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A Review of Renewable Materials for Automobile Brake Pad Production

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ABSTRACT:

An overview of materials suitable for the production of automobile brake pads using renewable materials is a review carried out to assess a number of options available in materials selection, production methods and testing of brake pads for road applications. This is with a view to harnessing the potentials of agricultural wastes and other renewable materials which exist in abundant quantities. Suitable, biodegradable, environmentally friendly materials from a hazy array are explored in this review. Turning around waste for productive use has enormous benefits such as environmental protection and wealth creation. It is recommended that the various materials and techniques be profiled and developed on commercial scale in order to translate the results into real technological gains.

Keywords: automobile, brake pads, renewable, friction material, evaluation, biodegradable, environmentally friendly.

Introduction

Brake pads are a mixture of five types of materials (Agunsoye *et al.*, 2017). They include binding, abrasive, filler, structural, and performance materials. These materials cut across over 2,000 possible substances. The exact composition of any brake pad is known only to the specific manufacturer. Quite often, proper selection of friction materials as well as the appropriate quantities of constituents is mainly based on experience or by trial and error method to make new formulations (Vignesh *et al.*, 2015). In most cases this has been shown to be more of an art than science (Ikpambese *et al*., 2014). In the various cases, a number of experimental techniques have been employed, from the formation of blends, optimization of process parameters, the production methods as well as the various tests, to determine performance parameters with respect to mechanical properties, thermal properties, metallurgical properties, water and oil soak, and environmental qualities such as squeal. A close look at the various materials and the research carried out on them are herein reviewed.

Banana peels

Idris *et al.,* (2015) examined the use of banana peels as a possible material for brake pads with

phenolic resin (phenol formaldehyde) as a binder. The resin was varied from 5 to 30 wt% with an 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 were seen to be increasing with increase in wt% of resin addition, while oil soak, water soak, wear rate and percentage charred decreased as the wt% of resin increased. On the whole, samples containing 25 wt% in uncarbonized banana peels (BUNCp) and 30 wt% in carbonized (BCp) gave better properties. The result of this research indicates that banana peel particles can be effectively used in brake pad manufacture.

Sawdust

Lawal, Bala, and Alegbede (2016) researched on Sawdust as an alternative material for brake pad. In this work, a new brake pad was developed using an agro-waste material of sawdust along with other ingredients. This was with a view to exploiting the characteristics of sawdust which are largely deposited as waste around sawmills. A brake pad was produced using sawdust as a base material following the standard procedure employed by the manufacturers. The sawdust was sieved into sieve grades of 100µm, 355µm and 710µm. The sieved sawdust was used in production of brake pad in ratios of 55% sawdust, 15% steel dust, 5% graphite, 10% silicon carbide and 15% epoxy resin using compression moulding. The properties examined were microstructure analysis, hardness, compressive strength, density, ash content, and wear rate and water absorption. The results obtained showed that the finer the sieve size the better the properties. The results obtained in this work were compared with those of asbestos-based commercial brake pads, and showed a close correlation. Hence sawdust can be used in production of brake pads.

Sugarcane Bagasse

Development of brake pads using sugarcane bagasse is a research work carried out by V. S. Aigbodion *et al.,* (2010). The bagasse was sieved into sieve grades of 100, 150, 250, 350 and 710µm. The sieved bagasse was used in production of brake pad in ratio of 70% bagasse-30% resin using compression moulding. The properties examined were microstructure, hardness, compressive strength, density, flame resistance, water and oil absorption. The microstructure reveals uniform distribution of resin in the bagasse. The results obtained showed that the finer the sieve size the better the properties. The results obtained in this work were compared with that of commercial brake pad (asbestos based) and found to be in close agreement. Hence bagasse can be used in production of brake pad.

Hemp fibre

According to Dr Luke Savage (2018) of the University of Exeter, natural fibres such as hemp can replace costly aramid fibres in brake pads, with no loss of performance and less impact on the environment, according to research by the Sustainable Technologies Initiative (STI). Brake pads are one of the key components in the race to develop greener transport, with 80 million sets used in the UK alone every year. Since the use of asbestos was phased out in the 1980s, most have been formulated using aramid fibres. They also incorporate significant amounts of heavy metal compounds. Around 20,000 tonnes of dust containing these materials are discharged into the environment as the pads wear. New research into eco-friendly brake pads, backed by the STI, has shown how a switch to natural fibres, such as hemp, could offer a more sustainable solution. In the Ecopad project, researchers demonstrated how renewable fibres can reduce reliance on synthetic materials and allow heavy metal constituents to be replaced with safer alternatives. The outcome is expected to provide up-to-date solutions to the global transport industry and revolutionalize the search for brake pad friction materials.

Palm kernel shell and coconut shell powder

Darlington Egeonu and Patrick N. Okolo (2015) reported that high quality brake pad was produced from locally sourced raw materials in their work carried out in Nsukka, Nigeria. The disc brake friction lining with geometrical specification of Mitshibushi L-300 was produced using palm kernel shell and coconut shell powder as base material, polyester resin as binder material, graphite as lubricant, metal chips and carbides as the abrasives. A commercially purchased brake pad served as control. Three different samples were produced by varying mass compositions of palm kernel shell and coconut shell. Sample A had equal mass of palm kernel shell (PKS) and coconut shell (CNS). Sample B had higher mass of PKS (83.03%) and lower mass of CNS (12.68%) while Sample C had lower mass of PKS (14.79%) and higher mass of CNS (35.92%). A constant pressure of 16.75kN/m^2 and particle size of 0.63mm (or 630µm) was used for all samples. The binder, lubricant and abrasive composition were kept constant. The test result showed that the coefficient of friction (static and dynamic) for samples A, B and C were (0.374, 0351), (0.383, 0354) and (0.362, 0.349) while the commercial pad was (0.388, 0.359). Percentage water absorption for samples A, B and C were 0.0522, 0.0399 and 0.0470 while the commercial pad was 0.0327. The hardness test results for sample A, B and C gave 3.3, 3.41 and 3.0 while the commercial pad was 2.53. The wear rate test gave 0.00366g/sec, 0.00456g/sec, 0.00334g/sec, 0.00312g/sec for samples A, B, C and commercial pad respectively. All the samples were tested under the same conditions. Sample C had a promising potential since it had a moderate water absorption, wear rate and hardness but had the least coefficient of friction.

Cow hooves

Bala *et al.,* (2016) investigated cow hooves as a possible brake pad material. They observed that asbestos has been used for so long as automobile brake lining material because of its good physical and chemical properties; but due to the health hazard associated with its handling, it is out of favour with manufacturers and several alternative materials are being increasingly used. A new brake was developed in this work using pulverized cow hooves along with epoxy resin, barium sulphate, graphite and aluminium oxide. This was with a view to exploiting the characteristics of cow hooves, which are largely discarded as waste materials. Samples of brake linings were produced using compressive moulding in which the physical and mechanical properties of the samples were studied. The results obtained showed that proper bonding was achieved as the percentage by weight of epoxy resin increased and percentage by weight of pulverized cow hooves decreased. The hardness, compressive strength, coefficient of friction, water and oil absorption, relative density and wear rate of the brake linings were determined and compared with existing brake lining properties. The result indicates that pulverized cow hooves can be used as brake friction material for automobiles.

Egg shells and Gum Arabic

Edokpia *et al.,* (2014) investigated the properties of eco-friendly (biodegradable) brake pad using egg shell (ES) particles and Gum Arabic (GA). The brake pad formulation was produced by varying the GA from 3 to 18 wt%. The following properties were tested: wear rate, hardness values, compressive strength, thickness swelling in water and SAE oil, thermal resistance and specific gravity. The microstructure of the brake pad showed that fair bonding was achieved with the formulations from 15 to 18 wt% of GA. The sample with 18 wt% of GA in ES particles gave the best properties. The temperature of maximal decomposition of ES particles was higher than asbestos and many agro-wastes currently used in the production of brake pad materials. The results obtained at 18 wt% of GA in ES particles formulation compared favourably with the commercial brake pad. Hence, the developed brake pad can be used in the production of brake pad for engineering application.

Coconut shells

In their work, Abutu *et al*., (2018) locally sourced non-hazardous materials and used them to produce brake pad using grey relational analysis (GRA) and experimental design via central composite design. Raw materials selected for production included coconut shell, epoxy resin (binder), graphite (friction modifier) and aluminium oxide (abrasive). Twenty-seven samples were produced separately using coconut shell as reinforcement material by varying process parameters. Formulation of the brake pads samples was done using rule of mixture and a weight percent of 52% reinforcement material, 35% binder, 8% abrasive and 5% friction modifier were used for the production. Grey relational analysis (GRA) showed that optimal process performance could be obtained using moulding pressure, moulding temperature, curing time and heat treatment time of 14 MPa, 140 °C, 8 min and 5 h, respectively. Optimized sample was produced using the optimal set of process parameters obtained from GRA and compared with commercially available sample produced by Ibeto Group. The experimental results showed that the performance of the optimized coconut shell-reinforced brake pad compared satisfactorily with commercially available samples and capable of producing less brake noise and vibration during application. Analysis of variance shows that curing time with a contribution of 30.38% and 31.40% have the most significant effect on the hardness and ultimate tensile strength of the coconut shell-reinforced friction material, respectively, while heat treatment time with a contribution of 46.3% and 24.23% had the most significant effect on the wear rate and friction coefficient of coconut shell-reinforced brake pad, respectively. The effects of all the factors on the properties of the friction materials were significant since their p values were greater than 0.010 (1%).

Periwinkle shells

The shell of periwinkle is the outer casing of the animal which is usually discarded after the flesh inside is consumed. They are usually considered as agricultural waste products in riverine areas of southern Nigeria. Yawas *et al*., (2013) developed brake pad using periwinkle shell as reinforcing material. The periwinkle shells used during the study were ground and sieved into grain sizes of 125, 250, 335, 500 and 710 µm, and were mixed with 35% phenolic resin binder. Five test samples were produced using compression moulding machine at a pressure of 40 kg/cm^2, a moulding temperature (160ºC) and a curing time (1.5 hours). All the samples were cured in an oven of temperature 140 ºC for 4 hours. The microstructure (surface morphology) of the developed friction materials was analyzed using scanning electron microscope (SEM) and the results indicated that the microstructure of the developed samples showed a homogeneous distribution as the periwinkle shell particle sieve size decreased. Mechanical, physical and tribological properties of the periwinkle-shell-based brake pads were also investigated and compared with the properties of asbestos-based brake pads. It was reported that the hardness, compressive strength and density of the formulated brake pads increased as the particle size of periwinkle shell decreased from 710 to 125 µm while the oil absorption, wear rate and water soak rate decreased as the particle size of the periwinkle shell decreased. The results obtained for the sieve size of 125 µm of periwinkle shell particles compared well with that of commercial brake pad. The optimal values of the test results reported include specific gravity (1.01 g/cm^3), coefficient of friction (0.41), hardness (116.7 HRB), Compressive strength (147 N/mm^2), and thickness swell in water (0.39 %) and thickness swell in SAE oil (0.37 %). It was therefore concluded that periwinkle shell particles could effectively serve in the production of brake pads

Rice husk and Ulexite

In this study, Ilker Sugozu investigated the use of rice husk (RH) dust when added to Ulexite (UX) for the purpose of estimating the effect on friction coefficient. RH includes silica which gives the pad materials a ceramic-like behaviour. To obtain RH dust, rice husk was ground after it had been dried. Different amounts of RH were included in the brake pad mix in addition to the other regular components. UX is a boron mineral which is widely used in boron glass production and in ceramic industry for increasing heat resistance and abrasion resistance. The newly formulated brake pads were tested by the friction assessment and screening test (FAST). The friction coefficient and wear rate were determined and investigations by scanning electron microscope (SEM) of the friction surfaces were carried out to estimate the performance of these samples.

Palm ash

Ruzaidi *et al*. (2011) conducted a study to produce a brake pad at varying compositions of palm ash and polychlorinated biphenyl (PCB) waste along with thermosetting resin as a binder and metal filler as abrasive. Five samples were produced using moulding pressure, moulding temperature and curing time of 122 MPa, 150 ºC and 5 minutes respectively, and were tested to examine its compression strength, water absorption rate, wear rate, and morphological properties. The test results showed that the brake pads with higher percentages of palm ash gave the better mechanical and wear properties. This indicates that the wear properties of the produced brake pads were comparable with conventional brake pad. The study also concluded that brake pads could be developed by replacing asbestos with other reinforcement materials such as palm ash and PCB waste which could lower the cost of producing brake pad. It was also suggested that compressive strength of the product could be increased if the percentage of palm ash in the composition is also increased while the samples with higher palm ash content may give optimum wear properties and water absorption rate which will lead to better properties of brake pad application.

Palm kernel shells

Fono–Tamo and Koya, (2013), developed brake pad materials for automobile using standard factory procedure from palm kernel shell. Mechanical properties of the material developed were studied. The results showed that the developed pad had an average hardness of 32.34 and average shear strength of 40.95 MPa. The coefficient of friction of the product was also tested and the result indicated that the pad possessed a frictional coefficient of 0.43. This result was in agreement with the work of Koya *et al*., (2004) in which it was stated that the coefficients of friction of palm kernel shell on metal surfaces were in the range of 0.37–0.52. In comparison, friction coefficient that falls within the range of 0.30–0.70 is desirable when using brake pad material (Roubicek *et al.,* 2008). The bonding of the material to the back plate was also tested and the result indicated a value of 3375 N/s. All the values of the responses though not as excellent as asbestos–based brake pads whose coefficient of friction falls within 0.37–0.41 as the recommended by SAE, was reported to be good and could be applied as automotive friction material therefore making palm kernel shell suitable for brake friction pads production.

Palm kernel shell and palm kernel fibre

Ikpambese *et al*., (2016) developed asbestos–free automobile brake pads from palm kernel fibres together with epoxy resin as binder. The fibres (PKF) were soaked in caustic soda solution (sodium hydroxide) for 24 hours to get rid of the remnant of red oil in the fibre. The fibres were then washed with water to remove the caustic soda and then dried under the sun for a period of one week. The binder used during the study was varied in formulations during production. The physical, morphological and mechanical properties of the composite were investigated to examine the effect of composition on the friction material. The results obtained from the study indicated that the coefficient of friction, temperature, wear rate, stopping time and noise level of the pads increased with increasing speed. The results also showed that moisture content, porosity; surface roughness, hardness, specific gravity, water and oil absorption rate remained stable with increase in speed. From the microstructure analysis it was observed that worn surfaces where the asperities ploughed were characterized by abrasion thereby exposing the white region of the fibres and increasing the smoothness of the composite material. The report showed that the brake pad sample with composition of 10% palm wastes, 40% epoxy–resin, 15% calcium carbonate, 6% Al_2O_3, and 29% graphite gave optimum properties. Therefore, it was concluded that palm kernel fibres could be used effectively as friction material in brake pad production.

Rice husk dust and rice straw dust

Investigation was carried out by Mutlu (2009) using rice husk dust (RHD) and rice straw dust (RSD) to study the tribological properties of brake pads. The study was conducted for four different mixtures of brake pads which were coded RS4, RS20, RH4 and RH20. The materials in each brake pad were composed of rice husk dust (RHD), rice straw dust (RSD), copper particles, barite, brass, cashew, steel fibres, graphite and alumina and production of samples was done using moulding temperature, curing time and heat treatment time of 180 ℃, 15 minutes and 4 hours respectively. The newly formulated brake pads were tested and examined to study their performance and determine the coefficient of friction, wear rate and morphological properties. The results of the study showed a mean coefficient of friction of 0.315– 0.381 which was very low to be applied in heavy duty automobile brake pads as specified in the work of Dagwa and Ibhadode (2008). The result of the wear rate varied from 0.000853–0.001041 g/mm^2. Also, the SEM micrographs of each coded samples was conducted and the results showed that there was homogenous distribution of the silica particles in the body (white points). It was also reported that the micro–voids on the surface of each sample were bigger and smaller in size which was reported to be due to the falling of the metal particles during friction. In addition to the micro voids observed in the sample, it was also stated that there were some micro cracks on the surface which stayed as effective in the friction surface. The study then concluded that RHD and RSD could be used effectively in brake pad formulations when combined properly with other additives and that the use of RHD significantly improved the overall performance of the formulated material. It was also established that the sample with 20 % rice husk (RH20) would provide a better friction coefficient and wear rate when used in brake pad formulation.

Lemon peel powder

Ramanathan *et al*., (2017) investigated the use of lemon peel powder as a filler material in brake pad production. Two samples composed of lemon peel particles (10–20%), epoxy resin (40 %), aluminium oxide (7.5–12.5 %), graphite (15%), iron oxide (7.5–12.5%) and calcium hydroxide (10 %) were produced by varying the compositions of lemon peel powder, iron oxide and aluminium oxide. The process parameters reported by the authors showed a curing time of 24 hours while other production parameters were not reported. Samples produced were also tested to study the wear rate, hardness, density, and water and oil absorption. The test results showed that the brake pad samples possessed a density of 1.55–2.00 g/cm^3, hardness of 26–32, percentage wear loss, water and oil absorption of 13.45–19.14%, 0.96 –1.38% and 0.01– 0.02% respectively. The authors therefore concluded that the sample composed of 10% lemon peel powder, 15% graphite, 12.5% Aluminium oxide, 12.5 % iron oxide and 40% epoxy resin, and 10% calcium hydroxide gave the optimum properties and could be applied in brake pad applications.

Maize husk

Maize husks are the outer covering of maize. For most applications, the husks need to be soaked in hot water to become flexible. This type of husk is commonly used to encase foods for baking or steaming thereby imparting light maize flavour. Ademoh and Adeyei (2015) published the result of their study conducted using maize husks as reinforcement material to produce automotive brake pads. Three friction composite compositions were developed using the maize husks as strengthening material with varied epoxy resin binder. Maize husks were ground and sieved to a mesh size of 300µm. Other ingredients used during the study include silica sand, epoxy resin, calcium carbonate, anhydrous iron oxide, talc as a release agent and powdered graphite.

Three samples were produced using curing time of 80–120 minutes and varying percentage weight of maize husk and binder (epoxy resin and hardener) at 1:2 while the weight of friction modifier (graphite powder), abrasives (silica and iron oxide), and fillers (calcium carbonate) were kept constant throughout the experiment. To ascertain suitability of the formulated composites for brake pad application, the samples were subjected to tests to determine the mechanical, physical and tribological properties. Some of the tests conducted include water and oil absorption, density, friction coefficient; wear resistance, thermal conductivity, hardness, compressive and tensile strengths. The authors therefore concluded that maize husks are suitable eco–friendly replacement for asbestos and other agro–biomass friction materials in automobile brake pads application.

Cow bone

Isiaka and Temitope (2013) investigated the influence of particle size distribution of cow bone powder on the mechanical properties of polyester matrix composites with the aim of considering how suitable it is to be applied as biomaterials. During the study, the cow bone used was thoroughly washed to get rid of unwanted materials and then crushed into smaller particle sizes using hammer. Sieve size analysis was conducted on the crushed bones and was sieved into three sieve sizes of 300, 106 and 75μm. Other materials used during the experiment include unsaturated polyester resin which served as the binder, methyl ethyl ketone peroxide (MEKP) as catalyst, polyvinyl acetate which served as the mould releasing agent, 2% cobalt solution (accelerator) and ethanol as the cleaning agent. During the production of the composite, 120 g of the polyester resin was mixed with 1.5 g each of catalyst and accelerator while the particulates of the cow bone was varied in 2, 4, 6, and 8 wt% predetermined proportions. The developed composites were tested using standard testing methods to determine its mechanical properties. The test results indicate that the sample reinforced with 8 wt% from sieve size of 75 μm gave a better tensile strength than the others in the polyester matrix while hardness results showed that the 300 μm particle size was the optimal; it also showed that the 300 μm particle reinforcement increased the hardness as the fibre content rose from 2 to 8 wt%. Also, the flexural strength results showed peak improvement with the addition of cow bone particles. The study further concluded that the optimal reinforcement could be obtained by the addition of 6 % of cow bone powder from 106 μm particle size. Though, from the results obtained, the authors reported that cow bones can serve as a reinforcement material in polyester matrix as well as a good replacement for asbestos, tribological properties such as wear resistance and friction coefficient which principally affect the frictional behaviour of a brake pad were not investigated.

Cocoa bean shells

Cocoa bean shells also called cocoa bean mulch or cocoa bean hull mulch are shells of cocoa beans which come off the beans during roasting process and are separated from the beans by strong air action, therefore ensuring a dry weed–free product. Oliver (2013) reported that the waste shells of cocoa beans are rich in anti–oxidants and fibre which constitute a great potential as brake pad ingredients. Also, Adeyemi *et al*., (2016) developed brake pad materials using cocoa bean shells. The materials used for the production of the samples include calcium carbonate, silica sand, anhydrous iron oxide, epoxy resin and graphite. The base material, cocoa bean shells were prepared by washing, sun–drying, grinding into a fine powder and sieving of the ground powder using a sieve of aperture 300 μm. Three samples were produced by varying the epoxy resin (50–60%) and Cocoa beans shells powder (21–31%) while keeping the calcium carbonate ($CaCO_3$), silica, iron oxide and graphite constant at 4, 7, 3 and 5% respectively. Experimental tests were conducted on the samples to determine the physical, mechanical and tribological properties of the material and to ascertain the feasibility of applying the product on automobile brake pad. The experimental results showed that the specimen labeled as sample 3 (60% epoxy resin and 21% cocoa beans shells powder) gave the optimum performance compared to other experimental samples. The responses obtained compared favourably with those of commercial brake pads (asbestos based). Though the samples performed well as reported by the authors, the presence of iron in the composition may result to poor corrosion resistance which was not investigated by the researchers. Lawal *et al*., (2016) reported that poor corrosion resistance of brake pads might lead to poor braking performance.

Sea shells

Abiodun *et al*., (2014) evaluated the properties of seashell reinforced unsaturated polyester composite using seashell particle size of 250 μm at varying percentage composition together with unsaturated polyester resin. Tensile, hardness, impact, flexural and water absorption tests were conducted to determine the properties of the material. The test results show that bending strength varies from 0.077 – 30.85 MPa, tensile strength, 90.70 –262.05 MPa, impact strength, 3.54 – 4.76, Brinell hardness, 20.10 – 24.87 and percentage water absorption, 0.908 – 1.211%. Also, it was concluded that the seashell–reinforced sample of 10 % seashell powder provided the optimal properties thereby making seashell suitable for production of seashell reinforced unsaturated polyester composite.

Fly ash

Fly ash is the finely divided residue obtained from the combustion of pulverized coal and is transported from the combustion chamber by exhaust gases. It is generally captured by particle filtration equipment such as electrostatic precipitators before the flue gases reach the chimneys of coal-fired power plants. This waste generated by thermal power plants poses a great environmental concern (Anushree & Alka, 2009). Notably, Natarajan *et al*. (2012) conducted a study on the effect of ingredients on the tribological and mechanical properties of different brake pad materials. A non–asbestos organic based friction material was utilized in developing brake pads which was applied in automobile brake system. Two different types of frictional materials having different combinations were developed. The first consisted of fly ash (range 10–60%) and the second was developed without fly ash. Fly ash, according to the study, is composed of substantial amounts of silica, calcium sulphate, alumina, and unburnt carbon. These two materials were studied to investigate the effect of ingredients on the tribological and mechanical properties of different brake pad materials. The result of the experiment showed that the presence of fibres in the phenol matrix improved the tensile strength and hardness of the friction material. It was reported that this result was expected because soft resin matrix is reinforced by the hard fibres. The results of the study also indicated that the coefficient of friction of the fly ash was in the range of 0.35 to 0.48. It was reported that these results were better when comparing barites-based (without fly ash) and asbestos-based brake pads. Also, the results showed that wear resistance of the friction material was greatly influenced by the amounts of rock wool, ceramic wool, zirconium silicate (zircon) and calcium hydroxide in the samples and the presence of friction dust powder, potassium titanate (traces) and wollastonite ($CaSiO_3$) strongly influence the friction coefficient of the product. Similarly, the increasing strength of the friction material was achieved by the presence of aramid fibre and glass fibre. It was therefore concluded in the report that the presence of the ingredients had a great impact on the properties of frictional materials. Though, according to the National Precast Concrete Association (NPCA) of 2010, some fly ash, especially those produced in power plants are usually compatible with engineering material, while some others need to be beneficiated and few other types cannot actually be improved for use in engineering application. Thus, the use of fly ash in friction material may pose some negative effects on the properties of friction material.

Conclusion

A comprehensive review of automobile brake pad production using renewable materials has been highlighted in this study. The review shows that physical, mechanical and tribological properties as well as environmental impacts of brake pads produced using these materials compared favorably with the commercial brake pad currently in the market. These renewable materials satisfied the requirements for automobile brake pads. Harnessing the results obtained from these research works into real gains for national interest would require the collective will of the policy makers and entrepreneurs. That would lead to an the much desired improvement in the local content in the automobile industry, increase job creation and contribute in raising the National Gross domestic Product (GDP).

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