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Extraction and Characterization of Sri Lankan Habarala (*Alocasia macrorrhizos* (L.) G.Don) Fibre for Potential Composite Applications

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***Abstract*— This study investigates the extraction and characterisation of natural fibre from Alocasia macrorrhizos (L.) G.Don, locally known as Habarala in Sri Lanka, with an emphasis on its potential as a lignocellulosic reinforcement for composite applications. Fibres were mechanically extracted from the stems using a decorticator, yielding an average fibre yield of 6.06%. The extracted fibres exhibited an average linear density of 11.57 Tex, fibre diameter of 31.19 µm, breaking force of 3.28 N, elongation at break of 1.74%, tenacity of 0.24 N/Tex, and moisture content of 14.83%. The mechanically extracted fibres were then subjected to three chemical treatment conditions (A1, B2, and C3) to evaluate changes in their physical, mechanical, and chemical characteristics. C3 produced the greatest reduction in linear density (26.53%) but also decreased breaking force and elongation at break, indicating deterioration of fibre structure. By comparison, B2 showed the best mechanical properties after treatment. FTIR analysis showed that the treatment removed hemicellulose and reduced lignin-related functional groups, while cellulose peaks became more prominent. The results suggest that mechanically extracted Habarala stem fibre is a promising lignocellulosic reinforcement for further evaluation in composite development.**

Keywords: Alocasia macrorrhizos; Habarala fibre; lignocellulosic fibre; mechanical decortication; alkali treatment; tensile properties; composite reinforcement

I. Introduction

Natural fibres have gained increasing attention as reinforcement materials for polymer composites because of their renewable origin, low density, biodegradability, and relatively low cost. Their specific mechanical properties and availability from plant-based resources make them attractive for applications where reducing material weight and dependence on synthetic reinforcements are important considerations (Karim et al., 2020; Asyraf et al., 2023). Consequently, research has expanded beyond established fibres such as flax, jute, hemp, and banana towards underutilized lignocellulosic resources that may offer additional sources of reinforcement materials (Dhir, 2022; Nayak et al., 2023).

The performance of a natural fibre as a potential composite reinforcement depends strongly on its physical, morphological, and mechanical characteristics. Fibre diameter, linear density, tensile behaviour, moisture affinity, surface morphology, and chemical composition can influence fibre processing and its interaction with a polymer matrix (Sadrmanesh & Chen, 2018). Mechanical extraction can provide relatively high fibre recovery, whereas retting and chemical treatments facilitate the removal of non-cellulosic constituents and separation of fibre bundles (Palanisamy et al., 2022). However, intensive chemical treatment may damage the fibre structure and reduce mechanical performance. Treatment conditions must therefore achieve sufficient removal of surface and non-cellulosic materials without excessive deterioration of the cellulose-rich fibre structure (Sawpan et al., 2011; Van de Weyenberg et al., 2005).

Alocasia macrorrhizos (L.) G.Don, commonly known as giant taro or elephant ear and locally referred to as Habarala, is a perennial plant of the family Araceae (Müller & Guzzon, 2023). It is widely available in the wet and intermediate zones of Sri Lanka and is traditionally associated with food and medicinal uses (*Flora of Sri Lanka*, n.d.). Although the stem contains natural fibres, its potential as a lignocellulosic fibre source has not been widely explored. In particular, information on suitable extraction methods and the physical, tensile, morphological, and chemical characteristics of Habarala stem fibre is limited. This restricts an assessment of its potential for technical applications, including its possible use as a composite reinforcement. This study explores fibre extraction from Sri Lankan *A. macrorrhizos* stems using mechanical decortication and evaluates untreated and chemically treated Habarala fibres as potential lignocellulosic reinforcement for composites.

II. Materials and Methods

A. Raw Material Collection and Preparation

Mature and healthy stems of *Alocasia macrorrhizos* were collected from the Western Province of Sri Lanka, cleaned to remove soil and contaminants, and cut into 70 cm lengths for extraction.



Figure 1: *Alocasia macrorrhizos* (L.) G.Don plant

B. Mechanical Fibre Extraction

Habarala fibres were extracted from the stems using a mechanical decorticator. The extracted fibres were subsequently dried under shaded ambient conditions at room temperature. After drying, the fibres were conditioned at 21 ± 1 °C and 65 ± 2% relative humidity prior to characterization.

C. Chemical Treatment of Mechanically Extracted Fibres

Mechanically extracted fibres were subjected to three chemical treatment conditions, designated A1, B2, and C3, using different concentrations of hydrogen peroxide (H_2O_2), sodium hydroxide (NaOH), sodium silicate, and wetting agent. Each treatment was carried out using 5 g of fibre. Following treatment, the fibres were thoroughly washed until neutral pH was achieved and air-dried in the shade. The treatment formulations are presented in Table 1.

Table 1 Chemical treatment conditions used for mechanically extracted fibres

Sample	Fibre weight (g)	H_2O_2 (%)	NaOH (%)	Sodium silicate (%)	Wetting agent (%)
A1	5	3	1.5	1	0.1
B2	5	6	3.0	2	0.2
C3	5	9	4.5	3	0.3

D. Physical and Mechanical Characterization

Fibre linear density was determined according to ASTM D1577-07(2018) and expressed in Tex. Single-fibre tensile testing was performed using a Universal Testing Machine according to ASTM D3822 to determine breaking force and elongation at break. Fibre tenacity was calculated from the breaking force relative to linear density. Moisture characteristics were determined according to ASTM D2654-22.

E. Fourier Transform Infrared Spectroscopy

The chemical characteristics of untreated and treated Habarala fibres were analyzed using a Bruker TENSOR 27 FTIR spectrometer. Spectra were recorded between 4000-400 cm^{-1} to evaluate absorption bands related to cellulose, hemicellulose, and lignin, assessing changes in the lignocellulosic structure after treatment.

III. 3. Results and Discussions

A. Characteristics of Mechanically Extracted Habarala Fibre

Mechanical decortication produced an average dry fibre yield of 6.06%, indicating that the stem of *Alocasia macrorrhizos* contains recoverable fibrous material that can be separated by mechanical processing.



Figure 2 Extracted Fibre

Figure 2 shows the Habarala fibre bundles obtained after mechanical decortication, cleaning, and drying. The extraction process enabled separation of continuous fibre bundles from the surrounding stem tissues for subsequent chemical treatment and characterization.

Tables 2 and 3 show that untreated mechanically extracted fibres had an average linear density of 11.57 Tex and a mean diameter of 31.19 µm. The average breaking force was 3.28 N, with an elongation at break of 1.74% and a tenacity of 0.24 N/Tex. The relatively low elongation indicates limited extensibility, a characteristic commonly associated with lignocellulosic fibres (Balakrishnan et al., 2020). For composite reinforcement, the characteristics of the extracted Habarala fibre should be considered collectively. Its high breaking force and low elongation indicate it can withstand tensile loading but has limited deformation before failure. Additionally, its moisture

affinity, due to hydrophilic groups, can affect its interaction with polymer matrices. Thus, modifying the fibre surface and removing non-cellulosic constituents are essential for effective composite development (Amiandamhen et al., 2020).

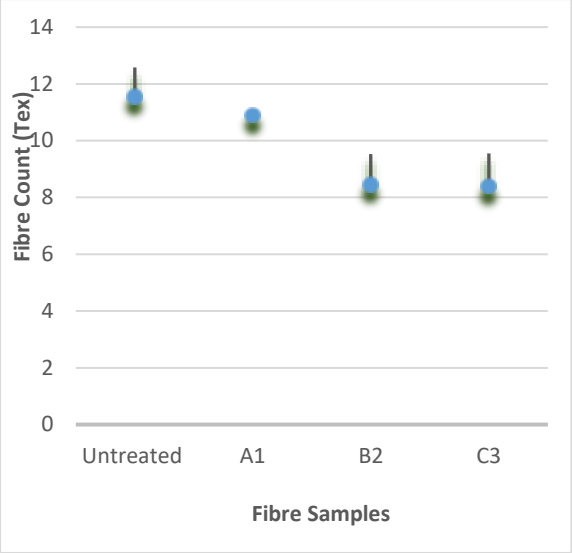


Figure 3 :Fibre count of untreated and chemically treated fibre

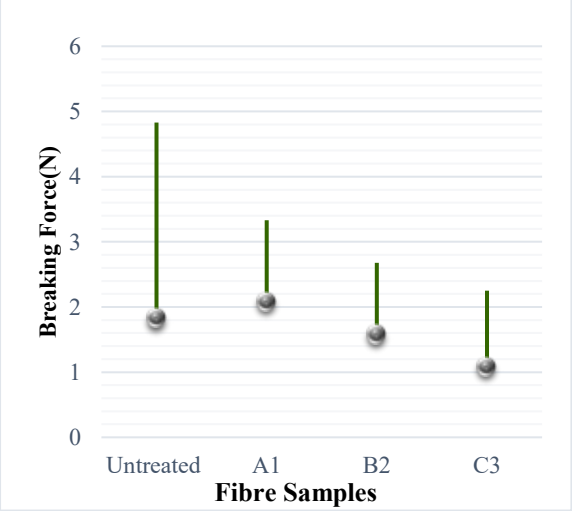


Figure 4 : Breaking force of untreated and chemically treated fibre

B. Effect of Chemical Treatment on Fibre Fineness

Chemical treatment produced a progressive reduction in both linear density and fibre diameter (Figure 1). The untreated fibre had a linear density of 11.57 Tex, whereas A1, B2, and C3 reduced the linear density by 5.19%, 17.98%, and 26.53%, respectively. C3 produced the lowest linear density of 8.50 Tex. A similar trend was observed for fibre diameter (Table4). The untreated fibre diameter of 31.19 µm decreased to 24.46 µm, 23.57 µm, and 19.37 µm for A1, B2, and C3, respectively. Thus, C3 resulted in an approximately 37.9% reduction in diameter compared with the untreated fibre. The reduction in linear density and diameter indicates material removal from fibre bundles during alkali treatment of lignocellulosic fibres, which eliminates hemicellulose, lignin, and non-cellulosic components, leading to finer fibre structures (Balakrishnan et al., 2019; Sawpan et al., 2011). As treatment intensity increases, Habarala fibres become progressively finer; however, the finest fibres may not be the most mechanically suitable, as shown by tensile results.

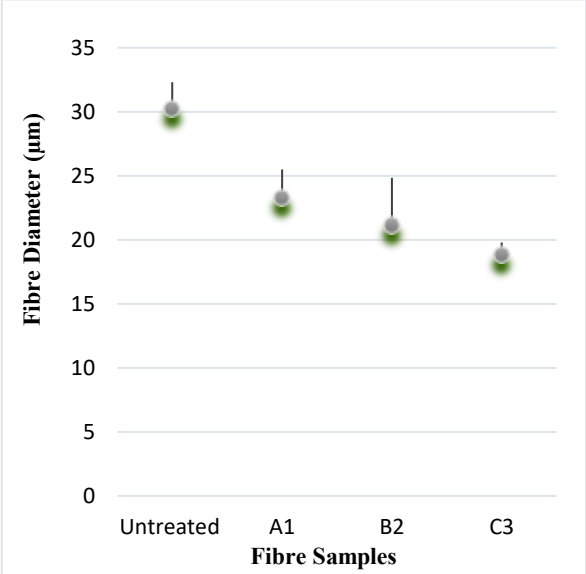


Figure 5 : Fibre diameter of untreated and chemically treated fibre

C. Effect of Chemical Treatment on Tensile Behaviour

Chemical treatment resulted in a progressive reduction in the breaking force of Habarala fibres. The untreated fibre exhibited the highest average breaking force of 3.28 N, while C3 recorded the lowest value of 1.75 N. Relative to the untreated fibre, breaking force decreased by 18.9%, 37.2%, and 46.7% for A1, B2, and C3, respectively. A similar response was observed for elongation at break. The untreated fibre exhibited an elongation of 1.74%, whereas C3 decreased to 1.14%. The reductions in elongation were 10.9%, 18.4%, and 34.5% for A1, B2, and C3, respectively.

Figure 3 results show a trade-off between fibre fineness and mechanical integrity. Higher treatment severity led to finer fibres but also greater losses in breaking force and extensibility. Non-cellulosic component removal can alter fibre structure, and excessive treatment risks degrading it (Sawpan et al., 2011; Van de Weyenberg et al., 2005). C3 produced the finest fibres but caused the greatest reductions in strength and elongation. In contrast, B2 showed a more balanced outcome, with a 17.98% decrease in linear density and a 24.4% reduction in diameter, alongside milder losses in breaking force and elongation compared to C3. This balance is crucial for considering treated fibres as composite reinforcements.

D. FTIR Analysis

FTIR analysis confirmed chemical changes in Habarala fibre post-treatment(Figures 5 and 6). The untreated fibre showed an absorption band at around 1730 cm^{-1}, linked to hemicellulose, which decreased after A1 treatment and was nearly absent in B2 and C3, indicating hemicellulose removal. The lignin band at 1500 cm^{-1} also diminished with treatment intensity, becoming weak in B2 and almost gone in C3. Meanwhile, the cellulose band near 1050 cm^{-1} became more pronounced after treatment, especially in B2, suggesting more exposure of cellulose(Balakrishnan et al., 2021). However, in C3, this could indicate potential structural alteration due to severe treatment, which aligns with mechanical results showing C3 had the greatest reduction in breaking force and elongation. Overall, FTIR and tensile results suggest that more severe chemical treatment beyond B2 refines the fibre but compromises its structural integrity.

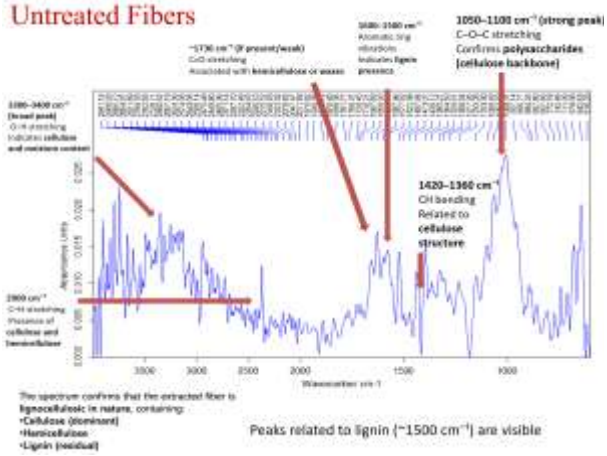
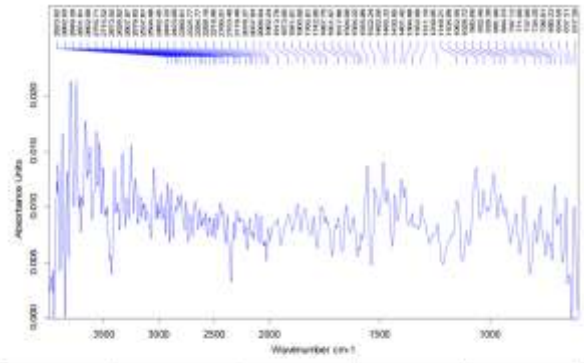


Figure 6 : FTIR spectrum of untreated fibre



Functional Groups and Position (cm⁻¹)	Untreated Fiber	A1 samples	B2 Sample	C3 Samples
Samples Hemicellulose (~1730 cm⁻¹)	Present	Reduced	Absent	Absent
Lignin (~1500 cm⁻¹)	Strong	Reduced	Very weak	Nearly absent
Cellulose peak (~1050 cm⁻¹)	Moderate	Strong	Very strong	Slightly reduced/altered
Fiber Quality	Low	Improved	Optimal	Possible degradation

Figure 7 : FTIR spectrum of C3 sample treated fibre

The reinforcement potential of Habarala fibre depends on maintaining sufficient mechanical integrity while improving fibre fineness and reducing non-cellulosic constituents that may affect fibre–matrix interaction (Karim et al., 2020; Amiandamhen et al., 2020). The untreated fibre showed a linear density of 11.57 Tex, diameter of 31.19 µm, breaking force of 3.28 N, tenacity of 0.24 N/Tex, and elongation at break of 1.74%. Following B2 treatment, linear density and diameter decreased by 17.98% and 24.4%, respectively. FTIR analysis also showed removal of hemicellulose, reduction of lignin, and greater exposure of cellulose, consistent with the effects reported for chemically modified lignocellulosic fibres (Sawpan et al., 2011; Le Troedec et al., 2007). Increasing the treatment severity to C3 produced finer fibres but reduced breaking force by 46.7% and elongation by 34.5%, indicating that further removal of non-cellulosic material was accompanied by deterioration of fibre integrity (Van de Weyenberg et al., 2005; Sawpan et al., 2011). B2 therefore offered a more appropriate balance between fibre refinement and retention of tensile performance. Nevertheless, the relatively high moisture affinity of Habarala fibre remains relevant because hydrophilicity can influence fibre–matrix interfacial behaviour in natural-fibre composites (Amiandamhen et al., 2020). The appearance of Habarala fibre after chemical treatment is shown in Fig. 8. Treatment with H_2O_2, NaOH, sodium silicate, and wetting agent facilitated the removal of non-cellulosic constituents from the fibre structure.



Figure 8 Habarala (Alocasia macrorrhizos (L.) G.Don) fibre after chemical treatment.

Overall, these findings support the further evaluation of B2-treated Habarala fibre as a potential reinforcement for composite applications.

IV. Discussion & Conclusion

This study established the physical, mechanical, and chemical characteristics of mechanically extracted *Alocasia macrorrhizos* fibre and quantified its response to different chemical treatment conditions. Mechanical decortication produced an average fibre yield of 6.06%. The untreated fibre exhibited a linear density of 11.57 Tex, mean diameter of 31.19 µm, breaking force of 3.28 N, elongation at break of 1.74%, tenacity of 0.24 N/Tex, moisture content of 14.83%, and moisture

regain of 17.44%. Chemical treatment progressively reduced fibre linear density and diameter, confirming increased fibre refinement; however, increasing treatment severity was accompanied by a corresponding loss in tensile performance. C3 produced the largest reductions in linear density (26.53%) and diameter (37.9%), but also reduced breaking force and elongation at break by 46.7% and 34.5%, respectively. In comparison, B2 reduced linear density by 17.98% and diameter by approximately 24.4%, while retaining comparatively better mechanical integrity than C3.

The FTIR results complemented these physical and mechanical observations, showing progressive removal of hemicellulosic and lignin-associated constituents and greater exposure of the cellulose-rich fibre structure after treatment. Taken together, the results demonstrate a clear trade-off between fibre refinement and retention of tensile properties as treatment severity increases. Among the conditions investigated, B2 provided the most balanced processing–property response, whereas further treatment under C3 resulted in greater fibre refinement at the expense of mechanical integrity. The measured moisture characteristics also confirm the hydrophilic nature of Habarala fibre, which should be considered during subsequent composite development. Overall, the findings provide a fibre-level basis for the further evaluation of B2-treated Habarala stem fibre as a potential reinforcement for composite applications. Future work should therefore focus on composite fabrication and the evaluation of fibre–matrix interaction, tensile and flexural behaviour, impact resistance, and moisture-related performance to establish its application-specific reinforcement capability.

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