

CHAPTER FIFTEEN

Evaluation of Leaf Morpho-Anatomical and Fibre Quality and Characterisation of *Luffa cylindrica* (L.) M. Roem. And *Luffa acutangula* (L.) Roxb.

SAGAYA Abdulquadri, LATEEF Adebola Azeez, TIAMIYU Bashir
Bolaji & ABDULRAHAMAN, Abdullahi Alanamu

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Abstract

Luffa, a genus of tropical and subtropical vines in the cucumber family, shows morphological variation influenced by environmental factors. However, scientific data on the thermal and mechanical properties of *Luffa* fibres remain limited. This study investigated the leaf morpho-anatomical characteristics and fibre quality of *Luffa cylindrica* and *Luffa acutangula*, using mature fruits collected from eight local government areas in Kwara State, Nigeria. Seeds were cultivated in a randomised complete block design. Morphological analysis revealed greater variability in *L. cylindrica* for stem girth, leaf size, and qualitative traits. Anatomically, both species were amphistomatic, with *L. cylindrica* bearing trichomes on both surfaces, unlike *L. acutangula*. Mechanical testing showed that *L. cylindrica* had superior tensile strength, modulus, flexural strength, and hardness, whereas *L. acutangula* exhibited higher impact energy and elongation. These findings suggested *L. cylindrica* is better suited for industrial fiber applications, supporting the need for its cultivation and promotion for commercial use.

Keywords: *Luffa cylindrica*, *Luffa acutangula*, Fibre quality, Anatomy.

Introduction

Species of the genus *Luffa* belonging to the family Cucurbitaceae are widely cultivated in tropical and subtropical regions for food, fiber, and industrial purposes (Cheng *et al.*, 2020). They are significant vines known for their economic value majorly from their fruit, which upon maturation and drying, yields a fibrous network natural sponge like fiber (Barirega & Van Damme, 2014). It has also been reported to be used for various applications such as tissue for engine filters, steel helmet lining, insulation, packing materials and

filters in factories. In Nigeria, *Luffa cylindrica* (smooth loofah) and *Luffa acutangula* (ridged loofah) are the most commonly cultivated species. They are known for their adaptability and diverse uses, particularly as scrubbing sponges and reinforcement in composite materials (Wambua *et al.*, 2003). Despite their uses, taxonomic delimitation, especially between *L. cylindrica* and *L. acutangula*, remains ambiguous due to their morphological similarities and interspecific hybridisation potential (Heiser & Schilling, 1990; Bal *et al.*, 2004). The *Luffa* species are influenced by a complex interplay of genetic factors and environmental conditions (Widen & Sheinmann, 2006). Understanding this variation is important for germplasm classification and identification of superior genotypes for specific applications. In addition, the anatomical information of the leaves and stems can provide significant taxonomic insights.

As Nigeria explores bio-based resources due to interest in sustainable, renewable and biodegradable materials, this has increased the search for the potential of natural fibres to replace synthetic ones in various applications. *Luffa* fibres, a natural, readily available and relatively expensive fibers, have been looked into as a possible alternative (Mohanty *et al.*, 2000). However, a comprehensive understanding of the morpho-anatomical and mechanical properties of *Luffa* species is critical for their optimal utilisation in bio-composites, textiles, and agro-industrial applications.

It is well documented that morphological traits have always been central to plant taxonomy (Zaman *et al.*, 2025), but recently, leaf epidermal features and anatomical markers have been used to resolve ambiguities (Mbagwu & Edeoga, 2006). *Luffa*'s fibrous vascular endocarp has attracted interest for use in industrial composites due to its biodegradability and high cellulose content (Tanobe *et al.*, 2005). However, environmental conditions and genetic variability influence their mechanical properties (Siqueira *et al.*, 2010). A comparative analysis of different species, particularly those cultivated in different geographical regions like Nigeria, remains limited and, therefore, necessitates region-specific characterisation studies of *Luffa*. The study aimed to address the gap by conducting a detailed investigation into the morpho-anatomical characteristics and fibre quality of *Luffa cylindrica* and *Luffa acutangula* accessions collected and cultivated in Kwara State, Nigeria.

Materials and Methods

Mature dry fruits of 20 accessions of *Luffa cylindrica* (18) and *Luffa acutangula* (2) were collected from eight (8), selected randomly from the sixteen (16) different local government areas with different provenances and settlements within Kwara State, Nigeria (Table 1). Voucher specimen were deposited, identified and authenticated at the herbarium, Department of Plant Biology, Faculty of Life Sciences, University of Ilorin. Seeds were extracted from the collected fruits and cultivated at the Botanical Garden of University of Ilorin using a randomised complete block design with three replicates per accession. Standard agronomic practices were followed to ensure optimal growth.

Morphological Characterisation: Morphological quantitative traits data including stem girth, leaf length and width were measured at seedling and maturity stages, using standard protocols (Radford *et al.*, 1974). Qualitative traits including leaf colour, flower colour, fruit shape and seed characteristics were visually assessed and recorded, using descriptive terminology based on established description (Zalapa *et al.*, 2006)

Anatomical Studies: Leaf peels sample from fully expanded mature leaves of all the *Luffa* accessions were prepared using nitric acid maceration. Epidermal peels obtained were stained with safranin. Stomatal density, length, width, size, index, and type and epidermal density and shapes were assessed with light microscopy (Khan *et al.*, 2017).

Fiber Testing: Mature dry fruits of *Luffa* accessions were processed to extract the fibrous vascular network. The fruits were retted for several days to enhance removal of outer skin and pulp. Resulting fibrous sponges were then thoroughly washed, dried and cut into test specimen of uniform dimension. Mechanical tests (tensile strength, strain, flexural strength, hardness, elongation, impact energy) were conducted on retted and dried fruit fibers. Six (6) accessions of already retted and air-dried *Luffa* species were randomly selected, pulverised and analysed for percentage chemical composition

Table 1: *Luffa* Species Accession Code Numbers, Location of Acquisition and GPS Coordinates

Accesssion code No	Location	GPS Coordinates
01 OGD	Ogidi, IL-West	8.21' N, 4.26' E
02 UIL	Unilorin Garden, IL-South	9.54' N, 4.45' E
03 AGB	Agbooba Area, IL-West	8.43' N, 4.50' E
04 ADW	Adewole Estate, IL-West	8.51' N, 4.42' E
05 SHK	Sheik Abdulkadri College, IL-West	8.29' N, 4.46' E
06 APL	Apalara Area, IL-West	8.25' N, 4.39' E
07 OKF	Okefoma Area, IL-West	8.40' N, 4.42' E
08 ARP	Airport Road, IL-West	8.49' N, 4.59' E
09 ALG	Alagbado Hospital, IL-South	9.40' N, 5'00' E
10 OKL	Okelele Area, IL-East	10.28' N, 5.07' E
11 AGS	Agric Sango, IL-South	9.43' N, 4.20' E
12 KSU	Kwasu Malete, Moro	9.64' N, 4.99' E
13 OLJ	Oloje Estate, IL-West	8.39' N, 4.19' E
14 OKY	Okeoyi, IL-East	10.26' N, 5.04' E
15 OFG	Offa Garage, IL-South	9.86' N, 4.95' E
16 OKS	Oke Ose, IL-East	10.85' N, 4.69' E
17 OMP	Omupo, Ifelodun	9.04' N, 4.98' E
18 OFF	Offa COHT, Offa	9.92' N, 4.95' E
19 EIY	Eiyenkorin, Asa	9.45' N, 4.47' E
20 AJS	Ajasepo ipo, Irepodun	10.04' N, 4.80' E

Note: - 14 OKY and 15 OFG are *luffa acutangula* while other accessions are *luffa cylindrical*

Data Analysis

Data obtained from morphological measurements, anatomical studies and fibre testing were analysed, using ANOVA on SPSS version 25 to determine significant differences. Significant post hoc test using Duncan Multiple Range Test (DMRT) were also conducted to identify specific between the means.

Results

Morphological Variation

The morphological analysis revealed significant variations between *L. cylindrica* and *L. acutangula*. *L. cylindrica* exhibited a larger range of stem girth (5.39 to 7.52 cm), leaf length (11.10 – 16.50), leaf width (7.37 – 13.03) compared to *L. acutangula* with stem girth (4.20 -6.49), leaf length (9.95 – 10.60) and leaf width (7.33 – 9.33) (Table 2). Statistical analysis indicated significant differences ($p < 0.05$) for these quantitative traits between the two species. Qualitatively, *L. cylindrica* displayed black, brown and oblong seeds while *L. acutangula* exhibited grayish black and ovate seeds (Table 3). *L. cylindrica* showed dark green leaves with bright yellow flowers and elongated cylindrical fruits, whereas *L. acutangula* had light green leaves with light yellow flowers and elongated spindle-shaped fruits. These qualitative traits provided distinguishing features between the two species.

Anatomical Features

Anatomical examination of foliar epidermis of both *Luffa* spp studied revealed that they were amphistomatic (i.e., possessing stomata on the upper and lower epidermal surfaces) with a predominance of Staurocytic stomata. Epidermal cells wall varied between polygonal and irregular shapes, often with polygonal forms on the adaxial surface and irregular patterns on the abaxial side (Table 4). *L. cylindrica* possess trichomes on both epidermal surfaces while *L. acutangula* lacked trichomes on the lower epidermal surfaces (Figure 1 and Table 5).

Table 2: Morphological Quantitative Features of the 20 Accessions of *Luffa* Species

ACC NO	STGTH(CM)	LFLGTH(CM)	LFWDT(CM)	SLFLGTH(CM)	SLFWDT (CM)
01OGD	5.99 ± 0.32 ^{abcd}	16.50 ± 0.67 ^a	13.03 ± 0.39 ^a	3.97 ± 0.12 ^a	2.00 ± 0.06 ^a
02UIL	5.74 ± 1.22 ^{abcd}	11.10 ± 0.60 ^{fgh}	7.37 ± 0.56 ^{ef}	3.87 ± 0.18 ^a	1.92 ± 0.06 ^a
03AGB	4.72 ± 0.97 ^{cd}	14.97 ± 0.41 ^{abcd}	10.40 ± 0.49 ^{bc}	3.97 ± 0.27 ^a	1.92 ± 0.04 ^a
04ADW	4.38 ± 0.68 ^d	16.50 ± 0.51 ^a	10.97 ± 0.41 ^{ab}	4.00 ± 0.44 ^a	1.97 ± 0.07 ^a
05SHK	4.86 ± 0.48 ^{bcd}	14.87 ± 1.29 ^{abcd}	10.20 ± 0.98 ^{bc}	4.20 ± 0.21 ^a	1.93 ± 0.13 ^a
06APL	4.30 ± 0.65 ^d	15.73 ± 0.46 ^{abc}	10.00 ± 0.26 ^{abc}	3.83 ± 0.12 ^a	1.98 ± 0.07 ^a
07OKF	4.22 ± 0.30 ^d	14.70 ± 1.08 ^{abcd}	8.63 ± 1.79 ^{bcdef}	3.93 ± 0.22 ^a	1.83 ± 0.03 ^a
08ARP	4.26 ± 0.29 ^d	16.40 ± 0.79 ^{ab}	10.93 ± 0.89 ^{ab}	3.77 ± 0.12 ^a	2.02 ± 0.09 ^a
09ALG	3.98 ± 0.50 ^d	13.33 ± 1.22 ^{cdef}	6.40 ± 0.49 ^f	3.80 ± 0.36 ^a	2.05 ± 0.23 ^a
10OKL	5.52 ± 0.82 ^{abcd}	14.03 ± 0.98 ^{abcd}	9.30 ± 1.10 ^{bcde}	3.67 ± 0.28 ^a	1.97 ± 0.07 ^a
11SNG	5.39 ± 0.53 ^{abcd}	13.47 ± 0.62 ^{cdef}	8.20 ± 0.89 ^{cdef}	3.73 ± 0.19 ^a	1.97 ± 0.09 ^a
12KSU	7.52 ± 0.97 ^a	13.93 ± 1.41 ^{abcd}	9.30 ± 0.75 ^{bcde}	3.80 ± 0.06 ^a	1.93 ± 0.09 ^a
13OLJ	7.21 ± 1.37 ^{abc}	12.63 ± 1.33 ^{defg}	9.07 ± 0.45 ^{bcde}	4.10 ± 0.10 ^a	1.90 ± 0.06 ^a

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14OKY	6.49 ± 0.47 ^{abcd}	10.60 ± 0.32 ^{gh}	9.33 ± 0.43 ^{bcde}	3.63 ± 0.09 ^a	2.00 ± 0.06 ^a	±
15OFG	4.20 ± 0.33 ^d	9.95 ± 0.09 ^h	7.33 ± 0.64 ^{ef}	3.80 ± 0.06 ^a	1.80 ± 0.06 ^a	±
16OKS	5.20 ± 1.45 ^{abcd}	11.20 ± 0.68 ^{efgh}	7.63 ± 0.48 ^{def}	3.67 ± 0.17 ^a	1.98 ± 0.12 ^a	±
17OMP	6.41 ± 0.34 ^{abcd}	13.13 ± 0.56 ^{cdef}	8.03 ± 0.74 ^{cdef}	3.87 ± 0.09 ^a	1.93 ± 0.09 ^a	±
18OFF	5.77 ± 0.98 ^{abcd}	14.07 ± 0.73 ^{abcd}	10.20 ± 0.61 ^{bc}	3.67 ± 0.20 ^a	1.92 ± 0.09 ^a	±
19EIY	6.34 ± 0.54 ^{abcd}	13.87 ± 0.52 ^{abcde}	8.10 ± 0.26 ^{cdef}	3.70 ± 0.29 ^a	2.03 ± 0.03 ^a	±
20AJS	7.34 ± 0.23 ^{ab}	13.67 ± 0.72 ^{bcdef}	9.67 ± 0.49 ^{bcde}	4.03 ± 0.13 ^a	1.88 ± 0.06 ^a	±

Mean values ± Standard errors, Duncan's Multiple range rankings of Morphological features of the 20 *Luffa* species accessions. Different letters along columns depicts significant difference at P<0.05. Acc. Cod. No. = Accession Code Number, STGTH = Stem girth, LFLGHT = Matured Leaf Length, LFWDTH = Matured Leaf Width, SLFLGHT = Seedling Leaf Length, SLFWDTH = Seedling Leaf Width C.V= Coefficient of Variance. ± Standard error.

Table 3 Morphological Qualitative features of the 20 accessions of *Luffa* species

Acc. No.	Leaf colour	Flower colour	Fruit shape	Seed colour	Seed shape
01OGD	Dark green	Bright yellow	Elongated cylindrical	Black and Brown	Oblong
02UIL	Dark green	Bright yellow	Elongated cylindrical	Black and Brown	Oblong
03AGB	Dark green	Bright	Elongated	Black and	Oblong

		yellow	cylindrical		Brown		
04ADW	Dark green	Bright yellow	Elongated cylindrical	and	Black Brown	and	Oblong
05SHK	Dark green	Bright yellow	Elongated cylindrical	and	Black Brown	and	Oblong
06APL	Dark green	Bright yellow	Elongated cylindrical	and	Black Brown	and	Oblong
07OKF	Dark green	Bright yellow	Elongated cylindrical	and	Black Brown	and	Oblong
08ARP	Dark green	Bright yellow	Elongated cylindrical	and	Black Brown	and	Oblong
09ALG	Dark green	Bright yellow	Elongated cylindrical	and	Black Brown	and	Oblong
10OKL	Dark green	Bright yellow	Elongated cylindrical	and	Black Brown	and	Oblong
11SNG	Dark green	Bright yellow	Elongated cylindrical	and	Black Brown	and	Oblong
12KSU	Dark green	Bright yellow	Elongated cylindrical	and	Black Brown	and	Oblong
13OLJ	Dark green	Bright yellow	Elongated cylindrical	and	Black Brown	and	Oblong
14OKY	Light green	Light yellow	Elongated and spindle		Greyish Black		Ovate
15OFG	Light green	Light yellow	Elongated and spindle		Greyish Black		Ovate
16OKS	Dark green	Bright yellow	Elongated cylindrical	and	Black Brown	and	Oblong
17OMP	Dark green	Bright yellow	Elongated cylindrical	and	Black Brown	and	Oblong
180FF	Dark green	Bright yellow	Elongated cylindrical	and	Black Brown	and	Oblong
19EIY	Dark green	Bright	Elongated	and	Black	and	Oblong

		yellow	cylindrical		Brown		
20AJS	Dark green	Bright yellow	Elongated cylindrical	and	Black Brown	and	Oblong

Table 4: Leaf Anatomical Features of the 20 Accessions of two *Luffa* Species

Acc. Cod. NO	Su rfa ce	STLT(mm ²)	STWT(mm ²)	STD	ECLT(mm ²)	ECWT(mm ²)
01OGD	U	10.20±0.58 ^{abcdef}	9.00±0.58 ^a	98.68±6.58 ^{bcd}	17.60±0.75 ^{abcde}	11.60±1.21 ^{cd}
	L	9.40±0.40 ^{cdefgh}	5.00±0.40 ⁱ	44.74±5.26 ^{ghijkl}	10.80±0.49 ^{lmn}	11.80±0.58 ^{cd}
02UIL	U	10.40±0.51 ^{abcde}	6.20±0.51 ^{fghi}	86.84±3.22 ^{bcd}	18.20±1.16 ^{abc}	10.20±0.66 ^{cdeh}
	L	8.40±0.75 ^{gh}	5.60±0.75 ^{ghi}	22.37±2.63 ^l	12.20±1.20 ^{klmn}	8.20±0.49 ^{ghi}
03AGB	U	8.60±0.24 ^{gh}	5.00±0.24 ⁱ	69.74±2.63 ^{defghij}	19.60±0.51 ^{ab}	11.80±1.07 ^{cd}
	L	11.20±0.58 ^a	5.60±0.58 ^{ghi}	47.37±6.3 ^{fghij}	14.80±1.24 ^{defghijk}	11.20±0.58 ^{ghi}
04ADW	U	10.20±0.37 ^{abcdef}	7.00±0.37 ^{efgh}	102.63±7.67 ^{bcd}	14.40±0.75 ^{efghijk}	12.80±1.50 ^{bcd}
	L	8.20±0.20 ^{hi}	5.20±0.20 ⁱ	31.58±2.46 ^l	13.40±0.87 ^{ijklmn}	8.20±0.37 ^{bc}
05SHK	U	11.20±0.58 ^a	5.40±0.58 ^{hi}	136.84±5.26 ^a	20.40±0.51 ^a	11.00±0.45 ^{cdefg}
	L	8.40±0.24 ^{gh}	12.20±0.24 ^a	80.26±6.71 ^{def}	15.80±0.37 ^{cdefghij}	10.20±0.20 ^{cdefgh}
06APL	U	9.60±0.24 ^{bcdefgh}	6.60±0.24 ^{efghi}	86.84±3.22 ^{bcd}	18.20±1.16 ^{abc}	10.20±0.66 ^{cdefgh}

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	L	8.20±0.49 ^{hi}	5.60±0.49 ^{ghi}	76.32±5.49 ^{defgh}	12.20±1.20 ^{klmn}	8.20±0.49 ^{ghi}
07OKF	U	10.80±0.37 ^{abc}	7.20±0.37 ^{cdefgh}	86.84±6.71 ^{bcd}	17.40±0.68 ^{abcdef}	12.80±1.66 ^{bc}
	L	8.60±0.40 ^{gh}	5.00±0.40 ⁱ	50.00±4.46 ^{efghijkl}	11.80±0.66 ^{klmn}	9.20±0.49 ^{defghi}
08ARP	U	10.60±0.40 ^{abcd}	7.80±0.40 ^{bcdef}	77.63±13.22 ^{defg}	18.00±1.67 ^{abcd}	11.20±1.24 ^{cdef}
	L	8.80±0.37 ^{fgh}	6.40±0.37 ^{efghi}	25.00±3.83 ^l	10.20±1.02 ⁿ	8.40±0.51 ^{fghi}
09ALG	U	10.20±0.20 ^{abcdef}	9.00±0.20 ^b	82.90±5.43 ^{cde}	18.00±1.05 ^{abcd}	11.80±0.86 ^{cd}
	L	9.20±0.20 ^{defgh}	7.00±0.20 ^{defgh}	22.37±1.61 ^l	10.60±1.12 ^{mn}	7.40±0.24 ⁱ
10OKL	U	10.20±0.20 ^{abcdef}	5.80±0.20 ^{ghi}	92.10±8.58 ^{abcd}	14.00±1.30 ^{ghijkl}	17.80±1.24 ^a
	L	8.60±0.40 ^{gh}	5.40±0.40 ^{hi}	28.95±1.61 ^l	4.40±0.24 ^o	14.60±1.60 ^b
11SNG	U	10.60±0.24 ^{abcd}	7.20±0.24 ^{cdefg}	119.74±6.38 ^{ab}	13.60±0.98 ^{hijklm}	8.80±0.49 ^{efghi}
	L	8.40±0.24 ^{gh}	6.20±0.24 ^{fghi}	30.26±3.35 ^l	14.20±1.74 ^{fghijk}	10.40±0.51 ^{cdefgh}
12KSU	U	11.20±0.37 ^a	8.00±0.37 ^{bcde}	100.00±9.16 ^{bcd}	17.80±0.73 ^{abcd}	10.40±1.69 ^{cdefgh}
	L	8.60±0.40 ^{gh}	5.40±0.40 ^{hi}	25.00±3.83 ^l	10.60±0.40 ^{mn}	8.80±0.58 ^{efghi}
13OLJ	U	11.00±0.45 ^{ab}	9.40±0.45 ^b	92.11±9.30 ^{bcd}	16.80±1.11 ^{bcdefgh}	11.20±0.37 ^{cdef}
	L	8.80±0.20 ^{fgh}	5.40±0.20 ^{hi}	42.10±5.34 ^{hijkl}	14.20±1.07 ^{fghijk}	8.40±0.51 ^{fghi}

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14OKY	U	8.20±0.37 ^{hi}	5.40±0.37 ^{hi}	72.37±2.94 ^{defghi}	15.60±0.87 ^{cdefghij}	9.20±0.49 ^{defghi}
	L	7.00±0.45 ⁱ	6.40±0.45 ^{efghi}	34.21±4.83 ^{kl}	13.20±0.73 ^{klmn}	10.80±0.37 ^{cdefgh}
15OFG	U	8.40±0.40 ^{gh}	7.20±0.40 ^{cdefg}	68.42±3.36 ^{defghijk}	14.00±0.71 ^{cdefghij}	9.00±0.45 ^{defghi}
	L	9.20±0.37 ^{defgh}	8.60±0.37 ^{bcd}	38.16±4.83 ^{ijkl}	13.80±0.80 ^{klmn}	8.40±0.51 ^{fghi}
16OKS	U	9.60±0.24 ^{bcdefgh}	8.40±0.24 ^{bcd}	72.37±2.94 ^{defghi}	15.60±0.87 ^{bcdefghi}	9.20±0.49 ^{defghij}
	L	8.20±0.20 ^{hi}	5.00±0.20 ⁱ	34.21±4.83 ^{kl}	13.20±0.73 ^{klmn}	10.80±0.37 ^{cdefgh}
17OMP	U	10.40±0.24 ^{abcde}	8.80±0.24 ^{bc}	98.68±11.39 ^{bcd}	16.60±1.63 ^{bcdefghi}	11.80±0.66 ^{cd}
	L	8.80±0.37 ^{fgh}	5.20±0.37 ⁱ	36.84±4.46 ^{ijkl}	13.20±0.97 ^{klmn}	8.60±0.60 ^{fghi}
18OFF	U	10.40±0.40 ^{abcdef}	9.20±0.40 ^b	117.10±6.38 ^{abc}	17.20±1.20 ^{abcdef}	11.40±0.75 ^{cde}
	L	9.00±0.32 ^{efgh}	5.40±0.32 ^{hi}	31.58±2.46 ^l	12.60±0.75 ^{klmn}	8.40±0.40 ^{fghi}
19EIY	U	9.60±0.24 ^{bcdefgh}	9.40±0.24 ^b	115.79±7.95 ^{abc}	17.40±0.51 ^{abcd}	11.40±0.51 ^{cde}
	L	8.80±0.37 ^{fgh}	6.20±0.37 ^{fghi}	31.58±2.46 ^l	13.20±0.97 ^{klmn}	8.00±0.32 ^{hi}
20AJS	U	9.80±0.58 ^{abcdefg}	9.40±0.58 ^b	98.69±9.76 ^{bcd}	18.00±0.55 ^{abcd}	11.80±1.11 ^{cd}
	L	8.40±1.03 ^{gh}	7.20±1.03 ^{cdefg}	34.21±3.83 ^{kl}	12.80±0.80 ^{klmn}	8.40±0.68 ^{fghi}

Mean values, standard error and different letters along columns depicting significant difference at 0.05 level using ANOVA test. Acc. Cod. No. = Accession Code Number, STLT = Stomata length, STWT = Stomatal width,

STD= Stomatal Density, ECWT = Epidermal cell width, ECLT = Epidermal cell length, U = Upper leaf surface, L = Lower leaf surface.

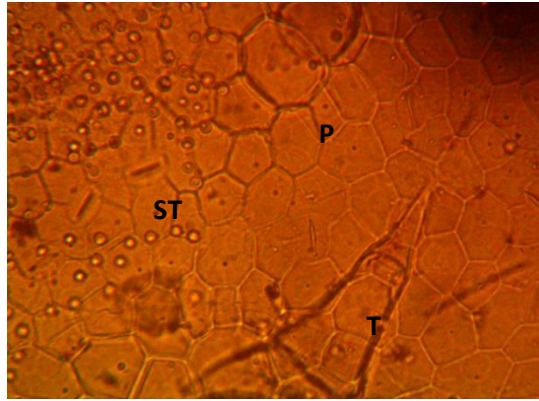
Table 5: Leaf Anatomical Features of the 20 accessions of two *Luffa* Species

Acc. Cod. No	Surface	ECD	STSZ(μm^2)	STID(%)	ECS	Trichomes
01OGD	U	426.31 $\pm$ 10.69 ^{cde}	72.09 $\pm$ 4.69 ^{ab}	18.83 $\pm$ 1.31 ^{abcde}	Polygonal	Present
	L	572.37 $\pm$ 5.89 ^a	36.91 $\pm$ 2.94 ^{ijklm}	7.24 $\pm$ 0.84 ^{kl}	Polygonal	Present
02UIL	U	436.84 $\pm$ 11.32 ^{bcde}	51.35 $\pm$ 6.89 ^{defghi}	16.63 $\pm$ 0.8 ^{bcdefg}	Polygonal	Present
	L	552.63 $\pm$ 25.05 ^a	36.75 $\pm$ 3.28 ^{ijklm}	3.90 $\pm$ 0.47 ^j	Irregular	Present
03AGB	U	438.16 $\pm$ 29.17 ^{bcde}	33.92 $\pm$ 2.82 ^{lm}	13.87 $\pm$ 0.79 ^{fghi}	Polygonal	Present
	L	576.32 $\pm$ 10.32 ^a	49.31 $\pm$ 3.60 ^{efghijk}	7.56 $\pm$ 0.95 ^{kl}	Irregular	Present
04ADW	U	482.89 $\pm$ 17.85 ^{bcd}	56.54 $\pm$ 7.23 ^{cdefgh}	17.45 $\pm$ 0.81 ^{abcdefg}	Polygonal	Present
	L	584.21 $\pm$ 5.66 ^a	33.61 $\pm$ 2.96 ^{lm}	5.12 $\pm$ 0.37 ^{kl}	Irregular	Present
05SHK	U	547.37 $\pm$ 13.71 ^a	47.74 $\pm$ 4.14 ^{fghijkl}	20.02 $\pm$ 0.79 ^{abc}	Polygonal	Present
	L	601.32 $\pm$ 13.26 ^a	80.41 $\pm$ 6.64 ^a	11.70 $\pm$ 0.65 ^{hij}	Irregular	Present
06APL	U	436.84 $\pm$ 11.32 ^{bcde}	50.26 $\pm$ 6.26 ^{efghij}	16.63 $\pm$ 0.80 ^{bcdefg}	Polygonal	Present
	L	568.42 $\pm$ 21.48 ^a	35.81 $\pm$ 1.52 ^{ijklm}	9.99 $\pm$ 6.38 ^{ijk}	Irregular	Present
07OKF	U	485.53 $\pm$ 7.02 ^{bc}	61.72 $\pm$ 7.80 ^{bcdef}	15.15 $\pm$ 1.06 ^{defgh}	Polygonal	Present
	L	567.11 $\pm$ 13.39 ^a	33.61 $\pm$ 3.50 ^{lm}	8.11 $\pm$ 0.70 ^{kl}	Polygonal	Present
08ARP	U	460.53 $\pm$ 8.58 ^{bcd}	64.70 $\pm$ 5.33 ^{bcd}	14.30 $\pm$ 2.25 ^{efghi}	Polygonal	Present
	L	561.84 $\pm$ 19.25 ^a	44.45 $\pm$ 5.61 ^{hijklm}	4.25 $\pm$ 0.60 ^l	Polygonal	Present
09ALG	U	440.79 $\pm$ 12.82 ^{bcde}	72.24 $\pm$ 4.58 ^{ab}	15.82 $\pm$ 0.87 ^{cdefgh}	Polygonal	Present
	L	569.74 $\pm$ 11.51 ^a	50.57 $\pm$ 4.02 ^{defghij}	3.78 $\pm$ 0.27 ^l	Irregular	Present
10OKL	U	432.89 $\pm$ 20.00 ^{bcde}	46.64 $\pm$ 3.88 ^{ghijklm}	17.61 $\pm$ 1.69 ^{abcdefg}	Polygonal	Present
	L	564.48 $\pm$ 12.02 ^a	36.28 $\pm$ 1.37 ^{klm}	4.89 $\pm$ 0.32 ^l	Irregular	Present
11SNG	U	436.84 $\pm$ 31.52 ^{bcde}	60.15 $\pm$ 4.23 ^{abcdefg}	21.63 $\pm$ 0.93 ^a	Polygonal	Present

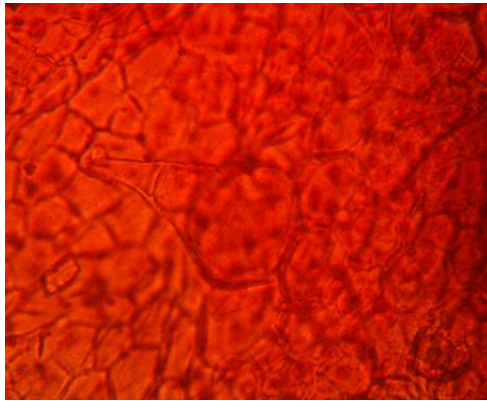
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	L	543.42±28.80 ^a	40.83±1.31 ^{ijklm}	5.33±0.67 ^{kl}	Polygonal	Present
12KSU	U	463.16±25.45 ^{bcd}	70.51±4.42 ^{abc}	17.90±1.78 ^{abcdef}	Polygonal	Present
	L	565.79±10.81 ^a	36.59±2.89 ^{ijklm}	4.24±0.65 ^l	Irregular	Present
13OLJ	U	384.21±20.13 ^e	81.67±6.38 ^a	19.48±2.29 ^{abcd}	Polygonal	Present
	L	553.95±11.09 ^a	37.54±5.61 ^{ijklm}	6.99±0.72 ^{kl}	Polygonal	Present
14OKY	U	436.84±14.80 ^{bcd}	34.39±2.66 ^{lm}	14.21±0.30 ^{efghi}	Polygonal	Absent
	L	560.53±7.62 ^a	34.24±3.52 ^{klm}	5.76±0.84 ^{kl}	Polygonal	Present
15OFG	U	465.79±27.55 ^{bcd}	47.43±3.17 ^{ghijkl}	12.95±0.96 ^{ghi}	Polygonal	Absent
	L	486.84±30.65 ^b	62.19±3.31 ^{bcd}	7.26±0.73 ^{kl}	Irregular	Present
16OKS	U	436.84±14.80 ^{bcd}	63.45±3.16 ^{bcd}	14.21±0.30 ^{efghi}	Polygonal	Present
	L	560.53±7.62 ^a	32.04±1.54 ^m	5.76±0.84 ^{kl}	Irregular	Present
17OMP	U	436.84±28.27 ^{de}	71.93±3.72 ^{ab}	18.55±2.15 ^{abcdef}	Polygonal	Present
	L	565.79±12.48 ^a	35.96±3.22 ^{klm}	6.10±0.67 ^{kl}	Irregular	Present
180FF	U	425.00±10.73 ^{bcd}	74.60±3.35 ^{ab}	21.62±1.16 ^a	Polygonal	Present
	L	567.11±9.63 ^a	38.01±1.33 ^{ijklm}	5.27±0.38 ^{kl}	Polygonal	Present
19EIY	U	438.16±20.87 ^{bcd}	70.83±3.43 ^{ab}	20.91±1.61 ^{ab}	Polygonal	Present
	L	563.16±10.73 ^a	43.35±5.72 ^{hijklm}	5.32±0.43 ^{kl}	Irregular	Present
20AJS	U	423.68±10.11 ^{de}	71.61±2.82 ^{ab}	18.79±1.51 ^{abcde}	Polygonal	Present
	L	569.74±12.76 ^a	46.96±5.74 ^{ghijklm}	5.71±0.72 ^{kl}	Polygonal	Present

Mean values, standard error and different letters along columns depicting significant difference at 0.05 level using ANOVA test. Acc. Cod. No. = Accession Code Number, ECD = Epidermal cell density, STSZ = Stomatal size, STID = Stomatal index, ECS = Epidermal cell shape, U = Upper leaf surface, L = Lower leaf surface.



A



B

Plate 1: Photomicrographs of the *Luffa cylindrica* (A: Abaxial surface with I; B: Adaxial surface. ST: Staurocytic stomata; T: Trichome; P: Polygonal epidermal cell; I: Irregular epidermal cell)

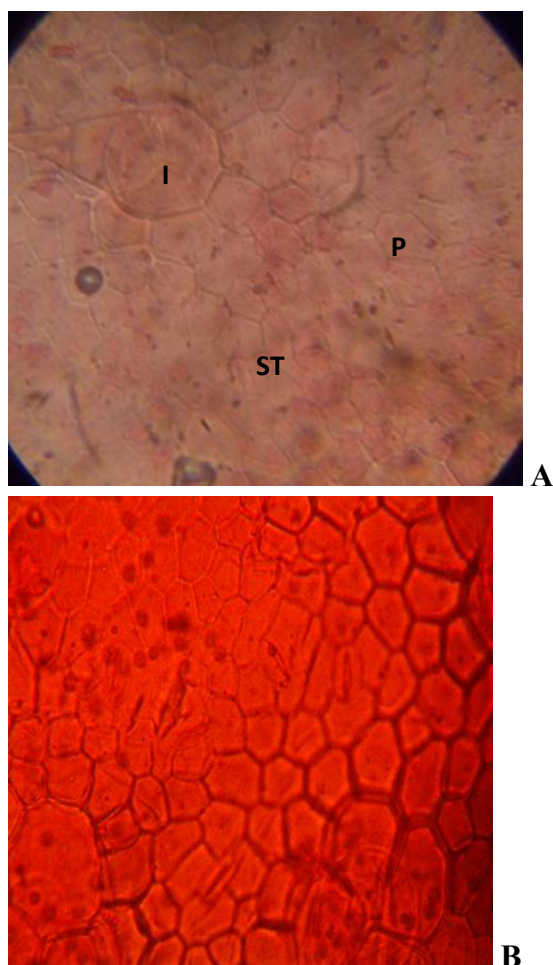


Plate 2: Photomicrographs of the *Luffa acutangula* (A: Abaxial surface with I; B: Adaxial surface. ST: Staurocytic stomata; T: Trichome; P: Polygonal epidermal cell; I: Irregular epidermal cell)

Fiber Mechanical Properties

The mechanical analysis of fiber revealed a significant difference ($p < 0.05$) in the mechanical properties of the fibers of the two *Luffa* species. Tensile stress ranged from 13.66 to 17.82 N/mm², tensile strain ranged from 0.05 to 0.09, percentage elongation ranges from 4.49% to 9.06%, tensile modulus ranged from 187.08 to 397.26 N/mm² (Table 6), flexural strength ranged from 45.65 to 8.82 N/mm², Impact energy ranged from 0.76 to 1.29J while hardness ranged from 91.01 to 96.71Hv (Table 7). *Luffa cylindrica* accessions demonstrates superior mechanical properties, particularly in tensile strength

(15–19 N/mm²), modulus, flexural strength (35–58 N/mm²), and hardness (up to 58 Hv), making it more suitable for applications requiring rigidity and strength. However, *Luffa acutangula*'s higher impact energy and elongation suggest it may be preferable for applications where flexibility and impact resistance are desired

Table 6: Mechanical Properties of Fires of the 20 Accessions of Luffa Species

Acc. No.	TStr (N/mm ²)	T Strain	% Elong	T Mod (N/mm ²)
01OGD	17.72±0.05 ^a	0.06 ±0.00 ^{cde}	6.64 ±0.17 ^{ef}	279.56±0.69 ^e
02UIL	17.82±0.09 ^a	0.08 ±0.01 ^{ab}	7.63 ±0.10 ^c	238.36±1.32 ^{ij}
03AGB	17.51±0.24 ^a	0.09 ±0.00 ^a	9.06 ±0.07 ^a	187.08±1.08 ^p
04ADW	17.70±0.09 ^a	0.07 ±0.00 ^{abcd}	6.97 ±0.17 ^{def}	261.52±0.62 ^g
05SHK	13.66±0.31 ^f	0.06 ±0.00 ^e	4.49 ±0.27 ^j	307.26±3.16 ^b
06APL	14.36±0.29 ^e	0.05 ±0.00 ^e	4.89 ±0.02 ^{ij}	287.05±0.04 ^c
07OKF	16.85±0.11 ^c	0.06 ±0.00 ^{cde}	5.99 ±0.03 ^{gh}	282.40±0.73 ^d
08ARP	17.53±0.17 ^a	0.09 ±0.00 ^a	8.46 ±0.13 ^b	206.44±0.26 ⁿ
09ALG	14.73±0.12 ^e	0.07 ±0.00 ^{abcd}	7.23 ±0.21 ^{cd}	210.16±0.17 ^m
10OKL	14.66±0.16 ^e	0.07 ±0.00 ^{abcd}	6.28 ±0.14 ^{fg}	240.91±0.29 ⁱ
11SNG	16.61±0.19 ^c	0.07 ±0.00 ^{abcd}	6.60 ±0.28 ^{ef}	237.26±0.11 ^j
12KSU	14.67±0.15 ^e	0.07 ±0.01 ^{bcd}	5.68 ±0.14 ^h	273.81±0.37 ^f
13OLJ	15.31±0.16 ^d	0.07 ±0.01 ^{bcd}	5.93 ±0.04 ^{gh}	251.03±0.56 ^h
14OKY	13.66±0.17 ^f	0.07 ±0.00 ^{abcd}	6.68 ±0.13 ^{ef}	207.25±0.16 ⁿ
15OFG	14.68±0.20 ^e	0.08 ±0.00 ^{ab}	7.61 ±0.21 ^c	195.14±0.08 ^o
16OKS	16.63±0.06 ^c	0.07 ±0.00 ^{abcd}	6.80 ±0.08 ^{def}	239.22±0.20 ^{ij}
17OMP	17.42±0.24 ^{ab}	0.08 ±0.00 ^{abc}	8.31 ±0.18 ^b	212.45±0.28 ^{lm}
180FF	16.92±0.05 ^{bc}	0.06 ±0.01 ^{de}	5.10 ±0.34 ⁱ	338.03±0.74 ^a
19EIY	16.50±0.18 ^c	0.08 ±0.00 ^{abc}	7.68 ±0.09 ^c	223.73±0.28 ^k
20AJS	12.69±0.34 ^g	0.06 ±0.00 ^{cde}	5.68 ±0.03 ^h	213.55±0.29 ^l

Table 7: Mechanical properties of fibres of the 20 accessions of *Luffa* species

Acc. No.	FL Strt (N/mm ²)	Impact (J)	Hardness (Hv)
01OGD	58.81 ±0.42 ^a	0.92±0.04 ^{hi}	96.44 ±0.51 ^{ab}
02UIL	57.48 ±0.48 ^b	0.78±0.01 ^k	93.70 ±0.12 ^{efgh}
03AGB	56.03 ±0.03 ^{cd}	0.87±0.01 ^{ij}	94.19 ±0.10 ^{defg}
04ADW	49.37 ±0.27 ^h	0.95±0.02 ^{gh}	94.67 ±2.34 ^{bcdef}
05SHK	49.47 ±0.25 ^h	1.06±0.02 ^{de}	96.06 ±0.02 ^{abc}
06APL	54.75 ±0.22 ^{fg}	1.08±0.01 ^{cde}	92.05 ±0.02 ^{hi}
07OKF	55.88±0.14 ^{cde}	0.88±0.02 ^{ij}	91.01 ±0.02 ⁱ
08ARP	58.42 ±0.24 ^a	0.79±0.00 ^k	94.91 ±0.12 ^{abcdef}
09ALG	57.47 ±0.04 ^b	0.84±0.01 ^j	96.01 ±0.01 ^{abc}
10OKL	56.54 ±0.26 ^c	0.91±0.00 ^{hi}	96.01 ±0.01 ^{abc}
11SNG	56.20 ±0.19 ^c	0.76±0.00 ^k	96.05 ±0.05 ^{abc}
12KSU	54.80 ±0.13 ^{fg}	0.98±0.00 ^{fg}	95.70 ±0.13 ^{abcd}
13OLJ	55.37 ±0.37 ^{def}	0.89±0.00 ^{ij}	94.43 ±0.06 ^{cdef}
14OKY	49.48 ±0.25 ^h	1.29±0.01 ^a	91.45 ±0.12 ⁱ
15OFG	45.65 ±0.21 ⁱ	1.13±0.04 ^{bc}	93.17 ±0.06 ^{efgh}
16OKS	55.30±0.18 ^{defg}	0.96±0.02 ^{gh}	95.14 ±0.06 ^{abcde}
17OMP	55.13 ±0.06 ^{efg}	1.07±0.01 ^{de}	95.15 ±0.05 ^{abcde}
18OFF	56.56 ±0.08 ^c	1.17±0.01 ^b	96.71 ±0.10 ^a
19EIY	56.55 ±0.29 ^c	1.10±0.01 ^{cd}	94.57 ±0.08 ^{cdef}
20AJS	54.58 ±0.12 ^g	1.03±0.01 ^{ef}	92.56 ±0.05 ^{ghi}

Mean values, standard error and different letters columns depicting significant difference at P< 0.05 level using ANOVA test. Acc. No. = Accession Code Number, TStre = Tensile stress, Tstrain = Tensile strain, %Elong = Percentage elongation, Tmod = Tensile Modulus, Fl strt = Flexural Strength, Impact = Impact energy (strength), Hardness = Hardness, ± Standard error.

Discussion

The study provided analysis of the morpho-anatomical characteristics and fiber quality of *L. cylindrica* and *L. acutangula*. Results observed variation in stem girth, leaf length and leaf width showing the inherent variability with the genus *Luffa*. This is influenced potentially by genetic and environmental variability and adaptation within the study region (Zalapa *et al.*, 2006). The distinct variability in qualitative traits supported the established taxonomic differentiation between the two species (Manikandaselvi *et al.*, 2016). Anatomical findings showed that *Luffa* species are amphistomatic, a common feature in dicotyledonous plant which facilitates gaseous exchange (Khan *et al.* 2017). Differential distribution of trichomes present in both upper and lower epidermal surface of *L. cylindrica* and absent in the lower epidermal layer of *L. acutangula* could have implications for transpiration regulation and defense against herbivory (Viera *et al.*, 2019). Morphological and anatomical traits confirmed that *L. cylindrica* possesses a broader range of adaptive features and fibre quality. The presence of trichomes on both surfaces and higher stomatal index suggested better adaptation to environmental conditions.

The significantly higher tensile strength observed in *L. cylindrica* suggests greater suitability for structural and reinforcement applications. This finding corroborates earlier reports by Boynard and D'Almeida (1999) and Tanobe *et al.* (2005), who reported favourable mechanical properties in *Luffa cylindrica* fibres.. Tensile strength is a crucial significant mechanical character that determines the suitability of fibers for reinforcement in composite materials and other structural application (Yan *et al.*, 2012; Kumar *et al.*, 2015). These findings further supported previous report of favourable mechanical properties of *L. cylindrica* fibres (Zampheri *et al.* 2016). The difference in fiber strength could be attributed to differences in the chemical composition such as cellulose content, microfibrillar angle and structural arrangements of fibers in the two species (Mohanty *et al.*, 2000). The mechanical and chemical superiority of its fibers aligns with previous reports (Boynard & D'Almeida, 1999; Tanobe *et al.*, 2005) while *L. acutangula* is useful, its softer, more elastic fibres are less suitable for load-bearing composites.

Conclusion

This study provided a comprehensive evaluation of the morphological, anatomical, and fibre-quality characteristics of *Luffa cylindrica* and *Luffa acutangula* accessions cultivated in Kwara State, Nigeria. Significant interspecific differences were observed in morphological traits, epidermal features, and mechanical properties of the fibres. *Luffa cylindrica* exhibited superior vegetative growth, greater tensile strength, higher tensile modulus, improved flexural strength, and greater hardness than *L. acutangula*. These characteristics indicated its greater potential for industrial applications, particularly in the production of bio-composites and other environmentally sustainable materials.

The anatomical features identified, including stomatal characteristics and trichome distribution, provided useful taxonomic markers for distinguishing the two species. The study, therefore, contributed valuable information for taxonomy, breeding programmes, conservation efforts, and industrial utilisation of *Luffa* species in Nigeria.

Future studies should integrate molecular characterisation techniques with morphological and anatomical data to strengthen species delimitation. Further investigations on fibre chemistry, durability, and large-scale industrial applications are also recommended.

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