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Production and Performance Evaluation of Brake Pad from Locally Sourced Agro-waste

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ABSTRACT
High-quality, asbestos-free brake pads were made in this study using basic materials that were purchased locally. The Toyota Corrolla 2006 modeldisc brake friction lining were made with powdered shell of African olive (Canariumschweinfurthii)and Udara nut (Chrysophyllumcainito) as the main material, polyester resin as the binder material, graphite as the lubricant, and metal chips and carbides as the abrasives. The commercial brake pad purchased (Toyota Corrolla 2006 model) was used for the comparison. By altering the mass composition of the shell of African olive and Udara nuts,three distinct samples were obtained. The masses of the shell of African olive and Udara nutsare equal in Sample A. Sample C has a larger mass of Udara nut (69.23%) and a lower mass of African olive (30.77%), whereas Sample B has a higher mass of African olive (73.08%) and a lower mass of Udara nut (26.92%). For every sample, a fixed pressure of 16.75 kN/m^2 and particle size of 0.63µm were employed. The composition of the lubricant, abrasive, and binder remained consistent. According to the test results, samples A, B, and C had static and dynamic coefficients of friction of 0.499, 0.508, 0.487, and 0.426, 0.429, 0.424, respectively, whereas the commercial pad had a coefficient of friction of 0.513 and 0.434. The commercial pad had a water absorption percentage of 0.086, whereas samples A, B, and C had percentages of 0.098, 0.094, and 0.096. Samples A, B, and C yielded hardness test ratings of 3.82, 3.93, and 3.52, respectively, whilst the commercial pad yielded 3.05. For samples A, B, C, and the commercial pad, the wear rate test results are 0.00307g/sec, 0.003978g/sec, 0.002767g/sec, and 0.002545g/sec, respectively. The same conditions were used to test each sample. Despite having the lowest coefficient of friction, Sample C showed the most promise due to its mild water absorption, wear rate, and hardness.

Keywords: *Brake Pad, African olive nut, Udara nuts, Resin, Hardness, composite*

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I. INTRODUCTION

One of the most crucial components of any braking system in any kind of car with disc brakes is the brake pad. Brake pads are among the key elements that improves car overall performance. Typically, they are composed of more than eight components. A good brake pad should help maintain a vehicle's braking characteristics by maintaining a constant coefficient of friction throughout a variety of operating situations, including temperature, applied load, speed, and braking mode). Brake pads have additional qualities including minimal absorption of water and oil, low rate of wear, high thermal stability, low noise, heat resistance, and should not harm the brake disc.Brake pads are steel backing plates with frictional compounds bounded to the surface facing the brake disc, according to Anderson (1992). Kinetic energy is transformed into thermal energy as a result of friction between the brake pads.

A vehicle stops when the brakes are applied because of friction between the brake pads and the revolving disc, which transfers a small amount of friction material to the disc and transforms the vehicle's kinetic energy into thermal energy. The car is stopped by the friction material acting against the disk, which causes the braking rotor and disk to "stick" to one another and generate stopping power. The disc and the drum are the two types of brake systems. A caliper attached to a wheel hub or suspension upright holds the brake pads in place and activates them. In disc braking applications, there are typically two brake pads per disc rotor and they are classified as metallic, semi-metallic, and organic.

Brake pads are typically made of a mixture of friction additives, binder, fillers, and strengthened fibers. All of these components are combined or blended in different proportions, and various production methods are used to create the brake pad material.The friction material's mechanical strength is increased by reinforced fibers, and the binder preserves the brake pads' structural integrity under heat and mechanical strain. It keeps a brake pad's constituent parts together and stops them from disintegrating. In addition to lowering the brake pad's total cost, fillers increase the brake pad's manufacturing feasibility. Lubricants and abrasives are both regarded as friction additives; lubricants remove unwanted surface films that form during braking, while abrasives raise the friction coefficient and remove iron oxides from the counter-friction material. At high temperatures, lubricant stabilizes the coefficient of friction.

In addition to these components' functions, the brakes' design influences heat flow, dependability, and noise levels. According to Chapman et al. (1999) andBlau (2001), asbestos was the best friction material in the industry during the years 1908–1960. Its percentage in car brakes ranges from 30% to 70%. Good strength and flexibility, as well as heat stability, are asbestos's advantages. However, asbestos has a carcinogenic effect on people. There have been numerous studies conducted in the field of developing asbestos-free brake pads as a result of the growing trend in this area. To replace the asbestos-free brake pad material, research has looked into the usage of bagasse (Aigbodia et al., 2010), palm kernel shell (Dagwa and Ibhadode, 2006), and palm oil clinker (Zamrie et al., 2011). Utilizing agricultural or industrial waste as a source of raw materials for composite production is a current trend in the field of study (Leman et al., 2008). By using the natural fiber waste, this will have more economic benefits and also save the environment. Therefore, the creation of automotive disk brake pads employing environmentally beneficial periwinkle A and B materials agricultural waste is consistent with this trend.

Enormous use of asbestos brake pad has a lot of negative environmental and health related consequences like lung cancer, Mesothelioma and asbestosis. Several alternative materials such as cellulose, steel, aramid and copper fibers have been used to produce brake pad free of asbestos. The challenge of the different alternative fibers used in place of the asbestos is the compatibility. Because of the health and compatibility issues. This study will be able to overcome the health risk associated with the use of asbestos in the development of brake pad and also still achieve a recommended range of coefficient of friction.

II. LITERATURE REVIEW

Dagwa and Ibhadode (2005), developed asbestos free friction lining material 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 materials. However, more pad wear was observed on the PKS pad at high vehicular speeds beyond 80km/hour which suggest that PKS is not suitable in the formulation of brake pads meant for high-speed cars. Bhabani and

Jayashree (2006), worked on sensitivity of friction and wear on composite friction materials made of organic fibers. The sensitivity of friction and wear behavior of selected composites based on variation in inclusion of organic fibers, viz: aramid, PAN, 21 carbon and cellulose to braking pressure and sliding speed were investigated. The sensitivity of coefficient of friction and wear to the operating variables (temperature, breaking force, and speed) were carried out on a subscale brake rig. The results showed that the inclusion of cellulose fiber increased the friction coefficient, while aramid fiber improved the wear resistance. The values of friction and wear of the developed composite material were not compared with the recommended values and the quantities of the cellulose fibre and aramid added were not optimized.

Shaoyang and Fuping (2006), compared the friction and wear performances of some brake material dry sliding against two aluminum matrix composites reinforced with different sizes (3.5 and 34 μm) of SiCp particles respectively, in place of the conventional cast iron drum for a chase machine. It was shown that the friction coefficient decreased with the increase in load and speed. It was also shown that friction fade took place at high temperatures, followed by excellent recovery upon cooling. The specific wear rate was found to increase with increase in load. The study did not specify the composition friction materials in question.

Ganguly and George (2008), carried out a study on an asbestos free friction material composite containing fibrous reinforcing constituents, friction imparting and elastomeric additives, the composites showed high wear resistance and good thermal conductivity. However, study was not carried out on the friction behavior of the composite.

Ibhadode and Dagwa (2008), developed an asbestos – free friction lining material from palm kernel shell. Taguchi optimization technique was used to achieve optimal friction material formulation and manufacturing parameters. The laboratory brake pads were tested for wear and effectiveness on a car and when compared with premium asbestos – based commercial brake pad they were found to perform satisfactorily. However, the study recommended that PKS particle of size lower than the 125μm could be used to develop brake pads for vehicles with higher vehicular speed. Also, the use of copper chip as one of the ingredients poses some health challenges as itis known to be associated copper toxicities.

Dilipet al. (2008), carried out the analysis of load- speed sensitivity of friction composites based on various synthetic graphites. The sensitivity of coefficient of friction of composites containing synthetic graphite with different particle sizes to braking pressure and sliding speed was investigated. The studies were carried out on a subscale brake testing machine following 4 loads x 3 speeds experimental design. The best performance was obtained from composites containing synthetic graphite having average passive size of 410µm. Other particle sizes which resulted in good performance were 38 and 169µm. Very fine particle size was not beneficial for desired combination of performance properties. The regression analysis coefficient of friction on orthogonal L9 (3x3) 23 experimental design method revealed that the first order influence of sliding speed and braking pressure were significant. The study is not in conformity with the Hall- Petch law which states that the strength of materials increases as the particle size decreases as it is evident that friction composite with particle size of 410µm performed better that those with 169µm Rajiv et el., (2006).

Jayashreeet el. (2008), studied the effect of brass fibers in increasing amounts on the friction and wear performance of non-asbestos organic (NAO) friction composites. Four friction materials based on parent composition and with varying amounts of brass and barite were developed as brake pads, and characterized for physical, chemical and mechanical properties. They were further tested for their friction and wear behavior in the fade and recovery (F&R) modes on a Krauss machine as per ECE R90 schedule. In addition, small specimen (24mm x 24mm) of the brake pads were evaluated by studying their friction sensitivity for loads and speeds in a simulated braking condition against a commercial disc on a reduced scale prototype (RSP). Results showed that composites with 8 % brass fiber where thermal conductivity (TC) was not highest proved exhibited the best combination of performance parameters related to friction and wear in both testing modes. The study was limited to friction sensitivity and did not consider wear sensitivity at loads and speed.

Adewuyi and Adegoke (2009), Carried out a study on the potentials of periwinkle shell as a coarse aggregate for concrete. It was discovered that design mix with compressive strength of 26.67 N/mm2, 19.50 N/mm2 and 19.83 N/mm2 at 28 days" dehydration period, met the ASTM – 77 recommended minimum strength for structural weight concrete. The study is limited to compressive strength of mix rather than the requirement of friction material.

Kukutschova et al. (2009), investigated the wear mechanism in automotive brake materials, wear debris and its potential environmental impact. A model semi metallic brake lining was subjected to a full scale automotive brake dynamometer test. The structural properties and surface topography of brake linings were analyzed at different stages of wear testing and correlated to frictional performances. The characteristic of wear particles were investigated. A combination of abrasive and adhesive wear with oxidative processes dominated the friction process. It was observed that the characteristics of the layer depend mostly on surface temperature, normal pressure and sliding speed. It was also shown that wear rates and friction levels depend on the chemistry, structure and hardness of the friction layer covering the surface of the pad or the disc. The various friction materials used in this study were not mentioned; hence it became difficult to know how the various material constituents influence the wear mechanism.

Gurunath and Bijwe (2009), worked on the potential exploration of novel green resins as binders for non-asbestos – organic (NAO) friction composites in severe operating conditions. In the study, four NAO friction composites based on these resins were developed. Results obtained showed that the new composites were remarkably better. It was concluded that apart from eliminating problems such as; emission of harmful volatiles, possibility of voids, cracks and shrinkages associated with traditional phenolicfor friction materials, the novel green resin binders exhibit better properties from the friction material point of view in severe operating conditions. The study is limited to effect of resins on the performance of non-asbestos – organic (NAO) friction composites;the influence of reinforcing materials on the performances of the friction material was not investigated.

Olufemiand Joel (2009), undertake a study on the suitability of Periwinkle shell as a partial replacement of River gravel in concrete. Physical and mechanical properties of the shells and well graded river gravel were determined and compared. Concrete cubes with periwinkle shells and alone as coarse aggregate were lighter and of lower compressive strengths compared to those with periwinkle shells and gravels. This study limited to the suitability of Periwinkle shell as a partial replacement of River gravel in concrete and not as a friction material.

Zamri et al. (2011), Investigated the potential of palm oil clinker as reinforcement in aluminium matrix composites for tribological applications Palm oil clinker particle (POCp) reinforced aluminium matrix composites at different weight % of POCp (0 –20%) were fabricated via powder metallurgy technique. Sliding wear behaviour of the composites was studied against mild steel mating surface using Pin-On-Disc configuration at different applied load (3 –51 N), sliding distances (0 –500 m) and sliding velocities (0.55 m/s). The analysis of worn surface and subsurface was studied using a scanning electron microscope (SEM). The results indicate that the composites exhibited better wear resistance at applied load below than 11 N. However, the study did not consider the effect of temperature on the tribological of the composite.

Kolapo and Akaninyene. (2012); Investigated the effect of periwinkle shell ash (PSA) as a substitute cement on concrete. Specimens were prepared from mixwithstrengthof 25N/mm 2, a total of 180 specimens were casted and tested for compressive and tensile strength for 7 to 180 days. The results revealed that compressive strength increased with the increase in curing time, but decreased as the PSA contents increased. The optimal strength was attained with 10% PSA content at 28 days compared was in agreement with the conventional concrete. The study concluded that 10% PSA content is adequate as cement substitution for structural concrete. However, the study is limited to the use of periwinkle shell as a substitute for cement on concrete.

III. MATERIAL AND METHOD

3.1 Raw Materials and Formulation of the Sample

The primary raw materials used in this research include filler, abrasive, solid lubricant, binder, friction modifier, and additives. The development of the natural fiber brake pad material follows a process that involves selecting raw materials, weighing, mixing, compacting, and binding. Three different formulations were created, each with varying proportions of the shell of African olive nut and Udara nut. The formulations were categorized based on these variations, while the amounts of abrasive, solid lubricant, binder, friction modifier, and lubricants remain consistent across all formulations. Figure 1 and Figure 2 shows the diagram of African Olive nut and Udara nut used for this study.

Figure 1: African olive (*Canariumschweinfurthii*)

Figure 2: Udara nut (*Chrysophyllumcainito*)

3.2 Material Preparation

With differing amounts of the shells of African Olive and Udara nut, three distinct combinations such as samples A, B, and C were made as shown in Table 1. The main materials are powdered African Olive nut and Udara nut, phenolic resin was used as the binder, graphiteas the lubricant, and the abrasives were metal chips and carbides. The commercial brake pad purchase (Toyota Corrolla 2006 model) was used as the base for comparison. Waste African Olive nuts and Udara nuts were gathered. Ethanol was used to eliminate the contaminants from the raw African Olive nuts and Udara nuts waste that were gathered. African Olive nuts and Udara nuts were thoroughly cleaned with ethanol, then crushed and ground into a fine powder (between 125 and 700 µm) and sieved using a crusher machine.

The shells of African Olive nuts, Udara nuts, metal chips, carbide, and graphite were then thoroughly combined for each of the samples below until a homogeneous mixture was achieved. After adding phenolic resin, the material were combined to create a pap-like consistency. Accelerator and catalyst at a 1:1000 ratio. The previously treated metal backing plate was inserted into the mold with the aforementioned blended slurry. Gelling began after it was left for 15 minutes; the heated surface of the molded samples indicated that this was an exothermic reaction. At this point, a pressure of 16.75 kN/m^2 was applied, and after six hours, complete cure had occurred. Abrasive machining was used to remove the extra material from the sample.Table 1 provides a detailed breakdown of the five different types of new materials.

Table 1: Samples of Brake Pad Composition

Compositions	**Sample A (grams)**	**Sample B (grams)**	**Sample C (grams)**
African Olive nuts	39	57	24
Udara nuts	39	21	54
Metal chips	25	25	25
Carbide	7	7	7
Graphite	9	9	9
phenolic	41	41	41
Total	160	160	160

IV. RESULTS AND DISCUSSION

4.1 Mass, Volume and Thickness

The fluid displacement method was used to calculate the volume of the samples. At room temperature, the samples were submerged in a 1000 mL cylinder of distilled water. The volume of the sample piece is the difference between the volume of water measured before and after the immersion. The samples were weighed using E200 electronic balance meter, which has an accuracy of ±0.01, to determine their mass. Using a Vernier caliper, the thickness of samples A, B, C, and Commercial Pad were measured. The readings were taking using three different locations(the middle and both ends), and an average was calculated. Table 2 displays the results for the calculated densities of the various samples.

Table 2: Results of the density of the various Samples

Samples	Thickness (cm)	Volume (cm^3)	Area (cm^2)	Mass (gram)	Density (g/cm^3)
A	1.99	153	87.10	385.92	2.52
B	1.69	128	87.19	329.14	2.57
C	1.75	133	87.17	365.34	2.75
Commercial Pad	1.45	103	83.30	339.36	3.29

4.2 Coefficient of Friction

This study considered both static and dynamic coefficient of friction for the produced brake pad and the commercial brake pad purchased (Toyota Corrolla 2006 model).

4.2.1 Static Coefficient

After positioning the brake pad on top of the polished steel plate, the angle of inclination was raised until the pad barely started to slip down the plate. Theheight, x, which is equivalent to the slope was measured. The steel plate's length, L, remained constant. Table 3 displays the calculated coefficient of friction for the samples under different conditions.

Table 3: Static Coefficient of Friction

CONDITION	FRICTION COEFFICIENCT		
	DRY	WET	OIL
Sample A	0.499	0.467	0.453
Sample B	0.508	0.475	0.456
Sample C	0.487	0.456	0.437
Commercial Pad	0.513	0.484	0.463

4.2.2 Dynamic Coefficient

The brake pad was put on a polished steel plate after being securely wound around with a small nylon thread that weighed very little. After passing through a frictionless groove pulley, the remaining thread end was fastened to a load hanger. A mass of 1000g was applied to the brake pad, with the mass of the pad multiplied by 9.81 m/s^2, gives the normal load. The load hanger was gradually loaded. The brake pad was lightly tapped after each loading, and the mass that provided it with a constant slow speed was recorded. The frictional load is the result of multiplying this mass by the load hanger's mass (100g) and 9.81 m/s^2. The result for dynamic coefficient of friction is shown Table 4

Table 4: Dynamic Coefficient of Friction Calculated

Sample	Oil			Dry			Wet		
	Normal Force (N)	Frictional Force (N)	μ	Normal Force (N)	Frictional Force (N)	μ	Normal Force (N)	Frictional Force (N)	μ
A	15.416	5.108	0.426	15.416	4.863	0.407	15.416	4.666	0.393
B	14.859	4.960	0.429	14.859	4.765	0.414	14.859	4.519	0.395
C	15.212	5.010	0.424	15.212	4.715	0.402	15.212	4.372	0.376
Commercial Pad	14.957	5.059	0.434	14.957	4.814	0.415	14.957	4.568	0.397

4.3 The Test of Hardness

The MensantoTensometer was used in this investigation. A brinellball with a diameter of 2 mm was used to puncture or deform the brake pad's surface during the indentation process. Hardness is the ratio of the force exertedto the spherical area of indentation.

Where r is the indentation's radius, the spherical area of the indentation = $4/3r^3$

Table 5 displays the results of the hardness test. Additionally, Table 6 displays the results for the samples' deformation under different loads.

Table 5: The samples' hardness test results.

Samples	Force (N)	Radius (mm)	Area (mm²)	Hardness
A	197	2.7	60.63	3.82
B	179	2.6	53.99	3.93
C	208	2.8	68.47	3.52
Commercial Pad	103	2.4	41.81	3.05

Table 6: Applied Loads and their Resulting Deformations

	Deformation (mm)					
Load (Newton)	**300**	**600**	**900**	**1300**	**2100**	**2500**
Sample A	1.65	2.55	3.05	3.35	5.85	6.25
Sample B	1.45	2.35	2.85	3.25	5.45	5.85
Sample C	1.75	2.85	3.35	3.65	6.15	6.45
Commercial Pad	1.85	3.25	4.46	5.85	6.55	7.45

4.4 Absorption of Moisture

After being weighed, the brake pads (lining and backing plate) were left at room temperature in a basin of water for 24 hours. The Metler E200 electronic balance was used for the weighing. The pads were removed from the immersion and their surface wetness was cleaned. They were weighed once more, and the mass difference between them allowed for the calculation of the mass of water absorbed and the percentage absorption over dry mass. The proportion of water absorption for each sample is displayed in Table 7.

Table 7: The Table displays the samples' percentage of water absorption.

SAMPLE	Dry Mass (gram)	Wet Mass (gram)	Mass of Water Absorbed (gram)	% of Water Absorbed
A	385.92	386.30	0.38	0.098
B	329.14	329.45	0.31	0.094
C	365.34	365.69	0.35	0.096
Commercial Pad	339.36	339.65	0.29	0.086

4.5 Characteristics of Wear

In the absence of a specially constructed alternative, a friction testing machine was devised using a standard center lathe, a used automobile wheel disc with an outer diameter of 300 mm and an inner diameter of 186 mm, a plain compression spring with dimensions of 42 mm long, outer diameter of 30 mm, inner diameter of 27 mm, and a fabricated brake pad holder. Fine emery paper, aluminum silicon grit No. p-400C, manufactured in England, was adhered to the wheel disc's contacting face using top bond. The disc was securely held in the lathe's chuck while it was operating at 180 rpm. After positioning the brake pad in the brake pad holder alongside the compression spring, the spring was fully compressed and pressed against the emery paper. The tool post clamped down tightly on the brake pad holder. Depending on the spring parameters and lining contact area, the linings/disc pressure was roughly 56.08 kN/m². For fifteen minutes, the disc was operated at its predetermined speed. Measurements of brake pad mass before and after the test run gave the wear sustained.
It's critical to recognize the test's limitations, which include the potential for compression spring misalignment, starting location-dependent variations in lining thickness, resulting uneven pressure throughout the lining surface, and variations in disc face linear speed at various radii. The mass and wear, wear rate, wear volume, and rateof wear are displayed in Tables 8, 9, 10, and 11.

Table 8: Mass and Wear of Samples

Samples	Mass before (gram)	Mass after (gram)	Wear (gram)
A	385.92	383.15	2.77
B	329.14	325.56	3.58
C	365.34	362.85	2.49
Commercial Pad	339.36	337.07	2.29

Table 9: Wear Rate (gram per minute)

Samples	Wear	Time (min)	Rate of Wear (g/min)
A	2.77	15	0.1847
B	3.58	15	0.2387
C	2.49	15	0.1660
Commercial Pad	2.29	15	0.1527

Table 10: Volume of Wear (i.e. wear/density (m3))

Samples	Wear (gram)	Density (g/cm³)	Wear Volume * 10^{-6} m³
A	2.77	2.52	1.0992
B	3.58	2.57	1.330
C	2.49	2.75	0.9055

Commercial Pad	2.29	3.29	0.6960

Table 11: Rate of Wear (wear volume/distance, (m^3/m)

Samples	Wear Volume * 10^{-6} (M^3)	Distance (m)	Wear Rate * 10^{-10} m^3
A	1.0992	2650.5	4.1471
B	1.330	2650.5	5.0118
C	0.9055	2650.5	3.4163
Commercial Pad	0.6960	2650.5	2.6259

4.6 DISCUSSION OF RESULTS

4.6.1 Absorption of Water

The brake pads made from our samples in the lab have a higher water absorption than the commercial brake pad purchased (Toyota Corrolla 2006 model). This could be because African Olive and Udara nuts are natural fibers, which are highly hydrophilic materials with a large number of hydroxyl groups (-OH) in the fibers. Because African Olive and Udara nuts are hydrophilic, fillers and water molecules form hydrogen bonds, which causes these lignocellulosic materials to absorb water.

African Olive nuts and Udara nuts often exhibit poor moisture resistance when hydroxyl groups are present. Water and the hydroxyl groups of cellulose, hemicellulose, and lignin in the cell wall generate hydrogen bonds that is whylignocellulosic materials are known to absorb water. According to Blau(2001), when the quantity of natural filler content increased, so did the maximum water uptake.

When exposed to moisture, the hydrophilic African Olive and Udara nuts swell. This swelling causes micro-cracking in the brittle thermosetting resin. The higher cellulose content in both materials allows more water to penetrate the interface through these micro-cracks, generating swelling stress that ultimately leads to composite failure. As the composite deteriorates, capillarity and moisture transport through the micro-cracks become more active. The capillarity mechanism enables water molecules to flow along the filler–matrix interfaces, while diffusion occurs through the bulk matrix. This results in water attacking the interface, leading to the de-bonding of the filler from the matrix.

Compacting pressure: the more porous the material, the more room there is for water molecules to fill it. According to Jayashreeet al. (2006), the percentage (%) of moisture absorbed is inversely related to the compacting pressure.Since African Olive and Udara nuts are fibers with the same mass, they will absorb water with nearly the same absorption ratio. Sample B demonstrates that the water absorption ratio of Udara nuts is greater than that of the African Olive nuts, and Sample B has the least amount of water absorption because Udara nuts has a higher water absorption ratio than African Olives nuts. It can be seen that all the samples have higher level of moisture absorption potential in comparison to the commercial brake pad purchased (Toyota Corrolla 2006 model). Sample A has the highest level of water absorption, followed by C and then finally B.

4.6.2 Wear Rate

For the reasons listed below, the brake pads made from our samples wear out more quickly than the commercial brake pad purchased (Toyota Corrolla 2006 model):

(1) When fabricating with our samples, the compacting pressure is significantly lower than the commercial fabrication pressure.

(2) The wear rate is influenced by the type of binder used. Phenolic resin is the best kind of binder for making brake pads (Onyeneke et al, 2014). However, polyester resin was used as a substitute because phenolic resin was scarce in the local market. Phenolic resin breaks down around 450 degrees Celsius, whereas polyester resin breaks down between 250 and 300 degrees.

V. CONCLUSION

As a result, the goal of creating a brake pad lining primarily from locally accessible materials has been achieved. The base materials, African Olive and Udara nuts, are non-carcinogenous, meaning they do not cause cancer, in contrast to asbestos, which is the base material of the majority of commercially available brake linings. Therefore, using African Olive and Udara nuts to fabricate brake linings should improve the environmental health of our cities and rural areas, as it is currently the most common method of disposing of them (African Olive and Udara nuts), which also contributes to the greenhouse effect.

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