [5, 6].

Research focus on the utilization of waste from agro industries as raw materials are increasing and specifically, for the production of safer and asbestos-free brake pads. Previous research have proven that agricultural waste sources have relevant qualities required for brake pads production [7-10]. Aside from being a potentially viable option for asbestos brake pad material, their economic value enhancement, may provide a means of "converting waste to wealth". These sources include PKS, [11], bagasse, [12], periwinkle shell, [13, 14], coconut shell, [7], sole and combined use of cocoa bean shell with maize husk and PKS, [15].

Despite the current research feat, there are still need for sources and composites with properties very close or even better than those of asbestos. Hence, the aim of present study is to develop and investigate break lining material composites from PKS, CNS, and CSS, powders as reinforcements with epoxy resin as binding material. Various mechanical properties of the developed materials were tested, results presented and discussed.

## 2. Materials and methods

### *2.1 Material preparation*

CNS, PKS, and CSS are the materials for the brake lining. The binder material for this research work is epoxy resin, while the fillers are carbonate, metal filings and graphite. The materials were all obtained at the local markets in Zaria, Kaduna state, Nigeria. To remove impurities, the materials were cleaned, and sundried for a week. To further remove the moisture contents, oven drying was

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applied on the shells at 105 ºC for five (5) hours. To enhance easy grinding, hammer was used to break the dried shells into smaller sizes. The reduced sizes were then grinded using a clean grinding machine and subsequently sieved into mesh various sizes. Particles of size 125µm were collected and stored, while particles of other sizes were discarded.

*2.2 Mixing and moulding*

About one kg of each samples were produced using the compositions summarized in Table 1. KERRO digital weighing balance (model no. BL 3002) with maximum capacity of 300g was used to measure the samples. Epoxy resin (shell epikote 816) was measured and added into a plastic container, followed by filler materials and thoroughly mixed. Finally, the reinforcing material(s) was/were added with more thorough mixing carried out. The composites were cured under the sunlight after the accelerator and catalyst were added. Filler materials remained constant during the formulation of the samples. However, at 5% interval, the composition of the matrix and reinforcing materials were varied at 25 wt%, 30 wt%, 35 wt% and 40 wt%. At first, individual reinforcing materials were used singly for the production of the composite materials, and then a combination of the three were used to form an hybrid composite material. For the hybrid formulation, the variation of matrix composition and CSS powder was carried out while the filler materials and other reinforcing powder remained constant. Some formulated samples for relevant test are presented in Figure 1 (a)-(c).


**Figure 1** Test samples for (a) compression strength test (b) oil and water absorption test (c) wear test

**Table 1** Compositions of PKS, CNS, CSS, and other additives

| Materials | Sample (wt%) | | | |
|---|---|---|---|---|
| PKS | 25 | 30 | 35 | 40 |
| CNS | 25 | 30 | 35 | 40 |
| CSS | 25 | 30 | 35 | 40 |
| **Additives** | **(wt%)** | | | |
| Resin | 58 | 53 | 48 | 43 |
| Methyl ethyl ketone (catalyst) | 1 | 1 | 1 | 1 |
| Cobalt naphthalene (accelerator) | 1 | 1 | 1 | 1 |
| Graphite | 5 | 5 | 5 | 5 |
| Carbonate | 5 | 5 | 5 | 5 |
| Metal Chips | 5 | 5 | 5 | 5 |
| Total | 100 | 100 | 100 | 100 |

*2.3 Formulated composites characterization and analysis*

The optimal composition among the samples of the formulated composite materials was determined by characterization. The average values of the 3 tested pieces having the same composition were recorded. Among the reinforcing materials, the density of CSS is yet to be reported in literature. An approximate method was used to measure the densities of PKS, CNS and CSS (ref). Highly sensitive weighing balance was used to measure the mass of the powders with 10 ml volume each. To calculate the density, the obtained mass was divided by its volume. The procedure was done five times and the average value for the densities were recorded. The relevant characterization tests conducted on the materials as explained thus:

*2.3.1 Absorption test for oil and water*

This test gave details on the solvent absorbing capabilities of materials. Weighed samples (W_1) were soaked in water for 24 hours in an enclosed system and reweighed (W_2). Equation 1 was used for the determination of the % water absorption [16]. A solvent-engine oil (SAE 20/50) was used to conduct similar test.

$$A = \frac{W_2 - W_1}{W_1} \times 100 \quad (1)$$

Where a can be refered tp as the water or oil absorption.

*2.3.2 Compressive strength (CP) test*

The CP test of the brake pads composites were evaluated at room temperature using a universal testing machine (UTM) (Cat.Nr.261) of 100 kN load capacity. Each sample, with 200 mm² initial cross-sectional area, was securely gripped by the lower and upper cross members of the UTM lock. Initially, a small load was applied, and subsequently the load was gradually increased until the sample failed. The calculation of the sample's CP was done using the weight of the load when failure occurred.

*2.3.3 Hardness test (HT)*

An indentation hardness test was conducted using a direct durometer (model: 5019 and serial no: 01554) was employed in determining the composite's hardness. The hardness test was done by evaluation the relative resistance of the composite's surface to the indentation made by the indenter having a specific dimension and under a specified load.

*2.3.4 Wear test*

In conduction the wear test, a pin on disk apparatus was used. Under the same condition, both the commercial and developed brake pads were subjected to similar test. The developed samples were used as the disc with hardened steel as the wearing pin. The samples initial weight were taken using a weighing balance before loading on the apparatus. The coefficient of friction was equally measured during the test. Infrared thermometer (model DT 800) was used in measuring the initial temperature. The arm of the apparatus was loaded with a load of 100g and used as a normal force for the determination of coefficient of friction. The test was allowed to run for half an hour and Equation 2 was used in calculation the friction coefficient.

$$\mu = \frac{F_r}{N} \quad (2)$$

$$W.R = \frac{W_f - W_i}{W_i} * 100 \quad (3)$$

Where $\mu$ is the friction coefficient, $F_r$ is the frictional force (N), N is the normal force, while W.R, $W_f$ and $W_i$ are the wear rate (%), the final weight (g) and the initial weight (g) respectively.

## 3. Results and discussion

*3.1 Densities of reinforcing materials*

The average densities measured for the various reinforcing materials of PKS, CNS and CSS are 1.56, 1.593 and 1.24 g/cm3 respectively. These showed that the reinforcing materials with the lowest density is CSS powder, and thus it is expected that it's composite will weigh lesser than the other materials. Also, slight increase was discovered in the densities with increase in reinforcing materials. Thus, CSS powder is suitable for less dense materials, which is a desirable quality for automobile brake pads. The measured densities for PKS and CSS were in agreement with previous research [17, 18].

*3.2 Composite's water absorption properties*

The water absorption test results conducted using three test samples with the same compositions are represented in Figure 2 (a)-(d). Suffix A, B, C and D are the 25, 30, 35 and 40 wt% respectively of PKS, CNS, CSS and combined materials (CM) added to form the composites.

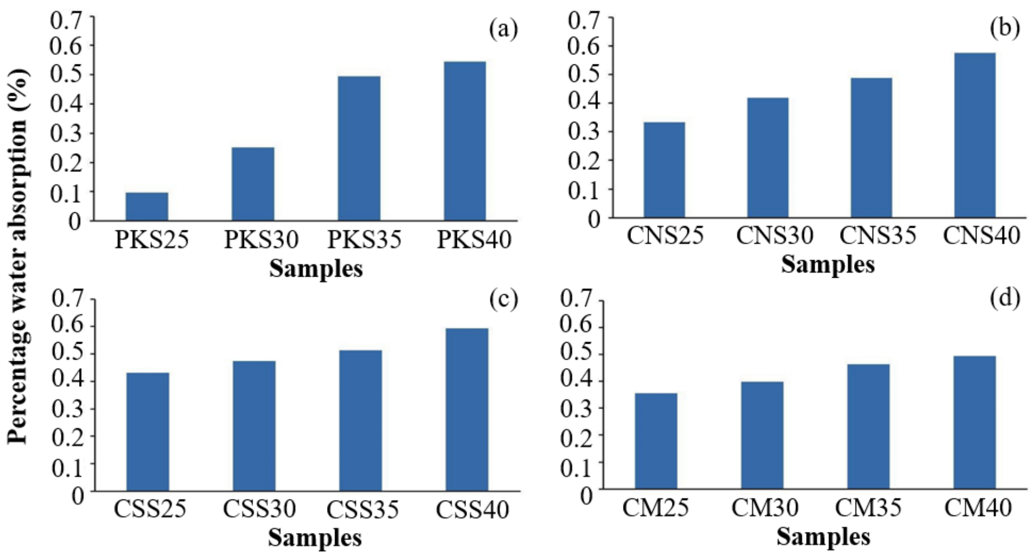


**Figure 2** Water absorption for (a) PKS reinforced composite, (b) CNS reinforced composite, (c) CSS reinforced composite, and (d) CM reinforced composite

Water absorption results as presented in Figure 2 (a)-(d) revealed that with increase in the reinforcing powder's composition, comes a proportionate increase in the quantity of absorbed water by the samples. Also, the rate of water absorption varies with the type of reinforcing powders used, and the highest percentage of water absorption of 0.59 % was realised for those produced using CSS powder (Figure 2(c)). Thus, confirming the more hydrophilic nature of CSS compared to other materials. Also, the water absorption rate for the hybrid composite is lesser than individual absorption rate as shown from the results (Figure 2(d)).

### *3.3 Oil absorption properties*

Oil absorption test results are presented in Figures 3 (a)-(d). The trends observed were similar to those of water absorption test. The oil characteristics were modified by the hybrid composites developed as a result of the combination of CSS with other materials. PKS was however, found to absorb oil the most followed by CSS.

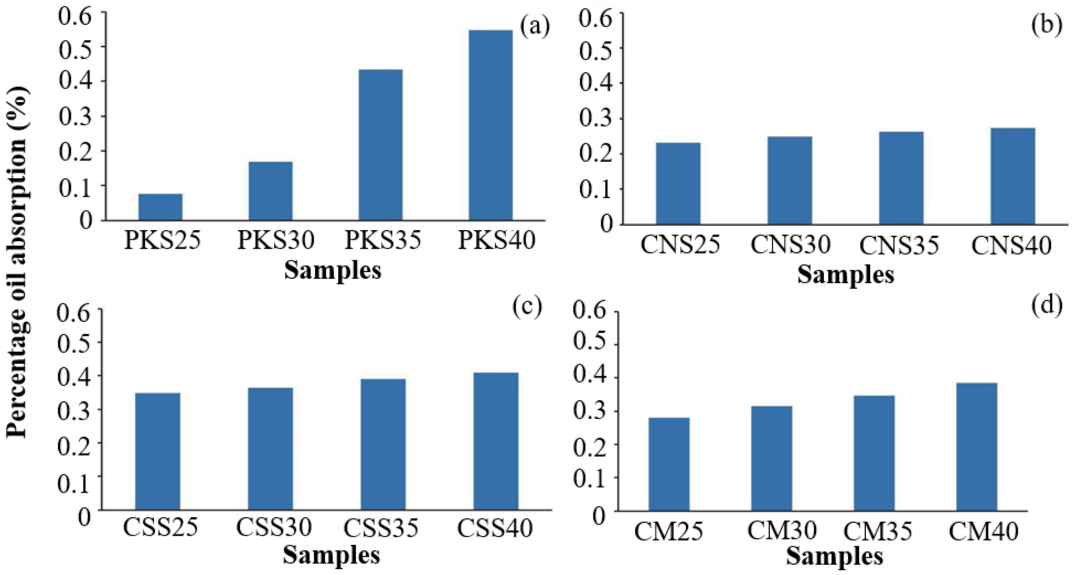


**Figure 3** Oil absorption of (a) composites reinforced by PKS, (b) composites reinforced by CNS, (c) composites reinforced by CSS (d) composites reinforced by CM

The results also revealed that the absorption capacity of water was more than those of oil for the developed composite material.

### *3.4 Compressive strength*

The average value of the three samples' compression test with are shown graphically in Figures 4 (a)-(d).

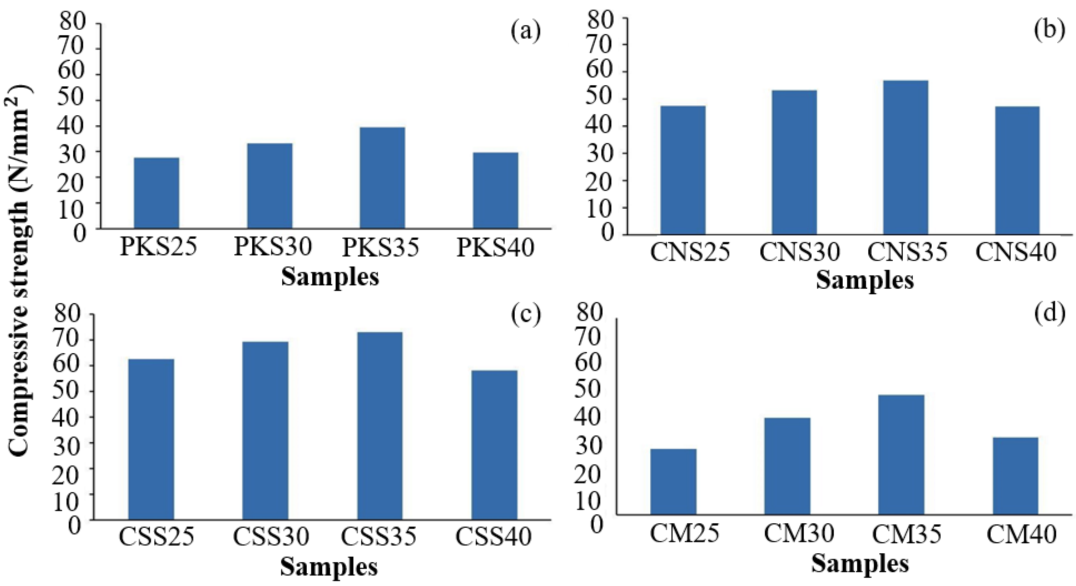


**Figure 4** Compressive strength of (a) composites reinforced by PKS, (b) composites reinforced by CNS, (c) composites reinforced by CSS, (d) composites reinforced by CM.

The pressure of the brake piston was estimated using the compressive strength test conducted on the composite materials that has been developed. The results of the compressive strength plot followed similar trends for each powder reinforced composite materials. An optimum composition of about 35 % for the composite materials was realised. However, the composite's compressive strength was decreased by further addition of reinforcement at 40 % (Figures 4 (a)-(d)). The results also revealed that the compressive strength of CSS powder reinforced materials is the highest compared to other material (Figures 4 (c)). The obtained results are consistent with previous research [19].

*3.5 Hardness value*

Hardness test results for three samples with same compositions are shown in Figures 5 (a)-(d).

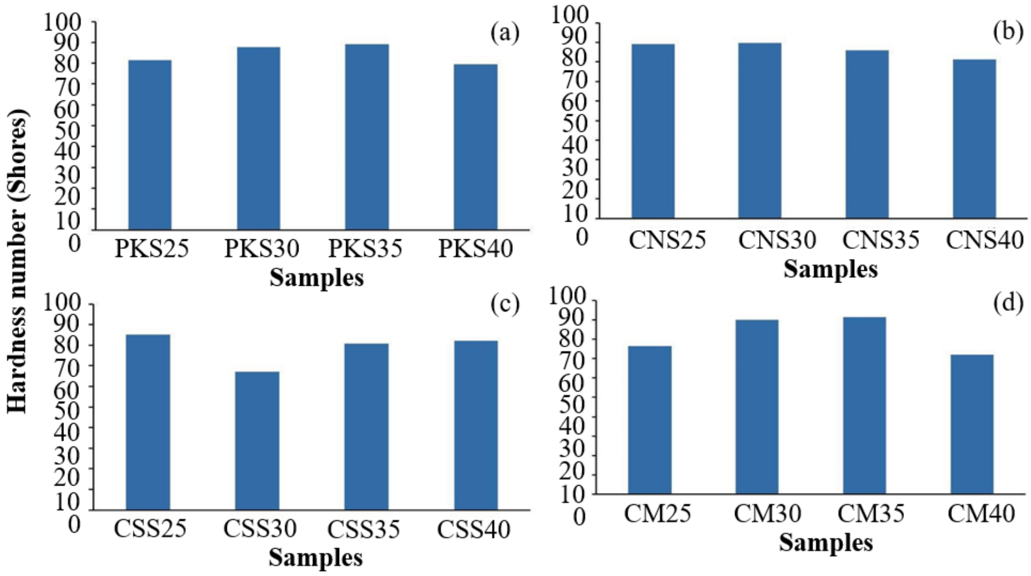


**Figure 5** Hardness number of (a) composites reinforced by PKS (b) composites reinforced by CNS (c) composites reinforced by CSS, (d) composites reinforced by CM.

The measured PKS and CM hardness numbers have similar trends with those of compressive strength. This implies that the lining materials having 35% of reinforcement is the most optimal as it gave the maximum hardness compared to the other formulations. Reinforcement of CNS and CM formulations with maximum hardness are 30% and 25% respectively. The results equally reveal that the highest hardness was achieved at 35% composition of the hybrid combination of the three reinforcement materials. The current maximum hardness values are also in line with those available in literatures [17, 18, 20].

*3.6 Wear properties*

The results of wear properties test performed on three tests with same composition are presented in Figures 6 (a)-(c).

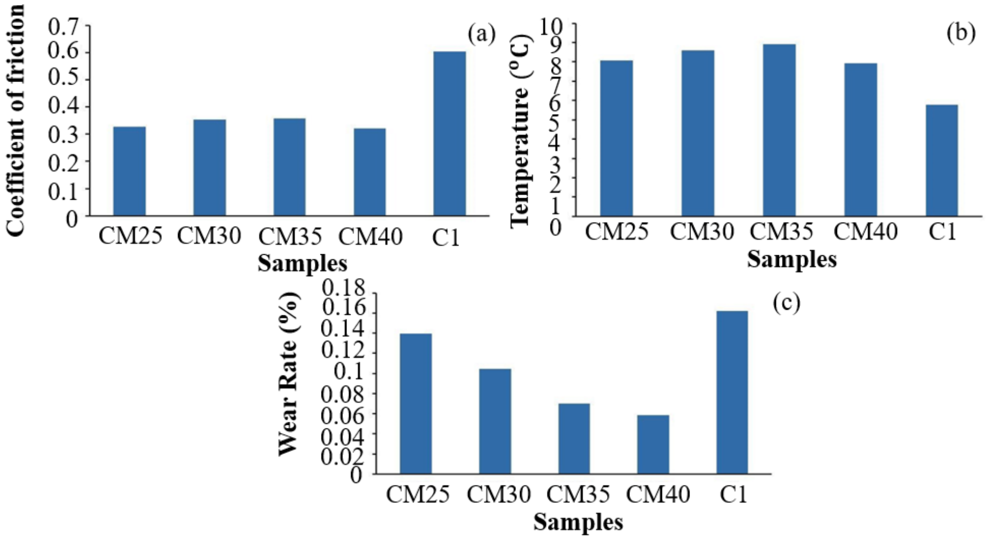


**Figure 6** (a) Average friction coefficient of CM reinforced composite, (b) Average temperature change of CM reinforced composite, (c) Average wear rate of CM reinforced composite.

Properties such as change in temperature and coefficient of friction were measure during the wear test. It was found that increase in the % compositon of reinforcing materials increased the coefficient of friction of the materials developed. Similar trends were noticed for all developed composite materials. The measured value friction coefficient for the developed lining materials are comparable with those agro waste-based brake lining materials reported in literature. Although, they are lower compared to those of commercial brake lining materials. The maximum friction coefficient of 0.57 was obtained for CSS powder reinforced material and closely followed by that of PKS and the least being that of CNS powder. Hybrid formulation of the three materials couldn't give a better friction coefficient as shown in Figure 6 (a).

The temperature change realised was in direct variation with the measure coefficient of friction for the considered materials. The value is thus expected to follow this trend since the temperature change is in direct proportion to the friction level developed between the two rubbing surfaces (Figures 6 (a) and (b)). On the contrary, the wear rate of the material developed are less when compared to the commercial brake lining materials. This could be linked to the variations between the formulations and constituents of the materials. Further optimization of the developed composite materials could make it a suitable alternative to the abestos based commercial brake lining materials.

## 4. Conclusions

CSS powder is viable for the production of brake lining material when combined with other fillers. It was observed that the sample's water and oil absorption increased with increase in the reinforcing powder's composition although they have higher absorption capacity for water that oil. The compressive strength of the developed composites increased with the addition of the reinforcing material up to an optimal composition of 35%. However, further addition of the reinforcing materials beyond the optimal value reduced the strength of the composite. The materials' hardness numbers were consistent with those of other researchers. The measured friction coefficients were also within the acceptable range for agro based materials. Although, they are below those of commercial brake lining materials. The wear rate for the materials developed are lower compared to those of commercial brake lining materials as a result of the variations in material composition. Optimization of the developed materials is encouraged for improving the properties. Better surface finishing of the samples could be achieved by the use of metallic moulds. Further research such as flexural, tensile and impact strength tests are recommended for further understanding of the samples behaviors under these loading conditions.

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