EXPERIMENTAL INVESTIGATION OF COIR AND COWBONE REINFORCED POLYMER COMPOSITES FOR TRICYCLE BRAKE PAD APPLICATION

Muhammad.B. Abdullahi [1]
abdullahimb@abu.edu.ng
[2]*Bello Abdulkareem* [2]
ogabello2002@yahoo.com
Abdulmumin. A. Alabi[3]
aaalabi@abu.edu.ng
Michael S. H[4]
Sarauniya000@gmail.com

[1,2,3,4]Ahmadu Bello University, Zaria, Nigeria

ABSTRACT

The purpose of an automobile brake is to absorb the kinetic energy of moving parts through friction. This study investigates the formulation of brake pad material using coir and cow bone reinforced polymer composite. Three different samples were created with varying proportions of coir, cow bone, and polyester resin: S1 (5% coir, 15% cow bone, 80% resin), S2 (5% coir, 10% cow bone, 85% resin), and S3 (5% coir, 5% cow bone, 90% resin). Mechanical tests showed that S3 outperformed the others in hardness (93.90), compressive strength (94.30 N/mm²), and tensile strength (18.82 N/mm²), indicating its potential for excellent braking performance. S3 also demonstrated low water absorption (1.99%), suggesting improved resistance to water-related damage, enhancing brake pad longevity. The wear index for S2 was also favorable (0.0135), indicating its potential for durable performance. Overall, the coir and cow bone reinforced polymer composite, especially the S3 formulation, offers superior mechanical properties compared to traditional brake pad materials. This innovative composite demonstrates great potential for tricycle brake pad applications, offering improved performance, durability, and environmental resistance.

Keywords: Brake pad, Cow bone, Coir, Polyester resin, wear index.

NOMENCLATURE

CS	Compressive Strength
PWA	Percentage of Water Absorption
Wa	Original weight
Wb	Wet weight

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INTRODUCTION

The primary purpose of a brake pad is to lower the speed of motion of an automobile by Generating heat at the interface of contact of the brake pad and the rotor disk through frictional action (El-Tayeb and Liew., 2009). Typically, brake pads are made up of three parts: adhesives bind, the backplate and the friction materials (Fan et al., 2008). Four categories of elements make up composite friction materials include: fibers, fillers, binders, and friction modifiers. (Liew and Nirmal., 2013). The binder is a thermosetting resin, typically phenolic experimental trial and error process are frequently used to choose the ingredients for a new formulation (Hee and Filip., 2005). Because of the complexity of these elements' effects on performance attributes (Kumar and Bijwe., 2010), a variety of pad formulations: metallic, semi metallic, organic, ceramic-based, etc. are reported in literatures. Positive confirmation of certain components' environmentally harmful properties has just been obtained (Hjortenkrans *et al*., 2006). More than 2000 distinct materials and their variants are now used as commercial brake components (Hong *et al*., 2009). Most braking materials are combinations of multiple materials to give the qualities needed by the brakes (Menapace *et al*., 2017). A reinforcement, abrasives, friction modifiers, fillers, and binding compounds are among the basic components of brake pads (Chan and Stachowiak., 2004). These materials affect how the friction coefficient varies. In Europe, the usage of amosite and crocidolite asbestos was outlawed in 1985, based the US Clean Air and Water Association (Chan and Stachowiak., 2004).

In recent years, the automotive industries have witnessed a growing emphasis on sustainable materials and innovative engineering solutions to address environmental concerns and enhance performance. As a crucial component of vehicular safety, brake pads play a pivotal role in ensuring reliable braking systems. Traditional brake pad materials, such as asbestos and metallic formulations, raise ecological and health concerns due to their environmental impact and potential health hazards. Consequently, there is a pressing need to explore alternative materials that not only meet performance requirements but also align with sustainability goals. As the automotive industry continues its transition towards eco-friendly solutions, the findings of this research are anticipated to provide a beneficial contribution to the growing body of knowledge on sustainable materials for brake pad applications. Some recent discoveries from researchers in this field include: Abutu et al, (2019) produced brake pad grey relational analysis and experimental design via central composite design using coconut shell, epoxy, graphite as frictional modifier and aluminum oxide as abrasive. Mohammad et al, (2018) carried out a review on material wear analysis of automobile brake pad using agricultural wastes. Anbua et al, (2024) reviewed renewable materials for brake pad application. They concluded that the materials satisfied the requirements for automobile brake pad. Gulsah et at, (2018) reviewed into the determination of friction wear and properties of eco-friendly brake pad reinforced with hazelnut shell and boron. Gulsah et al, (2021) carried out characteristics assessment methods for brake pad performance.

Gulsah et al, (2020) investigated the non-asbestos brake pad composites reinforced with shell dust. Joseph et al, (2023) developed brake pad for automotive application using organic wastes as reinforced material. Ahmad et al (2020) developed a brake pad from a composite formulation with 20% coconut fibre, 20% wood powder, 10% cow bone which exhibits similar hardness to commercial brake pad.
However, investigation on the composite's variations affect the crucial brake pad performance characteristics is an issue yet to be holistically achieved. Hence this work is focused in the aforementioned direction using coir and cowbone.

Through a holistic understanding of the performance and viability of coir and cowbone reinforced polymer composites, this study aims to drive innovation in the development of brake systems that align with both performance and environmental sustainability standards. This study focuses on the experimental investigation of coir and cowbone reinforced polymer composites as potential candidates for tricycle brake pad applications. Coir, derived from coconut husk fibers, and cowbone, a byproduct of the agricultural industry, are chosen for their renewable and eco-friendly characteristics. By incorporating these natural reinforcements into polymer matrices, we aim to develop brake pads that strike a balance between performance, environmental impact, and cost-effectiveness.
Polyester resin and coconut fibre were selected for this work owing to their excellent mechanical properties such as high strength and its resistance to impact and fatigue. It also exhibits resistance to wide range of chemical and corrosion. Aside its light weight, it is also capable of withstanding high temperatures. Coconut fibre is renewable, lighter in weight and biodegradable with high tensile strength which makes it durable and resistant to wear and tear. It is resistant to salt water which makes it suitable for use in marine environments. It can also absorb moisture and gradually release it which helps it maintaining moisture level.

The objectives of this research include evaluating the mechanical properties, thermal stability, and wear resistance of the developed composite materials. Through a comprehensive experimental approach, we seek to assess the feasibility of these sustainable composites for application in tricycle brake pads. The results of this investigation are anticipated to contribute valuable insights into the development of environmentally conscious and high-performance braking systems.

MATERIALS AND METHODS

Material Used for the Research Work

The materials used for the research include:
The polyester resin used as matrix (Anbua *et al*.,2024), the Cobalt Octoate (Anbua *et al*.,2024) used as accelerator and Methyl Ethyl Ketone Peroxide (Joseph *et al*., 2023) used as catalyst for the research work were obtained from the Nigerian Institute of

Leather and Science Technology (NILEST). The coir used was obtained from coconut fiber was gotten from Palladan Zaria. It was sun dried, heat treated, then pounded to smaller sizes. It was milled for 12hours with a ball milling machine and then sieved to a size of 250µm.

The cow bone used was purchased from the Zango Shanu abattoir. The bones were boiled for two hours, sun dried, carbonized at a temperature of 291^{o}C and calcinated at a temperature of 900^{o}C for a holding time of two hours. It was then milled for 10hours and thereafter sieved to a size of 300µm. Table1 outline the list of the equipment used for the experimentations.

Table1: List of Equipment

Name of Equipment	Specifications
Universal Testing Machine	Maximum capacity 500kN
Manual Oven	
Electronic Oven	1 ^{o}C to 900 ^{o}C
Microvickers Hardness Tester	Model MV1-PC
Digital Electronic Weighing Scale	
Electronic Universal Testing Machine	Model WDW-100KN
Martindale Abrasion Machine	STM 105
Syringe	50ml

Three different combinations tagged as S1, S2, S3 were prepared by varying the proportions of coir, cow bone and binder. The percentage composition of the cow bone and polyester were varied while that of the coir was kept constant. The appropriate portion of polyester resin was poured into a container followed by some portion of the cow bone and coir and then it was mixed thoroughly using a spatula almost at homogeneous state. It was then transferred into different moulds for that of tensile test, hardness test, compressive test and wear. Table2 outline the materials compositions of the developed brake pad.

Table 2: Material composition of the proposed brake pad

Number	Composition	SAMPLE 1 (% weight)	SAMPLE 2 (% weight)	SAMPLE 3 (% weight)
1	Coir	5	5	5
2	Cow bone	15	10	5

3	Polyester resin	80	85	90

Brake Pad Material Test Method

Material tests such as hardness test (ASTM D256), compression strength test (ASTM D695), tensile strength test (ASTM D412), wear test (ASTM G77), water absorption test (ASTM D570) was used during the development of the brake pad materials.

Characterization of Formulated Brake Pad

The Compressive Strength Test: The compressive strength test was investigated to ascertain the abilities of the brake pad friction lining to resist pushing or squeezing. The dimensions of the brake friction lining samples are 28mm thickness and 30mm x 28mm surface area. The force upon which the sample was recorded. The test was carried out on a 500kN Capacity Testing Machine.
Compressive Strength (CS) is given as;

$$CS= \frac{Force}{Area} \ (N/m^2) \quad (1)$$

(Gulsah *et al*, (2021)

The Hardness Test: Hardness is the ability of a material to resist plastic deformation. The hardness test was taken with the use a Microvickers Hardness Tester. The samples were machined to a size of 30mm x 28mm. The sample was the covered with a foil paper and then inserted beneath the indenter and the hardness value taken at three distinct locations on the surface of the sample. The mean value of the test was recorded. Tensile Strength Test: The tensile strength test was conducted to ascertain the strength of a material and its ability to resist fracture when stretched. The dimensions of the sample are 3mm thickness and 50mm x 12.5mm surface area. The test was conducted using an Electronically powered Universal Testing Machine. Water Absorption Test: The water absorption was conducted by weighing the samples before and after the experiment. The samples were immersed in water at room temperature for 24 hours. The samples were then removed, wiped with a tissue paper and weighed. A digital electronic scale was used. The percentage of water (PWA) absorption was then determined:

$$PWA = \frac{W_b - W_a}{W_a} \times 100\% \quad (2)$$

(Gulsah et al, (2021)

Where w_a and w_b are original weight and wet weight after exposure respectively.

Wear Test: The wear test was carried out by taking the different composition and model. The sample is placed on a sandpaper. The test records the number of times the sample oscillates the sandpaper. During this test, there was a total of 200 cycles for each sample.

Wear index = $\frac{No\ of\ cycles\ x\ wear\ loss}{1000}$(mm^3/Km) (3)

(Gulsah et al, (2021)

RESULTS AND DISCUSSION

The following graphs show the results for surface hardness, tensile strength and compressive strength for coir and cow bone-based brake pad.

Compressive Strength

Fig 1 shows the compressive strength of the samples. The results show that CS is higher in sample C with a composition of 5% coir, 5% cow bone, 90% polyester resin with a value found to be 94.3 while for sample A with a composition of 5% coir, 15% cow bone, 80% polyester resin has the lowest compressive strength with value found to be 82.05. As seen, the value of the composites compressive strength increases from sample A to sample C and this is due to the high compressive strength of cow bone and polyester resin (Aigbodion *et al*., 2010). It indicates how strong the friction lining of the mixture is when subjected to a large force. According to the value of compressive strength in brake pad is attributed to the surface area and pore packing capability of the material particular in the resin.

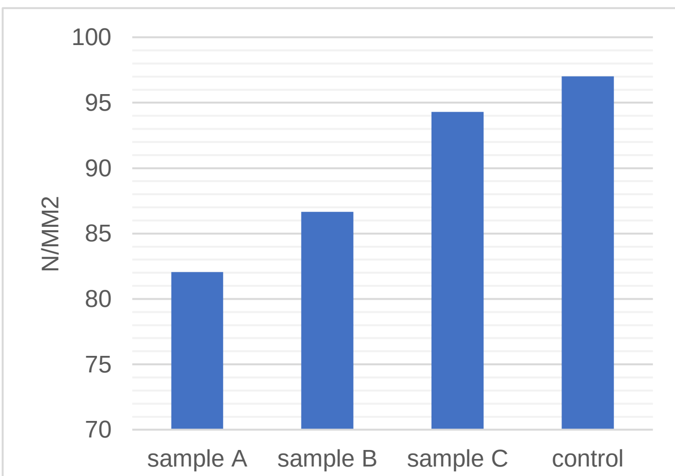

Fig 1. Comparison of the Compressive Strength Values.

Surface hardness

Fig 2 indicates the surface hardness result of the samples. The surface hardness for sample C with a composition of 5% coir, 5% cow bone, 90% polyester resin has the highest

hardness having a value of 93.9 while for sample A with a composition of 5% coir, 15% cow bone, 80% polyester resin has the lowest hardness value of 67.30. As seen, the hardness value of the composites increases from sample A to sample C. According to Dagwa and Ibhadode (2006); the high value of surface hardness is affected by the formulation of the brake pad. Also, Aigbodion (2010) shows that the particle size of the material used in the production of brake pad also affect the surface hardness value of brake friction lining.

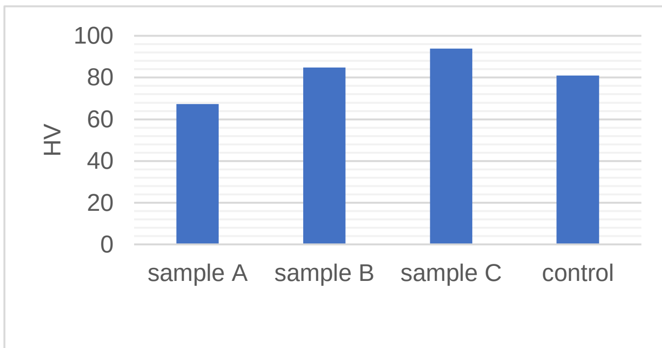

Fig 2. Comparison of the Surface Hardness Values.

Tensile Strength

Fig 3 shows the tensile strength of the samples. The results show that the tensile strength is higher in sample C with a composition of 5% coir, 5% cow bone, 90% polyester resin with a recorded value of 18.82 while for sample A with a composition of 5% coir, 15% cow bone, 80% polyester resin has the lowest tensile strength with a value of 14.67. As seen, the value of the composites tensile strength increases from sample A to sample C. The coarse particles lead to the improved toughness (Aigbodion *et al*., 2010)

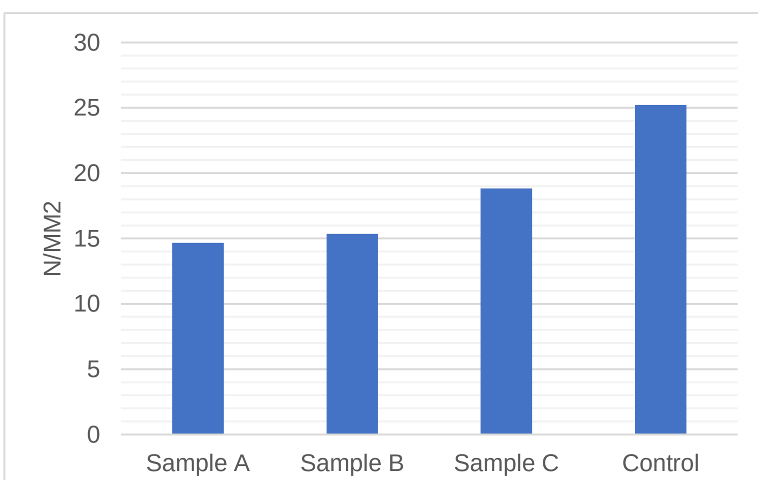

Fig 3. Comparison of the Tensile Strength Values.

Water Absorption

Fig 4 shows the results of the moisture test of the samples. The results show that the amount of moisture in the composite of the brake pad was lower at sample C with a composition of 5% coir, 5% cow bone, 90% polyester resin with a value found to be 1.99 while for sample B with a composition of 5% coir, 10% cow bone, 85% polyester resin has the highest amount of moisture with value 4.51. Polyester resin offers excellent, long-term durability to water and that leads to the resistance of the absorption. So, because of the high percentage of the polyester resin, sample C has the lower value for the water absorption.

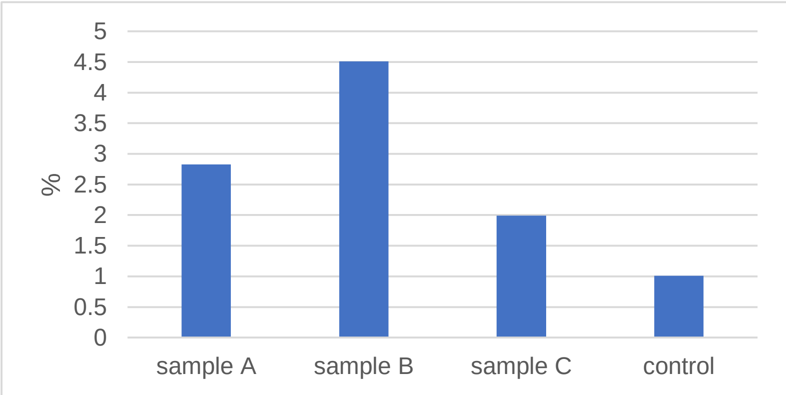

Fig 4. Comparison of the Water Absorption.

Wear Index

Fig 5 shows the results of the wear index of the various composites samples. The sample B with a composition of 5% coir, 10% cow bone, 85% polyester resin has the least value of wear index of 0.0135 and sample A with a composition of 5% coir, 15% cow bone, 80% polyester resin has the highest value of wear index of 0.0297. According to Dagwa et al (2006), a good brake pad is closely related with the quality of the material, as well as with safety and economy of operation.

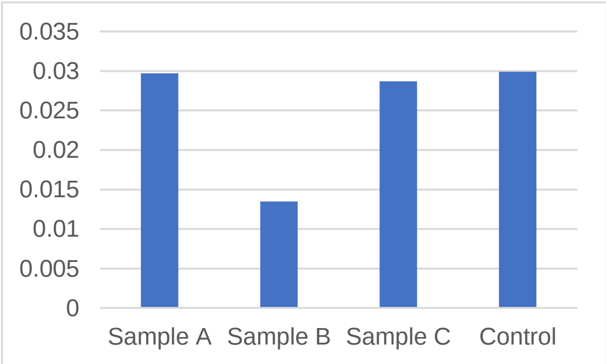

Fig 5. Comparison of the Wear Index Values.

CONCLUSION

The aim of developing a brake pad lining from locally sourced materials has been realized. Composite of cow bone and coir used as reinforcement, cow bone as friction and polyester resin as matrix by varying the percentage of the reinforcement filler and binder. The mechanical properties of the composite developed was studied, such as surface hardness, wear index, water absorption, compressive strength and tensile strength. Based on the analysis of the experiment conducted, sample C with a composition of 5% coir, 5% cow bone, 90% polyester resin values are higher in surface hardness, compressive strength and tensile strength and lower in water absorption. Sample B with a composition of 5% coir, 10% cow bone, 85% polyester resin values are lower in wear index. It was revealed that the highest value of the surface hardness is higher than the control value. The tensile strength of the highest value is lower than the control value.

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