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Development of Automobile Brake Pads Using Three Biological Materials

[*a] Uche Asonye, [b]Angela Ofoma, [c]Izuchi Duruanyim, [d]Juliet Duruanyim

Department of Agricultural and Bio-systems Engineering, Federal University of Technology, Owerri, Nigeria.
[a]asonye4gladys@gmail.com, [b]nkiruofoma14@gmail.com, [c]izuchi.duruanyim@futo.edu.ng, [d]ezenwajuliet@gmail.com

Corresponding Author: Asonye Gladys, asonye4gladys@gmail.com (08030531299)

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Abstract: *This research centers on the development of an automobile brake pad using three biological materials namely; palm kernel shell, coconut shell and periwinkle shell with a view to replace the use of asbestos whose dust is carcinogenic and harmful to the health. The brake pad was developed using three biological materials which were; palm kernel shell powder, coconut shell powder and periwinkle shell powder as base materials, epoxy resin as binder material, copper and zinc as abrasives and rubber dust from shoe as filler materials. The grounded base materials were sieved into different sieve grades in the ratio of 30% palm kernel shell, 30% coconut shell, 30% periwinkle shell, 10% epoxy resin, 10% rubber dust, 10% silicon, 6.0% copper and 4.0% zinc using compression moulding. The properties of scratch hardness, tensile strength, swell test and wear rate were examined and the results obtained were compared with those of the commercial brake pad (asbestos-based). The results obtained for the developed brake pads gave $2.50x10^{-6}$g/m (Wear rate), 0.909% (Swell test), 78MPa (Brinell Hardness test) and 6.52 MPa (Tensile strength) and compared favourably with $3.80x10^{-6}$g/m (Wear rate), 0.9% (Swell test), 101MPa (Brinell hardness test) and 7.00 MPa (Tensile strength) for conventional brake pads. This is an indication that the three biological materials studied can be used in the production of asbestos free brake pads, and also serves as a replacement for some of the base components in the production of conventional brake pads, which have both health and environmental implications.*

Keywords: *Development, Automobile, Brake Pad, Biological Materials*

INTRODUCTION

Brake pads are important part of braking systems for all types of vehicles that are equipped with disc brakes. They are considered as one of the key components for the overall performance of a vehicle and as heterogeneous materials, they are usually made from more than 10 ingredients. An ideal brake friction material should have constant coefficient of friction under various operating conditions such as applied loads, temperature, speeds, mode of braking and in dry or wet conditions so as to maintain the braking characteristics of a vehicle. In addition, it should also possess various desirable properties such as resistance to heat, low water and oil absorption, low wear rate and high thermal stability, exhibits low noise, and should not damage the brake disc (Ossia *et al.*, 2020). The brake pad, one of the components of braking systems is designed for high friction at different temperatures, loads, environments, and stages of wear (Eriksson, 2000). The cost of acquiring asbestos as raw material for the production of brake pads and brake shoe lining for motor vehicle brake systems leads to an increase cost of production and subsequently increase in the purchase price of brake pads and brake linings while the biological materials 1tilized are most often considered as agro-waste which are affordable and readily available.

Also, Environmental pollution is a serious health hazard to humans, as it has been universally confirmed that materials used for the manufacture of brake pad and brake linings of motor vehicle produces asbestos dust that is capable of causing cancer of the lungs and brains in humans when inhaled (Iloeje, 1989). Hence with the challenges of economic and environmental concerns in terms of cost of brake materials and the health hazards of asbestos, research is focusing on the phasing out of asbestos-based materials for engineering applications due to their carcinogenic impact on human and animal health and the development of more environmentally friendly alternatives such as, palm kernel shells, coconut shells, and periwinkle shells which are locally biodegradable materials and have been explored with varying performance levels in the development of automobile brake pads (Ossia *et al*., 2020). Engineering materials that have negligible negative impacts on human and animal health, as well as, the environment are considered to be "green" materials (Chinwuba & Akuro, 2021). The investigation of new materials, especially agricultural waste as a filler material, is providing new and low-cost materials for development of brake pads which are commercially viable and environmentally acceptable and which have all the required properties. The introduction of agricultural wastes such as Palm kernel shells, Periwinkle and Coconut shells which are used as the base materials in this research work show desirable qualities such as: high strength, resistant to wear, and non-poisonous, hardness and environmental friendliness. They are easily reducible to granular form and can be compounded with many of the known additives to form friction linings, also they are accessible and affordable. These are desired mechanical and chemical properties which these alternative materials should possess to make them suitable for the production of non-carcinogenic brake pads and brake linings (Navin & Rohatgi, 1994). A lot of research has been conducted to develop brake pads using different agricultural residues or wastes and because of current regulations, research on eco-friendly brake friction materials has increased momentum. The objectives for using alternative filler materials for brake pads are to eliminate the potentially destructive components used in the brake pad material formulation, reducing the brake pad wear rate and maintaining friction properties (Lee and Filip, 2013).

In recent times, researchers have tried a number of investigations and new ways to innovate new brake pad material, especially with agricultural wastes and other locally available materials. Achebe *et al*. (2018) examined the properties of an asbestos-free automobile brake pad developed with palm kernel fiber (PKF) as filler material combined with epoxy resin as a binder. They produced three sets of composition with procedures, equipment and standard materials to decide their possible performance. From the result, the hardness and specific gravity of the brake pad sample were increased as the filler content increased, showing that palm kernel fibre (PKF) can be used as a filler material and also as a substitute material for manufacture of the asbestos brake pad. Aigbodion *et al*. (2010) produced non-asbestos brake pads using bagasse as an asbestos substitute and phenolic resin was used as binder in the brake pads production. The results of their study in which they used 100 μm sieve of bagasse in the composition of 70% bagasse and 30% phenolic resin showed that bagasse can be used as an asbestos substitute in the manufacture of brake pads with good mechanical, physical and tri-biological properties. Ossia *et al*. (2020) used coconut shells as a filler to produced asbestos-free brake pads with other constituents and used epoxy resin as binder matrix. They conducted several tests to investigate the composition and optimal performance compared to the Honda (Enuco) model brake pad made in Nigeria. The results showed that a high percentage of ground coconut shell powder provided hardness, low breaking strength, impact strength and compressive strength, indicating that Coconut Shell powder increased the brittleness of the pads. Olabisi and Ademoh (2016) produced brake pads using maize husks as a filler with epoxy resin as a binder. They studied the mechanical, physical and tri-biological properties of the sample. Their result showed appreciable increase in the wear rate, hardness, compressive strength, tensile strength, density and friction coefficient properties of the sample which indicates that the brake pads produced was eco-friendly and suitable for asbestos-free brake pad friction material. Mgbemena *et al*. (2014) developed the Palm kernel shell (PKS) based pulverized non-asbestos friction material for reinforcing constituents and controlling friction of brake pads. Their results showed great improvement in the wear rate properties of the developed brake pads. Yawas *et al*. (2016) performed morphological tests of shellfish granules for friction plate material.

Asbestos-free automotive brakes using periwinkle shell particles as frictional filler material was developed. The thermal tests conducted on the shellfish material for friction properties showed quite good results. Idris and Aigbodian (2019) produced new brake pads using banana peels waste to replaced asbestos and Phenolic resin (phenol formaldehyde) as a binder. The resin was varying from 5 to 30 wt% with interval of 5 wt%. Morphology, physical, mechanical and wear properties of the brake pad were studied. The results showed that compressive strength, hardness and specific gravity of the produced samples increased with increase in wt% resin addition, while the oil soak, water soak, wear rate and percentage charred decreased as wt% resin increased. The samples, containing 25 wt% in uncarbonized banana peels and 30 wt% carbonized banana peels gave the better properties in all. The result of their research shows that banana peels particles can be effectively used as a replacement for asbestos in brake pad manufacture. Yawas *et al.,* (2013), studied the development of asbestos-free automotive brake pads using periwinkle shell particles. This was with a view to exploring the characteristics of the periwinkle shell, which is largely deposited as a waste, in replacing asbestos which has been found to be carcinogenic. Five sets of brake pads with different sieve size (710–125 lm) of periwinkle shell particles with 35% resin were produced using compressive moulding. The physical, mechanical and tri-biological properties of the periwinkle shell particle-based brake pads were evaluated and compared with the values for the asbestos-based brake pads. The results obtained showed that compressive strength, hardness and density of the developed brake pad samples increased as the particle size of periwinkle shell decreased from 710 to 125 lm, while the oil soak, water soak and wear rate decreased with decreasing particle size of periwinkle shell. The results obtained at 125 lm of periwinkle shell particles compared favorably with that of commercial brake pad. Dagwa and Ibhadode (2006) developed asbestos free friction lining materials from palm kernel shell. In their study the mechanical and physical properties as well as the static and dynamic performance compared well with commercial asbestos-based lining material.

Olerie *et al.* (2007) investigated the changes induced by repeated brake applications and how much material modification affected friction and wear properties of the automotive break disc. Surface films were investigated by transmission electron microcopy (TEM) after preparing thin cross-sections with a focused beam instrument (FIB). Kim and Jang (2000) studied the friction and wear of friction materials containing two different phenolic resins reinforced with aramid pulp, investigated the friction and wear characteristics of automotive materials containing two different phenolic resins (a straight resin and a modified novalac resin) using a pad-on-disc type friction tester. Cho *et al.* (2005), worked on the development of fly-ash based automotive brake linings. They developed friction composite using fly ash obtained from a specific power plant in Illinois. Additives such as phenolic resin, aramid pulp, glass fibre, potassium titanate, graphite aluminium fibre and copper powder were used in the composite development phase in addition to fly ash. The developed brake lining composites exhibited consistent coefficient of friction in the range of 0.35–0.4 and wear rates lower than 12 wt%. Aku *et al.* (2012) studied the characterization of periwinkle shell as asbestos-free brake pad materials. They found out that periwinkle shell is an agricultural waste. The waste is produced in abundance globally and poses risks to the humans as well as environmental health. Thus, their effective, conducive, and eco-friendly utilization has always been a challenge for scientific applications. The characterization of the periwinkle shell was investigated through X-ray diffractometer (XRD), thermogravimetric analysis (TGA/DTA), Fourier transform infra-red density, hardness values and wear rate of the periwinkle shell were also found. Results obtained were found to be comparable with asbestos commonly used in brake pad production. The use of palm kernel shell, coconut shell and periwinkle shell have been attempted as singular base materials in the development of brake pads, however this present research optimizes the high lignin and cellulose content of coconut shell, high porosity and low density of palm kernel shell and the high compressive, hardness and good bonding properties of periwinkle shells as combined base materials in the production of automatic brake pads with higher efficiency and better mechanical properties.

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MATERIALS AND METHODS

2.1 Materials

2.1.1 Palm kernel shells

The palm kernel is the edible seed of the oil palm fruit. The fruit yields two distinct oils: palm oil derived from the outer parts of the fruit, and palm-kernel oil derived from the kernel. The pulp left after oil is extracted from the kernel is formed into "palm kernel cake", used either as high-protein feed for dairy cattle or burnt in boilers to generate electricity for palm oil mills and surrounding villages. Palm kernel shells (PKS) shown in plate-1 below is a by-product of palm-kernel oil production, has been found to be a good base material for bio fuel production (Dagwa and Ibhadode, 2006). The shells that remain after the oil has been extracted are called PKS (palm kernel shells).

Plate-1 The palm kernel shells

2.1.2 Coconut Shells

Coconut shell, shown in plate-2, is the outer hard cover of Coconut. It is a waste product that has found use as an alternative fuel source and has also been maximized in the handicraft industry to make very interesting pieces of art. Furthermore, the coconut shell waste is renewable, cheap and easily accessible. Previous studies have shown coconut shell has a potential as a friction material for non-asbestors brake pad on light weight automobile such as motorcycle, due to some of its great physical properties like high compressive strength (Belhocine and Nouby, 2015).

Plate-2 Coconut shells

2.3 Periwinkle Shells

Periwinkle shell shown in Plate 3 is a waste product generated from the consumption of a small greenish-blue marine snail periwinkle, housed in a V shaped spiral shell and found in many coastal communities within Nigeria and other tropical swampy regions of the world. The shell is a very strong, hard and brittle material (Dagwa and Ibhadode, 2006). The edible part of periwinkle is eaten as sea food while the shell, shown in plate-3 is disposed off as waste. Recently, the shells have found use as coarse aggregates in concrete areas where neither stones nor granite are readily available for purposes of paving water-logged areas, soak away and slabs for home and also in road construction. However, large amounts of these shells are still disposed as waste, constituting environmental problem. Hence, the use of this material in the development of an automobile disk brake pad will reduce or eliminate these environmental concerns.

Plate-3 Periwinkle Shells

2.2 Methods

The Process of developing the brake pads is shown in Fig. 1.

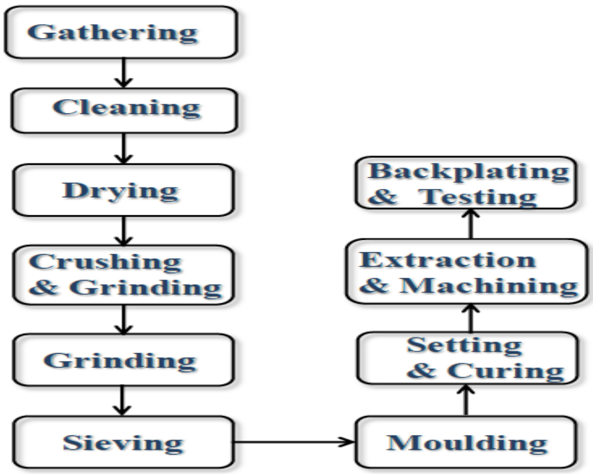

Fig. 1 Brake pad sample development process (Ossia *et al*., 2020)

2.2.1 Sample Collection and Preparation

The following materials used for the production of the automobile brake pads were carefully selected and they include the following; Palm kernel shell powder, Coconut shell powder and Periwinkle shell powder used as base materials; Silicon powder as the lubricant, Copper and zinc as abrasives, Epoxy resin as binder material, Rubber dust as filler material and Water. In selecting these materials, some important factors were considered which include; High coefficient of friction, Low wear rate, good heat dissipation while retaining the mechanical strength, Ability to dry up as quickly as it passes through water. The collected samples were thoroughly cleaned to remove dirt, impurities and bad smell.

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2.2.2 Drying and Crushing

The palm kernel shells, coconut shells and periwinkle shells were dried in sunlight for 3 days to reduce their moisture content; after which they were grinded in the laboratory to powdered condition of different grit sizes using a hammer mill.

2.2.3 Sieving

The grinded shells were separated into different grain sizes (90μm, 125μm, 250μm, 300μm and 500μm) using the tyrap sieve shaker and separated into different bags with their grain size labels.

2.2.4 Moulding / Mixing

The mould was designed with solid works software and fabricated in the Engineering Workshop of the Federal University of Technology, Owerri. The process involves cutting into shape and welding. The mixture of palm kernel shell, coconut shell and periwinkle shell powder were poured into a clean bowl and stirred thoroughly to get a homogenous constituent. The binder (Epoxy resin) was added last to avoid the mixture getting hard before leaving the bowl, and other additives included were copper, zinc for abrasiveness, carbon black for strength and rubber dust for vibration absorption.

Plate-4 Moulded base material for the brakepad

Samples of different compositions were mixed and moulded to get four samples of brake pads which were labelled Samples A, B, C and D respectively. The moulds were waxed thoroughly using mirror glaze wax and allowed to dry for 6 minutes. The mixture was then poured into the mould gently until the required depth of 5.25mm is covered with the material. A locally produced hydraulic press was applied to compress the mixture together to the back plate firmly at a pressure of 250kgf/cm. The samples produced was then left to harden for 60minutes.The moulded and compacted brake pad samples were heated in an electric oven *(Model: GE30)* for 2 hours at 120^0C to ensure proper binding of the constituent material. The demoulding process involved removing the samples from the mould gently; such that cracks will not be introduced on the samples. Extraction was done after leaving the newly made brake pads for 1 day to cool and become very hard. The grease applied before the mixture was poured into the mould for easy extraction. The extracted brake pad sample is then machined to shape using the milling machine **(***Model: HURE SA-PU771, France)* and a cutting disk with a spindle speed of 288 rpm.

Plate-5 The produced brake pads from biological materials

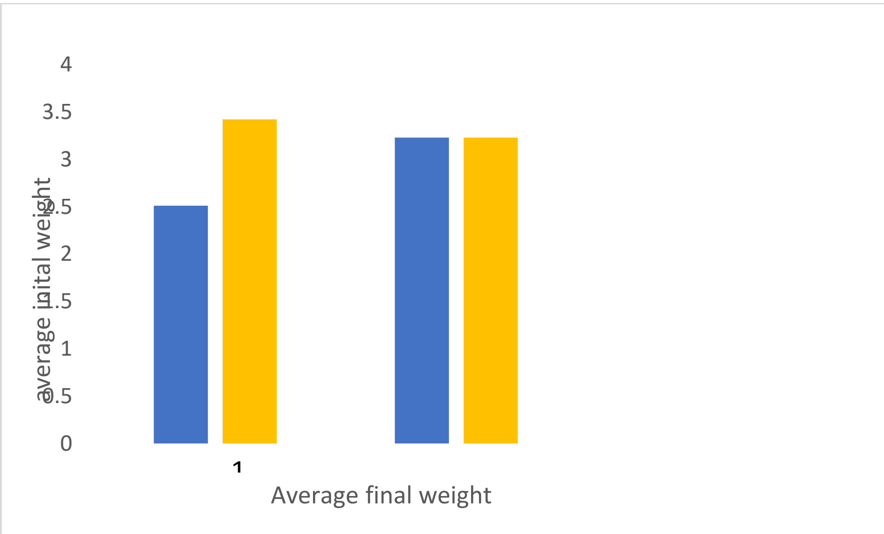
RESULTS AND DISCUSSION

Tests were carried out to evaluate the performance of the brake pad samples developed and the results obtained were compared with the commercial brake pad (asbestos based).
The tests carried out include;

i. Wear rate test
ii. Water and oil absorption test (thickness swell test)
iii. Brinell hardness test
iv. Tensile strength test

3.1 The Wear Rate Test

The results of the wear rates test compared favourably with the asbestos-based brake pad which is the control. Wear rate of conventional brake pad is 3.80×10^{-6}g/m while the least wear rate obtained with the developed brake pad was 2.50×10^{-6}g/m as shown in Fig. 2. This could be attributed to increasing interfacial bonding between Palm kernel shell particles, coconut shell particles. Periwinkle particles and epoxy resin, reducing possibility of particle pull out (reduce wear). This confirms the possibility of using these biological materials as a replacement for asbestos-based materials in the production of brake pads.



= Coconut shell + pks+ periwinkle shell = Control

Fig. 2. Wear rate test of developed and conventional brake pads

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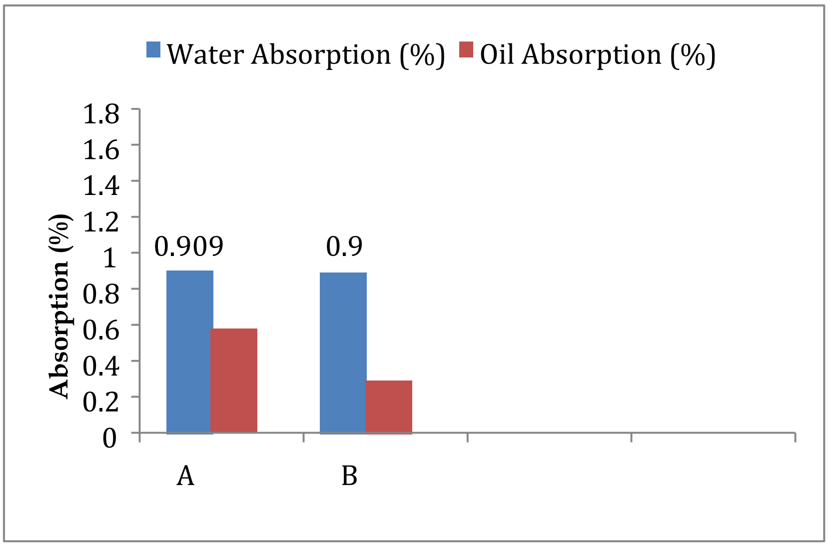
3.2 The Swell Test

Water and oil absorption rates of the developed brake pads were carried out and compared with the conventional brake pads. Results obtained indicated closeness as shown in Fig. 3.

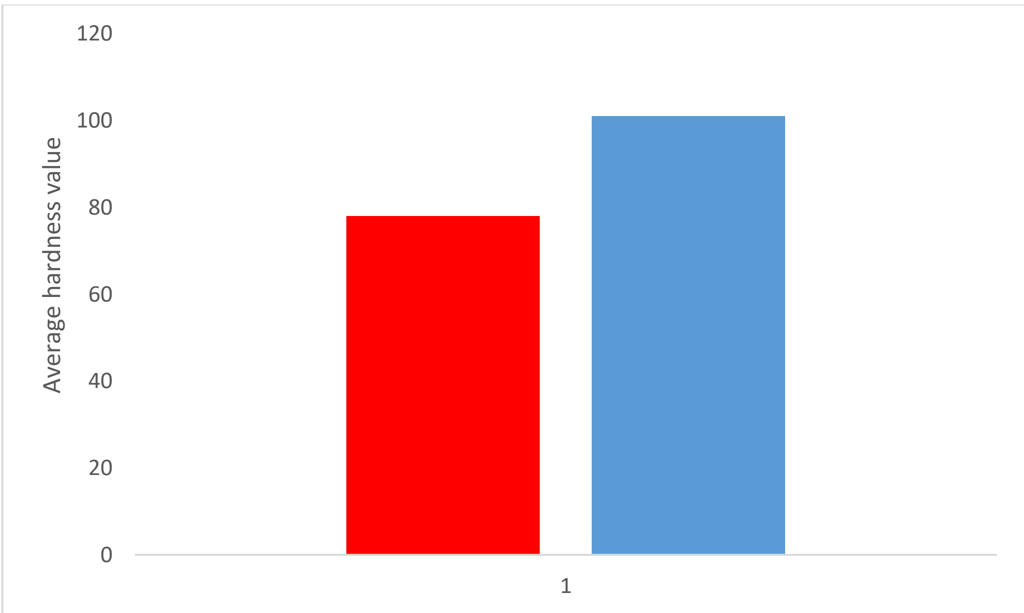


A = Developed brakepad, **B** = Conventional brakepad

Fig. 3. Analysis of oil and water absorption of the samples

3.3 Brinell Hardness Test

The result of the hardness test obtained compared favourably as hardness value for conventional brakepad is 101MPa and average hardness value obtained for the developed brakepads gave 78MPa as displayed in the Fig. 4 below.



Coconut shell + pks+ periwinkle shell = Control

Fig. 4. Analysis of average hardness value for developed and conventional brake pads.

3.4 Tensile Strength Test

The behaviour of the developed brakepads showed significant effects on the tensile load required to produce a specific extension of the samples before rupture as shown in Fig. 4. The Tensile test was used to measure the specimen's plasticity tendency under tensile loading. Tensile strength of the conventional brake pad is 7.00MPa and the average tensile strength value obtained for the developed brake pad (palm kernel shell + periwinkle shell + coconut shell) was found to be 6.52MPa which compares favourably with the asbestos based brake pads.

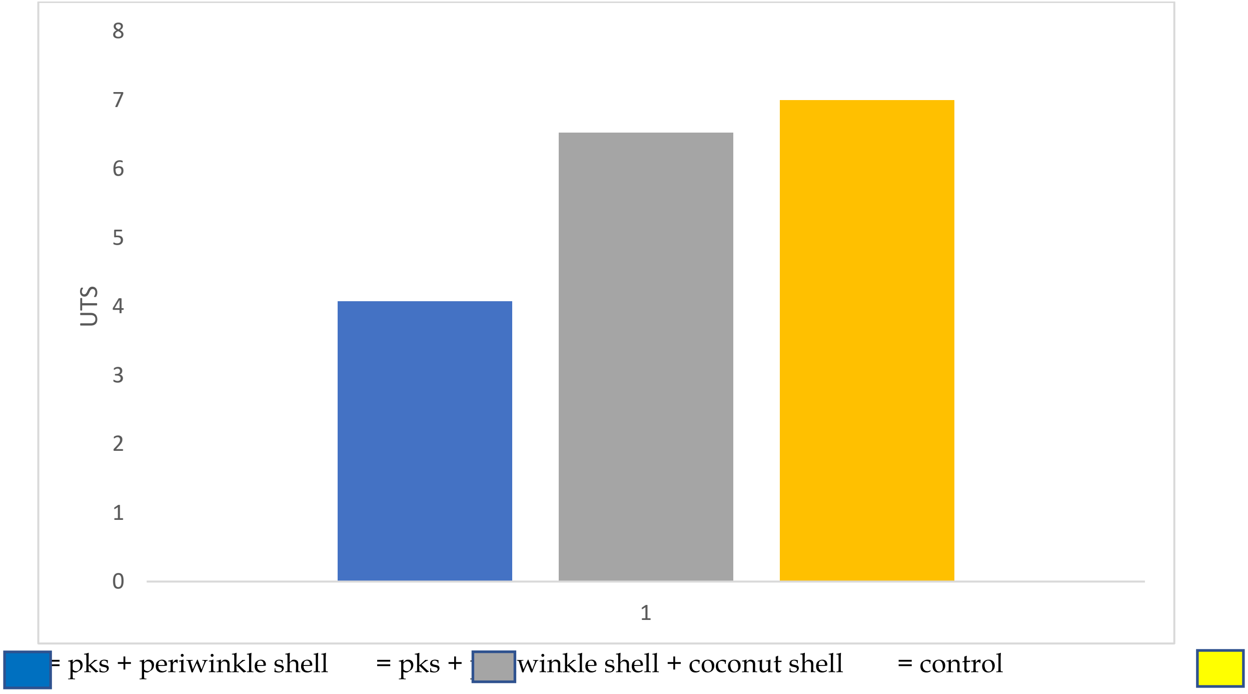


Fig. 4. Analysis of Tensile Strength for the developed and conventional brake pads.

CONTRIBUTION TO KNOWLEDGE

An automobile brake pad was successfully developed from three biological materials which are considered agro-waste. Palm kernel shell, coconut shell and periwinkle shell were used in combination with binder (epoxy resin) and filler (rubber dust from shoe) materials to produce automobile brake pads. The use of the three biological materials in this research optimized the unique characteristics of the three biological materials such as the high lignin and cellulose content of coconut shell, high porosity and low density of palm kernel shell and the high compressive, hardness and good bonding properties of periwinkle shells to produce brakepads with strong mechanical and frictional properties that are also affordable and environmentally friendly.

CONCLUSION

The challenges of economic and environmental concerns in terms of cost of brake materials and the health hazards of asbestos, has led to research focus on the phasing out of asbestos-based materials for engineering applications and the development of more environmentally friendly alternatives such as, palm kernel shells, coconut shells, and periwinkle shells which are locally available as they are classified as agro-wastes and are equally biodegradable materials.

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Results obtained for the different tests gave average values of 78Mpa Hardness value, 0-909 swell rate, 6.52 Mpa Tensile strength and 2.50 x 10-6g/m wear rate which compared favorably with the conventional asbestos-based brake pads. Palm kernel shell, Periwinkle shell and Coconut shells used in combination as base materials in this research work gave optimal results over previous research works that were carried out in which each of these biological products were used individually as base materials for automobile brake pad production. The outcome of this research is an indication that the three biological materials studied can be used in the production of asbestos free brake pad, and also serves as a replacement for some of the base components in the production of brake pads, which have both health and environmental implications.

CONFLICT OF INTEREST

The authors declare no conflict of interests.

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