



Jute and Pineapple Leaf Fibre Reinforced Epoxy Silicon Carbide Brake Composites: A Comparative Screening Study

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Abstract

Background: Natural fibre reinforcements offer renewable feedstocks for brake friction materials, but their suitability depends on mechanical integrity, thermal response and frictional behaviour. **Objective:** This study compared jute and pineapple leaf fibre (PALF) reinforced epoxy composites containing silicon carbide as preliminary brake material candidates. **Methods:** Composite specimens were prepared using LY556 epoxy, HY951 hardener and silicon carbide. Three reported Izod energy measurements per reinforcement were analysed descriptively. Available tensile outputs, pin-on-disc friction values and thermogravimetric observations were evaluated while separating measured results from estimates and unresolved records. **Results:** Reported impact energies averaged 70.67 ± 1.15 J for jute and 68.67 ± 1.15 J for PALF, corresponding to a 2.9% higher mean for jute. These values represent unnormalised absorbed energy; specimen dimensions and the stated units require confirmation. The jute tensile output showed a peak load of 3.747 kN and tensile strength of 19.275 MPa. Reported friction coefficients were 0.40 for jute and 0.42 for PALF, although operating conditions and repeatability were unavailable. Thermal descriptions suggested multistage mass loss, but inconsistencies between curves and narrative prevented a defensible quantitative stability ranking. Estimated compression values were excluded from experimental comparisons. **Conclusion:** The available evidence identifies modest differences in reported impact energy and friction

coefficient, supporting further screening rather than validated brake pad substitution. Missing fibre fractions, curing parameters, friction test conditions and raw thermal records limit reproducibility. Future work should establish complete formulations, verified impact units, replicated mechanical and tribological measurements, temperature dependent friction, wear rates and dynamometer fade and recovery performance.

Keywords: brake friction materials; pineapple leaf fibre; jute fibre; epoxy composites; silicon carbide; thermogravimetric analysis



I. INTRODUCTION

Brake friction materials must generate controlled friction while sustaining contact pressure, repeated heating and progressive surface damage. Their performance is governed by the evolving pad-disc contact, rather than by a single bulk material property. Contact plateaus, third-body debris and changing surface composition influence friction and wear [1]. Consequently, a promising reinforcement must be evaluated through complementary mechanical, thermal and tribological measurements before a brake application can be established.

Natural fibre reinforcement provides a route for incorporating renewable feedstocks into asbestos-free friction composites. Recent work identifies opportunities alongside unresolved questions concerning durability, thermal response and noise [2]. Pineapple leaf fibre (PALF) is obtained from agricultural residues, whereas jute is a widely used lignocellulosic reinforcement. Their composition, morphology and processing history affect composite properties [3]. Moisture affinity and fibre-matrix compatibility remain important limitations, motivating drying and surface modification [4]. A natural fibre component does not, by itself, establish that an epoxy composite is biodegradable or environmentally preferable over its full life cycle.

Jute-containing non-asbestos organic composites and other plant fibre brake materials have already been investigated [5], [6]. Thus, the research gap is not the first use of natural fibres in brake pads. A more focused question is how jute and PALF compare within an epoxy-silicon carbide material system when impact response, tensile evidence, thermal mass loss and friction are considered together. Such comparisons require matched formulations and consistent test conditions; otherwise, fibre effects remain confounded with processing and loading differences.

The present study examined jute and PALF reinforced LY556/HY951 epoxy composites containing silicon carbide as candidate brake friction materials. Its objectives were to compare the reported impact energies, assess the available tensile and friction evidence, and interpret thermal observations within their experimental limits. The contribution is a comparative screening dataset and a bounded assessment of the evidence needed for subsequent brake material validation. It does not establish equivalence to commercial brake pads or isolate reinforcement effects independently of fibre loading.

II. LITERATURE REVIEW

Matějka et al. [5] investigated jute fibres and powdered hazelnut shells in non-asbestos organic, non-metallic friction composites, demonstrating that plant-derived constituents have an established place in brake material research. Ikpambese et al. [6] evaluated palm kernel fibres for asbestos-free automotive brake pads. These studies support the selection of renewable reinforcement candidates but cannot predict the performance of a different epoxy formulation without direct testing.

Hamamcı and Sali [7] investigated jute incorporation in phenolic brake pads and reported formulation-dependent changes in friction, wear and water absorption. Their work reinforces the need to evaluate trade-offs: improved frictional response need not coincide with increased strength. PALF studies reviewed by Asim et al. [3] identify potential reinforcement applications, while Li et al. [4] describe the importance of surface treatment and moisture control. These findings provide a rationale for fibre preparation; they do not demonstrate improved interfacial bonding in the present specimens.

Binder selection is also consequential. Bhatt et al. [8] investigated a high-performance epoxy binder in copper-free brake pads. Their results justify research into epoxy friction materials, but the performance of that binder cannot be transferred to LY556/HY951 without evaluating cure state and temperature-dependent behaviour. Omrani et al. [9] emphasised that natural fibre composite tribology depends on reinforcement, orientation, surface treatment, normal load and sliding speed. Abutu et al. [10] showed that manufacturing parameters affected the properties of seashell-reinforced brake pads. Together, these studies indicate that a defensible jute-PALF comparison must document both formulation and processing, rather than attributing all observed differences to fibre identity.

III. METHODOLOGY

A. Materials and formulation

Two reinforcement systems were examined separately: jute and PALF. LY556 epoxy resin and HY951 hardener formed the binder system, and silicon carbide of the reported 120-grit grade was used as the particulate additive. The recorded pin-on-disc formulations contained 300 g resin, 30 g hardener and 75 g silicon carbide for each reinforcement. These quantities define a 10:1 resin-to-hardener mass ratio and a 405 g non-fibre charge. Table I gives the formulation quantities that were documented.



Table I. Documented formulation for each reinforcement system

Constituent	Jute system	PALF system
LY556 epoxy	300 g	300 g
HY951 hardener	30 g	30 g
Silicon carbide	75 g; 120 grit	75 g; 120 grit
Reinforcement	Jute	PALF
Fibre mass	Not recorded	Not recorded

On a non-fibre basis, the charge comprised 74.07% resin, 7.41% hardener and 18.52% silicon carbide by mass. These values are not the final composite mass fractions because fibre mass was not recorded. The formulation was explicitly associated with the friction specimens; its use for all mechanical and thermal coupons was not independently documented. Fibre loading was therefore not assumed to be equal across groups.

B. Preparation and specimen geometry

The documented fibre preparation involved washing with distilled water and mild detergent, rinsing, and oven drying within 60–80 °C. Alkali treatment using sodium hydroxide was described, but concentration, treatment duration, bath temperature and the post-treatment washing endpoint were not recorded. Fibre cutting and sizing were mentioned without a numerical length distribution. Unidirectional reinforcement was specified for the pin-on-disc specimens.

Hand lay-up was identified in the fabrication procedure. The record also referred to compression moulding, but did not supply a consolidation pressure or establish the sequence of lay-up and pressing. Accordingly, no pressure-assisted consolidation protocol was assumed. Mixing order, actual mixing speed, degassing, cure duration, cure temperature and post-cure schedule were not sufficiently documented to reconstruct a fully reproducible fabrication protocol. The friction pins were reported as 6 mm in diameter and 30 mm in length. Coupon geometry was taken from the available tensile machine output rather than from generic specimen drawings.

C. Mechanical measurements

Mechanical reporting was assessed against the frameworks of ASTM D3039 [11] and ASTM D256 [12]. Three Izod absorbed-energy values were tabulated for each reinforcement. They were analysed as reported energy in joules, rather than as normalised impact strength. The record did not establish notch geometry, specimen thickness,

pendulum capacity, calibration or compliance with a specific edition. No normalisation by thickness or ligament area was performed.

Tensile testing was described with reference to ASTM D3039 [11]. The available jute output recorded an initial width of 24.3 mm, thickness of 8 mm and gauge length of 150 mm, giving an initial section of 194.4 mm². Peak stress was recalculated by dividing the peak force by this area. Displacements were retained as machine-reported values, because an extensometer record and strain definition were not available. Test speed, conditioning, grip configuration and failure mode were not recorded. A separate PALF peak load appeared in the written results, but was not accompanied by a matching machine output or confirmed specimen area.

Compression values were screened for measurement provenance. The PALF value of 8.3 MPa was explicitly described as an estimate obtained using a 0.4 conversion factor. The jute value of 7.71 MPa also equals 0.4 times its reported tensile strength to the stated precision. Neither value was accepted as an independently measured compressive strength. No compression ranking was included in the experimental results.

D. Thermal and friction measurements

Thermogravimetric analysis (TGA) was described over 30–600 °C at 10 °C/min, with ASTM E1131 cited as the method framework [13]. Atmosphere, purge rate, instrument model, exact initial sample mass and repeat count were not recorded. Thermal observations were therefore treated as qualitative descriptions of mass loss. No thermal conductivity was inferred from TGA, and decomposition intervals were not interpreted as safe operating temperatures.

Pin-on-disc testing was reported for the cylindrical composite specimens. The available outputs were friction coefficients of 0.40 for jute and 0.42 for PALF. Normal load, sliding speed, track radius, sliding distance, counterface material and roughness, temperature, sampling interval and repeat count were not recorded. ASTM G99 [14] was used to identify the information necessary for reproducible sliding measurements; compliance with that standard was not claimed. Wear rates were not calculated because mass loss, volume loss and sliding distance were unavailable.

E. Data treatment

For the six impact observations, arithmetic means, sample standard deviations using $n - 1$ in the denominator, and coefficients of variation were calculated. The percentage difference was



calculated relative to the PALF mean. For friction, the difference was expressed relative to the jute value. These comparisons are descriptive. No analysis of variance or statistically significant improvement was claimed because independent batch replication, measurement uncertainty and complete test records were unavailable. Estimated values and unresolved curve assignments were kept separate from the numerical comparison.

IV. RESULTS AND DISCUSSION

A. Impact energy

The jute values were 70, 70 and 72 J, whereas the PALF values were 68, 70 and 68 J. Table II presents the descriptive statistics. Jute had a mean absorbed energy of 70.67 J and PALF 68.67 J, with an identical sample standard deviation of 1.15 J. The between-group mean difference was 2.00 J, or 2.9% relative to PALF. Figure 1 shows the individual observations and the mean $\pm$ one sample standard deviation.

Table II. Descriptive analysis of reported Izod absorbed energy

Metric	Jute	PALF
Recorded values (J)	70, 70, 72	68, 70, 68
Specimens (n)	3	3
Mean (J)	70.67	68.67
Sample SD (J)	1.15	1.15
Range (J)	70–72	68–70
CV (%)	1.63	1.68

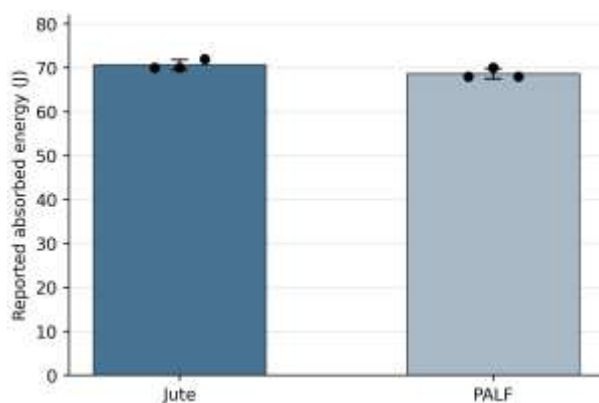


Figure 1. Reported impact energies. Points are the three observations per group; bars show means and error bars show sample SD. Joule units are retained from the record and require laboratory confirmation.

The slightly higher jute mean suggests greater energy absorption for the tested specimens under the recorded conditions. Fibre bridging, pull-out and matrix deformation are plausible contributors, but no fracture-surface microscopy was available to

distinguish these mechanisms. The PALF and jute observations overlap at 70 J; therefore, a categorical claim of superior impact performance is not justified. Identical SD values indicate similar spread within these small groups, rather than established manufacturing repeatability.

The absolute energy values require particular care. A reported pendulum energy is dependent on geometry, notch condition and machine correction; it is not interchangeable with normalised impact resistance [12]. Until units and specimen dimensions are confirmed, comparisons with published J/m or kJ/m² values would be invalid. The modest relative difference is a screening observation, not evidence of increased service durability.

B. Tensile response

The jute machine output recorded a peak load of 3.747 kN and tensile strength of 19.275 MPa. Division of 3747 N by the recorded initial area of 194.4 mm² reproduced 19.275 MPa, supporting the internal consistency of these quantities. The yield load was 2.996 kN with a reported stress of 15.412 MPa. Peak and breaking loads were close, at 3.747 and 3.740 kN, respectively, indicating limited additional load retention after the recorded peak.

Table III. Available jute tensile machine outputs

Quantity	Recorded value
Initial width $\times$ thickness	24.3 $\times$ 8 mm
Initial section	194.4 mm ²
Gauge length	150 mm
Yield load / stress	2.996 kN / 15.412 MPa
Peak load / tensile strength	3.747 kN / 19.275 MPa
Displacement at peak	3.733 mm
Breaking load / stress	3.740 kN / 19.239 MPa

The reported displacement at peak was 3.733 mm. It was not converted to strain because the displacement channel was not confirmed as gauge-section elongation. Moreover, the output's stated 0.33% elongation was not reconciled with the displacement and gauge-length entries. Tensile modulus and strain at failure were consequently omitted. Failure localisation and grip effects also remain unresolved, so the single output cannot establish a population mean or full conformity with ASTM D3039 [11].

The written PALF result stated a peak load of 1.557 kN and displacement of 2.877 mm. However, the



curve placed beneath that description peaked near 3.7 kN and was consistent with the jute output. Without an unambiguous PALF machine record and measured cross-section, a tensile-strength comparison is not defensible. The original claim that PALF had greater tensile strength was therefore not supported by the available comparative measurements.

C. Frictional response

The reported friction coefficient was 0.42 for PALF and 0.40 for jute, a difference of 0.02 or 5.0% relative to jute. This observation indicates a modest numerical distinction, but does not demonstrate friction stability or superiority. A larger coefficient is useful only within an application-specific balance of friction consistency, wear, rotor compatibility, noise and temperature sensitivity.

The evolution of contact plateaus and debris can strongly affect organic brake friction [1]. Fibre orientation and operating conditions are also important in natural fibre composite sliding [9]. Consequently, the present values cannot be attributed uniquely to PALF or jute without matched fibre content and documented loading conditions. Silicon carbide may contribute abrasive contact, but its effect was not isolated because no otherwise identical silicon-carbide-free control was tested.

No time-resolved friction traces or repeat measurements were available. Statements concerning stable friction, lower PALF wear rate and improved wear resistance were therefore not used as measured conclusions. A reproducible comparison requires friction versus time or sliding distance, uncertainty estimates, and wear volume per unit normal load and sliding distance [14]. The two friction values are suitable for planning additional tests, not for assigning a brake friction classification or predicting stopping performance.

D. Thermal response

The thermal descriptions assigned early mass loss near 30–120 °C to moisture, followed by higher-temperature degradation of the organic constituents. Such an interpretation is broadly consistent with the distinct but overlapping thermal decomposition of lignocellulosic components [15]. However, without derivative thermogravimetry, atmosphere information and constituent controls, specific mass-loss stages cannot be assigned uniquely to cellulose, hemicellulose or epoxy.

Table IV. Thermal observations and their interpretive limits

Observation	Jute description	PALF description
Heating programme	30–600 °C; 10 °C/min	30–600 °C; 10 °C/min
Early loss	≈4%; 30–120 °C	≈4%; 30–120 °C
Main interval	250–400 °C	220–380 °C
Later interval	400–500 °C	380–500 °C
Final residue	≈12% stated	≈12% stated

Table IV preserves the stated thermal descriptions as provisional observations, rather than verified transition temperatures. The jute plot used an unspecified mass unit and appeared to retain a final mass fraction different from the stated 12%. The PALF plot showed considerable loss before the claimed main degradation interval. These discrepancies prevented calculation of comparable onset temperatures, 5% mass-loss temperatures or derivative peak temperatures. The curves were not digitised to generate apparently precise thermal metrics.

Although the narrative places the principal jute interval at a higher temperature than PALF, that ordering is not accepted as an established thermal advantage. Residue can include char and inorganic material depending on the atmosphere, so it cannot be labelled ash without the relevant procedure [13]. TGA also does not measure thermal conductivity, glass transition, temperature-dependent modulus or brake fade. The stated 220–250 °C stability limits therefore cannot be used as permissible braking temperatures.

E. Implications for brake material development

The available results identify a small jute advantage in reported impact energy and a small PALF advantage in reported friction coefficient, alongside incomplete tensile and thermal comparisons. They do not reveal a universally superior reinforcement. Different binder systems and manufacturing routes in published brake studies [5]–[8], [10] further limit direct numerical benchmarking. A higher impact energy does not establish higher compressive strength, and a single friction value does not establish reduced wear or fade resistance.

The main practical implication is the need for a controlled formulation study. Fibre fraction, orientation and treatment should be held constant when reinforcement identity is varied, while silicon carbide loading and cure state should be quantified. Replicated tests across temperature, speed and



pressure are necessary to determine whether the observed differences persist. Brake dynamometer screening, such as the SAE J2522 procedure [16], should follow material-level testing to assess friction behaviour over realistic operating sequences.

V. CONCLUSION

Jute and PALF reinforced epoxy–silicon carbide composites were examined as preliminary brake friction material candidates. The three reported impact observations per group yielded means of 70.67 ± 1.15 J for jute and 68.67 ± 1.15 J for PALF, a descriptive difference of 2.9%. The available jute tensile output was internally consistent at 3.747 kN peak load and 19.275 MPa tensile strength. Reported friction coefficients were 0.40 and 0.42 for jute and PALF, respectively. These findings support further comparative screening, while providing no basis for claims of commercial brake pad equivalence, improved wear life or validated high-temperature operation.

The principal limitations are unrecorded fibre fractions and cure conditions, incomplete impact-test geometry and unit verification, unresolved PALF tensile evidence, estimated compression values, inconsistent thermal plots, and missing friction operating conditions and replicate data. No reference pad, unreinforced control, wear-rate dataset, microscopy, environmental assessment or dynamometer validation was available. Accordingly, neither reinforcement can presently be selected as the superior brake material.

Future work should establish complete mass-balanced formulations and traceable processing records; verify impact energies and normalise them using measured specimen dimensions; repeat tensile and directly measured compression tests; and obtain raw TGA and derivative curves under specified atmospheres. Tribological testing should quantify friction evolution, temperature sensitivity, wear rate and counterface damage under matched conditions. A commercial reference pad and suitable binder controls should be included, followed by dynamometer fade and recovery testing [16]. Moisture ageing, fibre variability, wear particle generation, cost and life-cycle impacts should also be assessed before sustainability or application claims are advanced.

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