MORPHOLOGICAL AND MECHANICAL CHARACTERISTICS OF *NEUROPELTIS ACUMINATAS*(NA) FIBERS

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ABSTRACT

This present work aims to determine the morphological and mechanical characteristics of fibers from a Cameroon liana locally called "NdikKussa" scientific name *Neuropeltisacuminatas* (NA). The vines are cut in a forest of southern CAMEROON in NGALANE near EBOLOWA. The fibers are extracted by us using the traditional method used to make the kussa. SEM micrographs of the cross section of the fiber are made and tensile tests on fibers of 90 mm length are conducted. These investigations reveal that the cross-section of the fiber is rectangular with channels around which cells are distributed with visible lumens. They also reveal a Young module is 6.043GPa, a maximum tensile stress is 61.64 MPa, and an elongation of 0.0102%.

Keywords: Fibers; SEM Micrographs; Characteristics; Morphological; Mechanical; *Neuropeltisacuminatas*; ndik- kussa.

INTRODUCTION

Natural fibers can come from the wide range of available plants like: cotton capsules, sisal leaves, jute stems, hemp and flax. But over the past half-century, natural fibers have been replaced in our households, clothing and industries by man-made fibers[1]. However, over the past decade, European and then global industries and institutions have shown a growing interest on plant fibers both from an economic and environmental point of view [2]. Concerning the automotive sector, hemp Linen, sisal and even abaca are incorporated into the armrests, rear shelves, seatbacks or motor shields [3]. Cameroon, which is part of this vast floristic and phytogeography ensemble, has been recognized as the second forest cover in this zone after the Democratic Republic of Congo [4].

Recently, many studies on natural fiber composites have been made. Natural fibers such as kenaf[5], bagasse [6], jute [7],[8], ramie, oil palm [9] and hemp[10], have been investigated as reinforcements for fiber reinforced plastics.Those studies were performed to improve the mechanical properties such as tensile strength, impact strength, flexural modulus and etc. Among these properties, even though the flexural modulus of those natural fiber composites has been calculated by rule of mixtures, the calculated values havenot been in agreement with the experimental [11], [12]. Advantages of natural fibers are their low price, low density, abundance, renewability, and biodegradability, and environmental friendliness [13], [14], [15], [16], [17]. The main disadvantages of natural fillers utilized polymeric composites are their low wettability and non-homogeneity [18]. The fibers are mostly hydrophilic natural fibers, and they have low tensile strength [19]. These problems can be alleviated by suitable compatibilisers and coupling agents[20].

The objective of this work is to evaluate the characteristics of NA fiber (Neuropeltisacuminatas) and show that this fiber can constitute a quality reinforcement in the development of composite materials.

The fibers are obtained by the traditional method consisting of a retting for a few days and then a threshing.

The present work summarizes part of a doctoral thesis currently underway at the University of Douala in Cameroon. It focuses on the Multi-Scale Characterization of NA fibers (Neuropeltisacuminatas). In this context,the study a new plant fiber: "NdikKussa" NA (Neuropeltisacuminatas) shows all its importance. As a result, the NA is presented in a detailed manner until the extraction of its fiber, then a SEM micrograph is performed, which allows to know the morphology of these fibers; after a tensile test, the value of the Young's modulus of the fiber has been known; analyzes and discussions have been carried out on the results obtained, and finally this work ends with a conclusion.

MATERIALS AND METHODS

Materials

The plant of NA

Neuropeltisacuminatas is a woody vine with twisted stems up to 40 m long and up to 25 cm in diameter. It has alternate, simple leaves with petioles 8-25 mm long; The lamina is elliptical, 5-12 cm × 5-6 cm, rounded to wedge-shaped at the base, having an entire margin. This liana has inflorescence with axillary and terminal clusters, up to 50 flowers, 12-30 cm long. Its flowers are bisexual, regular, fragrant; The pedicels are 4 mm long, bracts strongly accrescent after flowering; The sepals are circular to elliptical, 1.5-3 mm long and pubescent. Its fruit is a rounded capsule 7 mm in diameter, surrounded at the base by the persistent calyx and dilated bract. Its seeds are globose, black, glabrous.NA fibers have since been used by our ancestors in South Cameroon. These formed a pile of fibers that they used as a dish sponge and toilet gang.In ancient forests, it becomes one of the dominant climbing species (Figure 1)[21].

(a) (b (c) (d

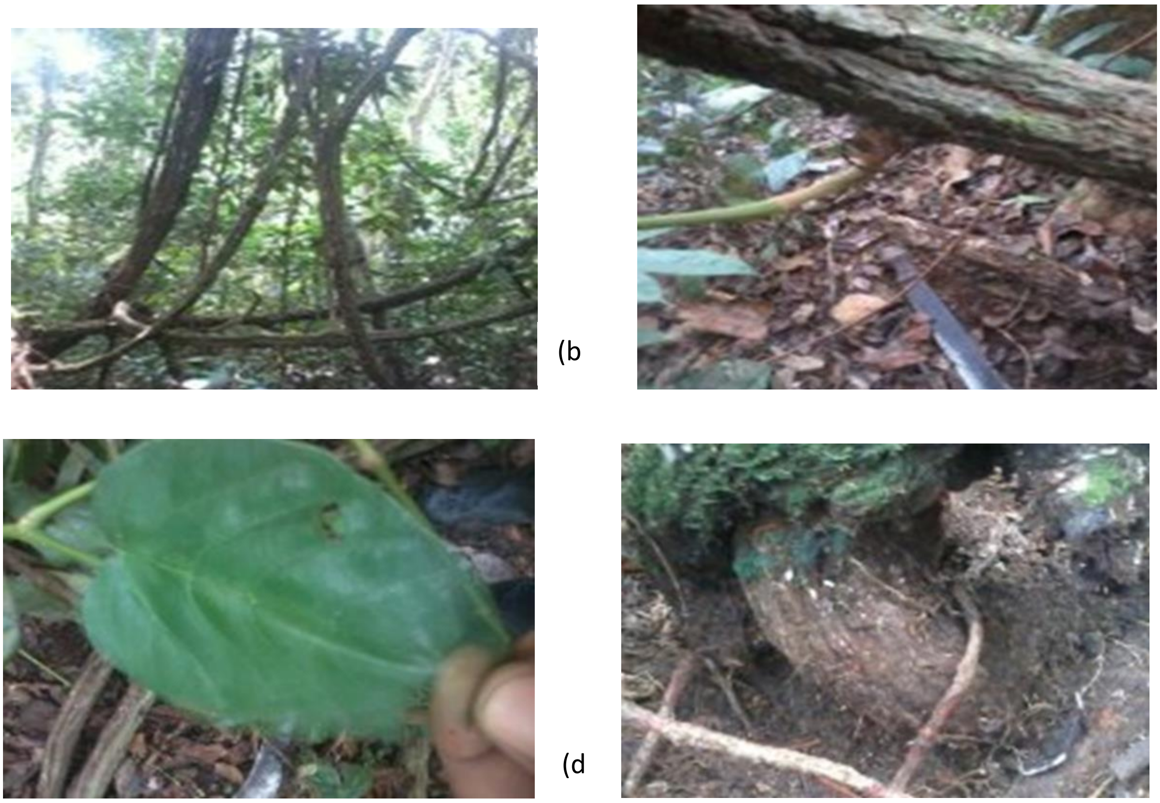


Figure 1:Description of NA plant: a- NA creepers in the forest b- The harvested NA c-The youngleafsprout of NA d- The root of NA

Examination of fiber microstructure

The JEOL - T220 scanning electron microscope (SEM) is used for image acquisition at a voltage of 5-20 kV. Fiber samples are adequately prepared; the lateral surface and the cross section are examined.

Traction test

The traction test is performed on an INSTRON version IX2716-010 machine type 004 with a PC interface for automatic acquisition of forces and displacements. Individual fiber test pieces of NA are made by providing both ends of mooring heads. Between the two mooring heads a free length of 90 mm is left. Traction tests are carried out on 14 specimens at a speed of 20 mm / min [22].

Methods

Extraction of the fiber

For this first study, the method used is the traditional method: NA creepers are retted with water for a few days, they are then crushed. During this threshing, the epidermis and the bundle of fibers are detached, the wax that emerges is gradually removed by hand. When the wax is completely removed, the pile of fiber is washed with water.Extraction of the fibers made it possible to obtain a pile of fibers (Figure 2).The fibers obtained are similar to those found on the market called "kussa".

Figure 2: Cluster of fibers obtained

Determination of the WEIBULL module

It is a matter of determining the maximum stress applied to a material so that the probability of rupture is smaller than 0.01. It is the statistical methods that will allow to estimate this maximum stress; this statistical method is the WEIBULL method.

The fragile materials show a great dispersion with regard to their characterization.

This is why it is best to use this method. Thus, the probability of rupture $\boldsymbol{P_r}$[23]of a fiber of length L subjected to the tensile test with a stress σ is written:

$$\boldsymbol{F(\sigma, L) = P_r = 1 - e^{-L\left(\frac{\sigma}{\sigma_0}\right)^m} = \frac{i-0,5}{N}} \quad (1)$$

Where P_r is probability of rupture,
Llength of the fiber
$m$the slope coefficient of WEIBULL
Nisnumber of test samples
$i$is roll number of the fibers
$\boldsymbol{\sigma}$ismaximun tensile stretch
$\sigma_0$is minimal tensile stretch.

If the tracking probability of the stress fiber σ is noted $\boldsymbol{P_s}$ [24]:

$$\boldsymbol{P_s = 1 - P_r = e^{-L\left(\frac{\sigma}{\sigma_0}\right)^m}} \quad (2)$$

Where P_s is probability of follow-up of our fiber of constraint

By writing the equation in logarithmic form, it becomes:

$$\boldsymbol{L_n(P_s) = L_n\left(e^{-L\left(\frac{\sigma}{\sigma_0}\right)^m}\right) \Rightarrow L_n\left[\frac{1}{L}\left[L_n\left(\frac{1}{P_s}\right)\right]\right] = m\big(L_n(\sigma) - L_n(\sigma_0)\big)} \quad (3)$$

Maximum stress determination

Therefore the value of the maximum stress that can be applied to the NA to have a probability of failure of less than 1% [27] (Nguyen and al, 2014), can be calculated:

$$P_r < 0{,}01 \rightarrow 1 - P_s < 0.01 \quad (4)$$

Equation 4 provides:

$$P_s = \boldsymbol{e}^{-L\left(\frac{\sigma}{\sigma_0}\right)^m} > 0.99 \quad (5)$$

The value of σ can be derived from equation 5 and give:

$$\sigma = \sigma_0\left[-\frac{1}{L}Ln(0.99)\right]^{\frac{1}{m}} \quad (6)$$

RESULTS AND DISCUSSION

Micrograph SEM of the fibers

The images of Figure 3 clearly highlight the appearance, shape and microstructure of the NA fiber; from the outset, it is noted, the presence of four major channels, three of which are divided into two cavities. The first two channels, one having two cavities, the other having a single cavity are placed on either side of a small channel which acts as an axis of symmetry for the latter. Under the small channel, there is a staged distribution of two channels each having two cavities. All around these channels is a distribution of basic cells, whose lumens are also apparent.

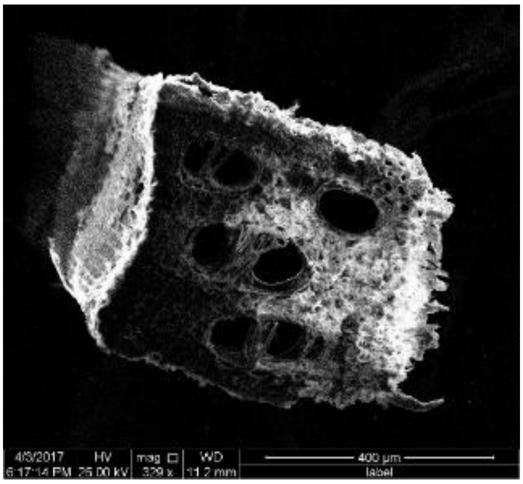


Figure 3: SEM image of NA fiber cross-section

A modeling of this section of fiber is made, then straightened (Figure 4). The rectified form gives an equivalent model of the fiber section of NA. This equivalent model gives a general idea of the shape of the section: it is square or rectangular, rounded at the four ends and having five channels, four of which have almost the same shapes and dimensions while the fifth is smaller. Of the first four similar channels, three are divided into two cavities.

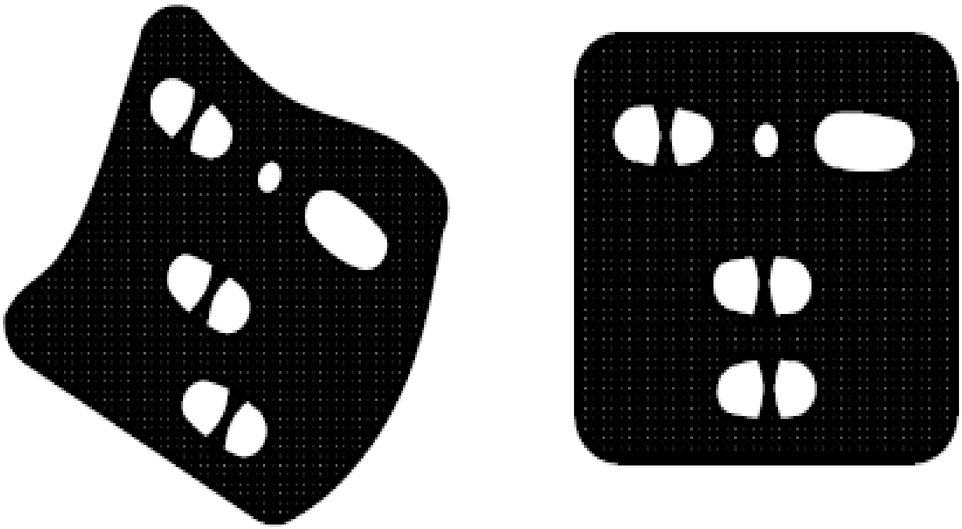
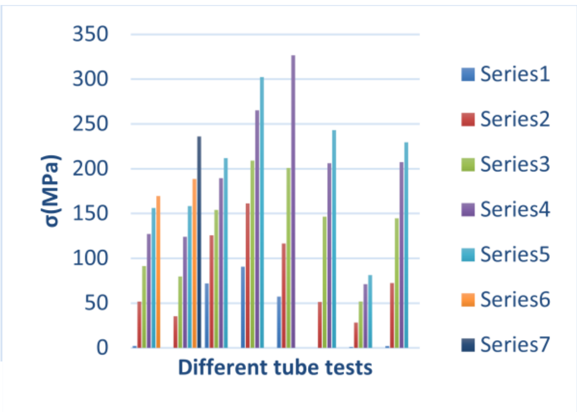


Figure 4: Outer shape of the cross-section of the NA fiber: on the left, modeled section; right section modeled and straightened.

The transversal section of the NA fiber has a structure that differs from the other natural fibers. Those fibers generally have 2 aspects: one of them is like an onion spiral (Sisal). The other one has a channel in the center with a regular and concentric distribution of its base cells (RC, Alpha) [25], [26].

Mechanical Properties of NA Fiber

Figures 5 (a) and 5 (b) show the stress and strain distributions obtained during the tests.

(a)


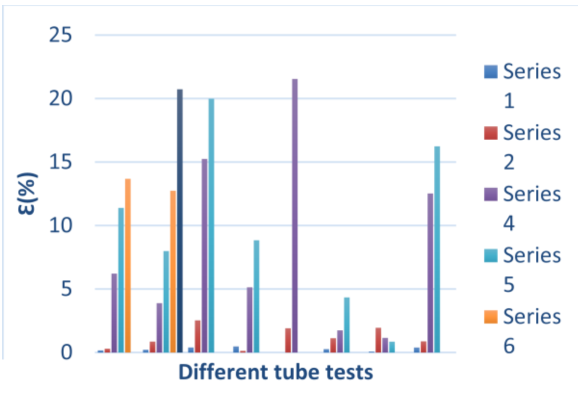
(b)


Figure 5: Stress and stretching distribution: a- constraints (MPa) b- stretching (%)

It can be observed that the deformations are very weak. This may be due to threshing during fiber extraction, or because of many existing channels in the fiber structure, which prevent the entire fiber volume from participating in the pulling.Figure 6 shows the curves σ (Ɛ) of NA fibers. The behavior of the NA tested in tension has two phases: elastic deformations (Ɛ ≤ 3%), and nonlinear deformations. Amongst the above σ (Ɛ) curves, the one that will have the nearest linearity coefficient to the WEIBULL's one, will help by its equation to calculate the various stretching's to the rupture of the NA fiber.

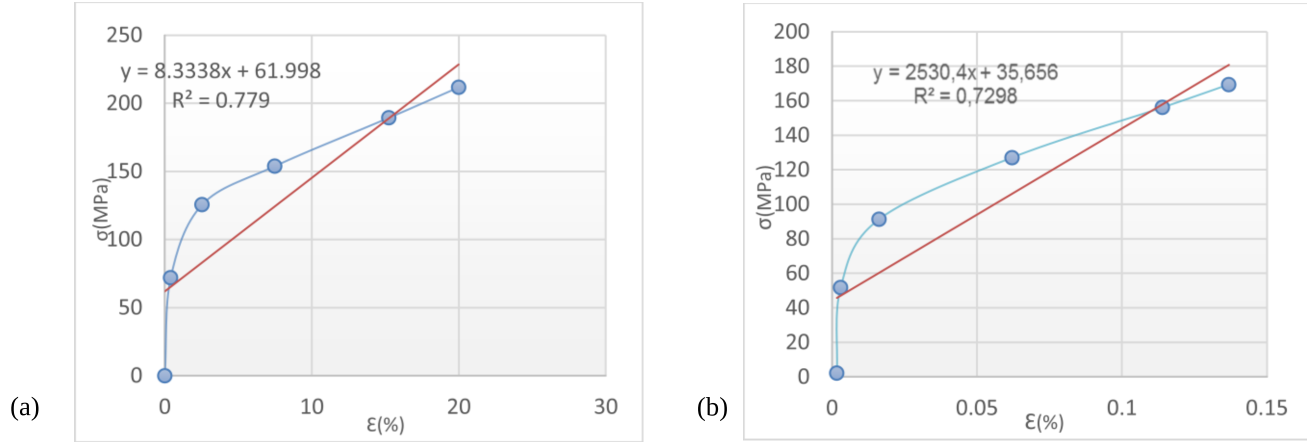


Figure 6: Curves σ (Ɛ) of the NA: a- curve σ (Ɛ) of the sample 3 b-curve σ (Ɛ) of the sample 9

Weibullity Verification

All these probabilities are gathered in the following table 1:

Table 1: Calculation of fracture probabilities and fiber monitoring.

σ rupture (Mpa)	Roll numbers	σ rupture increasing order	$P_r(\text{rupture})\ \frac{i-0,5}{N}$	$P_s(offollow)\ 1-P_r$	$L_n(\sigma)$	$L_n\left(\left(\frac{1}{L}\right)L_n\left(\frac{1}{P_s}\right)\right)$
169.419	1	81.1939	0.035	0.965	4.396	-7.834
235.887	2	84.331	0.107	0.893	5.132	-6.678
211.742	3	155.914	0.178	0.822	5.355	-6.129
302.207	4	169.419	0.25	0.75	5.435	-5.745
326.535	5	190.223	0.321	0.679	5.463	-5.448
243.011	6	200.9	0.392	0.608	5.493	-5.197
81.1939	7	211.742	0.464	0.536	5.711	-4.972
229.380	8	229.380	0.535	0.465	5.788	-4.766
200.439	9	235.887	0.607	0.393	5.463	-4.568
155.914	10	243.011	0.678	0.322	5.493	-4.374
84.331	11	249.772	0.75	0.25	5.52	-4.173
190.223	12	270.085	0.821	0.179	5.598	-3.957
249.772	13	302.207	0.892	0.108	5.711	-3.699
270.085	14	326.535	0.964	0.036	5.788	-3.245

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The curve ln ((1/L) ln (1/Ps))as a function of ln(σ) is plotted. The significant results of this treatment are presented below. The trend line is a straight line which allows to say that: the resistors fit well to the Weibull distribution (Figure 7). The Weibull method is therefore applied in conjunction with the maximum likelihood method.

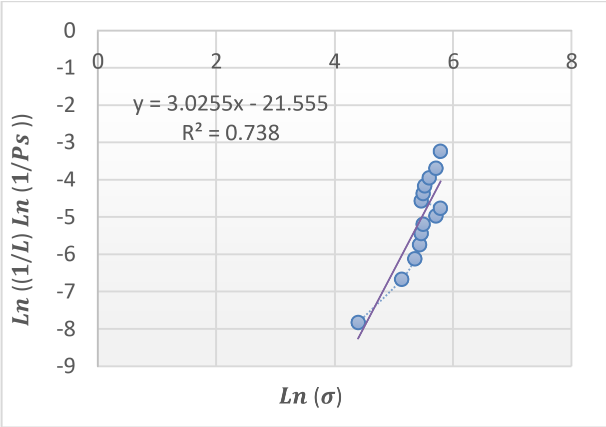

Figure 7: Weibullity Verification of NA Resistance Data

Mechanical Characteristicsdetermination

The linearization coefficient obtained is R^2 = 0.738which corresponds to that of the fibers of the sample 1, and the equation of this line is: y = 3.0255X–21.555, which gives a modulus $m = 3.0255$ and$\sigma_0 = 1241.955$ MPa.

The value of σ can be derived from equation 5 and give:

$$\sigma = 1241.955\left[-\frac{1}{90}Ln(0.99)\right]^{0.33} = 61.64\ MPa \quad (6)$$

The linearization coefficientR^2 = 0.738obtained in figure 7 is close to R^2 = 0.7298of the σ (Ɛ) curve of figure 6-b; therefore, to calculate the stretching of the NA fiber; having calculated the constraints; the relation σ (Ɛ) of the following figure 6-b,will be used:σ = 2530.4 Ɛ + 35.656.Now, to calculate the Young module of the NA fiber, with the relation: $E = \frac{\sigma}{\varepsilon}$.The mechanical characteristics (Young module, stretching to the rupture, and the constraints to rupture) of NA are grouped in the following Table 2.

Table 2: Mechanical Characteristics of Fiber

Fiber	E (GPa)	Ɛ (%)	σ (MPa)
NA	**6.043**	**0.0102**	**61.64**

Where Ɛisstretching to the rupture
E is Young module

A comparison with the information available in the literature concerning the mechanical characteristics of natural fibers makes it possible to notice that the Young's modulus of NA fibers is smaller than that of cotton, flax, hemp, jute, ramie, sisal, RC, coconut and alpha. This module would be weak because of the extraction method, which has surely damaged the physical structure of the fiber, or because of many internal channels of the fiber.

Table 3: Mechanical characteristics of NA fiber compared with other fibers [28

Fibers	E (GPa)	Ɛ (%)	σ (MPa)	Références
Cotton	5.5-12.6	7-8	287-597	[28]
Lin	58	3.27	1339	[28]
Hemp	35	1.6	389	[28]
Jute	26.5	1.5-1.8	393-773	[28]
Ramie	61.4-12.8	1.2-3.8	400-938	[28]
Sisal	9-21	3-7	350-700	[23]
RC	2.3-17	10.9-53	150-1738	[23]
Coco	4-6	15-40	131-175	[28]
Alpha	12.7	1.6	75-154	[28]
NA	**6.043**	**0.0102**	**61.64**	**-**

CONCLUSION

The morphology and mechanical characteristics of the fibers of *Neuropeltisacuminatas* were studied. It permits to discover the shape of the cross-section of the NA fiber: square or rectangular with rounded corners and channels in the center. A statistical analysis of the experimental values of the mechanical properties of the fiber was conducted. The following results were obtained during the study: that the module of elasticity of the fiber studied is6.043 Gpa; That the tensile strengths of the NA fit suitably to the Weibulldistribution. The young module of NA fiber is shorter than those of the natural fibers that were studied in the past. However, more studies are necessary to know its level of reinforcement in the composite materials. Experimentation with other extraction methods should be carried out to investigate the impact on the characteristics of the fiber.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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