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# Influence of the extraction method of "*Neuropeltis acuminatas*" (NA) liana fiber for biocomposites

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**Abstract**

As part of a drive to exploit untapped local resources to replace synthetic fibers used in composite materials, a study focused on the extraction and characterization of plant fibers from "Ndik Kussa" (*Neuropeltis acuminatas*), a liana that grows in the wild, was done. Here we consider the hypothesis of vegetal fiber variability. Three extraction methods were studied: mechanical (manual beating), biological (simple water retting), and chemical (5% NaOH alkaline solution). This was followed by physical, chemical, thermal, and mechanical characterization of the fibers obtained after extraction. Apparent density, moisture content, and water absorption rate were determined for physical characterization. The average density, water content, and water absorption rate obtained experimentally for different NA fiber samples show variability depending on the extraction methods. The lowest apparent density of 0.24 g/cm3 is obtained by the mechanical extraction method (MEF), and the highest of 0.74 g/cm3 by the chemical extraction method (NAF). On the other hand, the highest water absorption rate of 294% is obtained for fibers extracted by the biological extraction method (RUF), and the lowest of 171% by the mechanical extraction method (MEF). The chemical composition of the fiber was analyzed by Fourier transform infrared spectroscopy (FTIR), and the thermal stability was evaluated by differential scanning calorimetry (DSC) and thermogravimetry (TGA/DTG). The mechanical properties, obtained by uniaxial tensile testing, show that the mechanical performance of NA fiber is close to that of the plant fibers used in literature to produce composite materials. Depending on the extraction process, the values for the Young modulus were 7.1GPa, 9.6GPa and 9.9GPa for NAF, RUF and MEF respectively. The highest ultimate mechanical tensile strength of 578 MPa was obtained for the biological extraction method (RUF), and the lowest of 285 MPa for the chemical extraction method.

**Keywords** Neuropeltis acuminatas, Liana fibers, Extraction, Mechanical and chemical properties

## 1 Introduction

The use of plant fiber as reinforcing elements in bio-composite materials is a concept that has already been industrialized and commercialized [1]. Their use has been proven in every industry, including transport, aeronautics, and automotive [2]. More specifically, they can be found in garden furniture, cladding, door frames, and in the interior trim of cars [3]. Part of the spare wheel compartment of the Mercedes is made of a composite of polypropylene and abaca fiber, a species of banana tree [2, 4, 5]. However, the mechanical properties of natural plant fibers vary considerably either within the same species or from one species to another [6]. They are available in all varieties, at low cost, and can be obtained from different parts of plants. Using simple water retting, Olembé et al. [7], Betene et al. [8] and Chengoué et al. [9] were able to extract plant fibers from *Ananas comosus* stem (AC), *Rhecktophyllum camerunense* (RC), and banana pseudo-stem fibers, respectively. These extracted local fibers have been the subject of several research studies, thus demonstrating their ability to reinforce composite materials [2, 5, 7].

The production of plant fibers does not require major investment and complies with environmental standards [10]. The fact that some of them are derived from the residues of commercial agriculture (*Ananas comosus* stem fiber, banana pseudo-trunk fiber, okra fiber) is a major asset for the industry sectors concerned Ntenga et al. [1], Fokam et al. [11] showed that the addition of fibers from palm nut shells improved the tensile performance of cement mortar for small quantities of fiber. Betene et al. [8] show that the characteristics of RC fibers are similar to those of Sisal, Hemp, and Flax fibers; and that it is possible to envisage replacing these fibers with the latter. Mewoli et al. [12] also show that the characteristics of *Triumfetta cordifolia* bast fibers from the equatorial region of Cameroon enable them to be classified in the same group as flax and jute fibers, given that they can all withstand thermocompression molding temperatures and could therefore be used in similar applications. Chengoué et al. [9] show through their experiments that pseudo-banana trunk fibers can be used as reinforcing agents in thermoplastic materials, as their degradation temperature is higher than the processing temperature of some polymer matrices such as polyethylene and polypropylene.

In order to determine the extraction conditions conferring the best performance on plant fibers, much work has been carried out in the literature on the influence of extraction methods. Deepa et al. [13] studied the effect of chemical treatments with sodium hydroxide and sodium chlorite on nettle fibers. The results show that the tensile strength of treated fibers increases by 27% compared with untreated fiber. Similar results were obtained by Betené et al. [14] in a comparative study of biological and chemical fiber extraction from Megaphrynium macrostachyum stem fibers. The highest mechanical characteristics were obtained for chemical fibers.

Very few authors have worked on *Neuropeltis acuminatas* (NA) plant fiber from Cameroon. Betene et al. [8] in a comparative study of different plant fibers from wild Cameroonian plants, obtained NA fiber density and absorption rates of 0.84 $g.cm^{-3}$ and 276.1% respectively. A study by Obame et al. [15] on the influence of surface chemical treatment with sodium hydroxide on the characteristics of NA fibers showed that treatment with 5% NaOH solution resulted in a higher tensile strength of 321 MPa and a Young's modulus of 8.4 GPa. The results also show that a higher NaOH concentration improves fiber/matrix interface properties (increase in arithmetic mean roughness and quadratic

mean roughness). Nnengue et al. [16] showed that adding a small proportion of NA fiber to a gypsum matrix (composite) resulted in a slight improvement in mechanical performance.

The scientific problem addressed in this study is the influence of the variability of fiber extraction methods on their physical, chemical and mechanical properties. We assume that whatever the extraction method used, the final properties of the fiber remain acceptable for use as a reinforcement in composites. In this article, we will study how the chemical, thermal, and physico-mechanical properties of plant fibers are influenced by 3 extraction processes: the mechanical extraction method by manual beating (MEF), the biological extraction method by simple water retting (RUF) and the chemical extraction method by alkalization of NaOH at a concentration of 5% (NAF). Our results will be compared with those of other plant fibers in the literature.

## 2 Materials and methods

### 2.1 Biomass and fiber extractions from the neuropeltis acuminatas liana

The Ndik Kussa liana (*Neuropeltis acuminatas*) denoted NA(Fig. 1) was collected at Ngalane, Ebolawa in the South region of Cameroon, (2° 54′ north, 11° 09′ east). This plant was identified by Professor ATANGANA Ateba, of the Laboratory of Mechanics and Production at the University of Douala Cameroon.

NA plant fibers are found on the skin of the liana plant. Prior to extraction, preliminary work was done to prepare the liana for extraction (Fig. 2).

#### *2.1.1 Mechanical extraction*

The method used for mechanical extraction is manual beating of the freshly harvested NA vine with a smooth stick. This facilitates the separation of fibers from each other and from the body of the stem. This operation is repeated until the fibers get soft, followed by repeated washing in distilled water to eliminate sticky matter and to obtain the fibers by MEF (Fig. 3).

#### *2.1.2 Extraction by water retting and chemical extraction with 5% NaOH*

The protocols for extraction by water retting (RUF) and chemical extraction with NaOH (NAF) were identical. For RUF extraction, the solution is simple water from the national


**Fig. 1** On-site image of the *Neuropeltis acuminatas* (NA) plant: (**a**) presentation of the NA in the forest; (**b**) harvested NA stem having a diameter of 9 centimeters

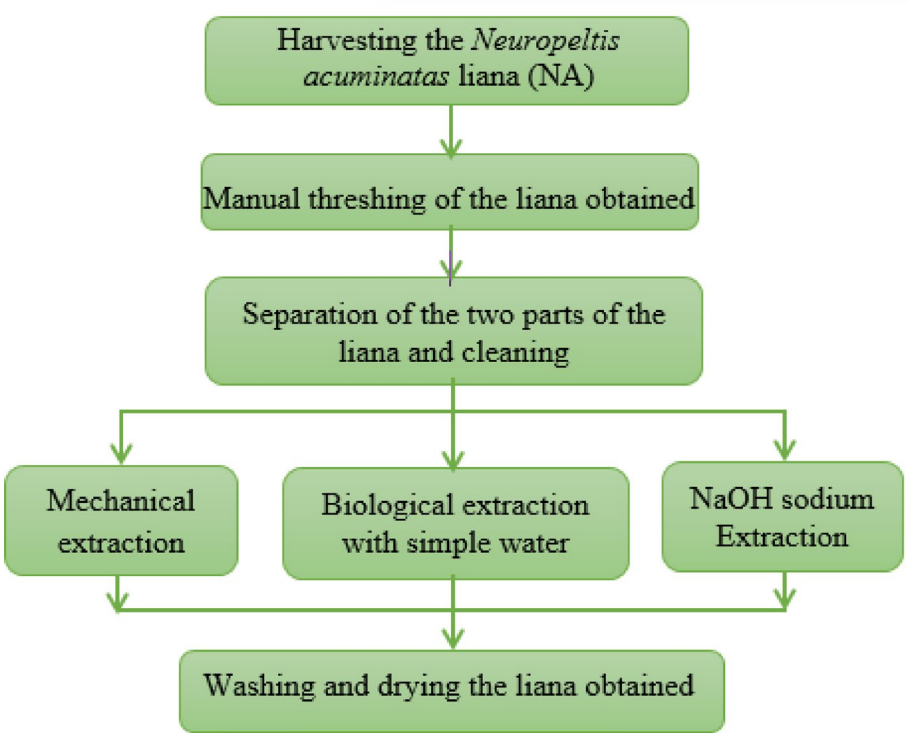


**Fig. 2** Different methods for extracting NA fibers


**Fig. 3** Mechanical extraction: (**a**) harvested NA liana; (**b**) liana obtained after threshing; (**c**) fiber obtained after washing

water distribution network. For FNA extraction, the solution is an alkaline solution containing 5% NaOH, in accordance with the work of Chengoué et al. [4]. lightly beaten NAF vines (Fig. 4b) are immersed in containers containing the appropriate solution for either 64 days (for the simple water solution) or 72 hours (for the alkaline solution) (Fig. 4c). After this time, the vines are removed from the water and dehisced by hand (Fig. 4d), washed several times with distilled (Fig. 4e) and dried at room temperature of about 24 °C (Fig. 4f).

## 2.2 Physical characteristics

### *2.2.1 Apparent density*

Apparent density ( $d_F$) is measured according to NF P 94 – 053 using a gravimetric approach based on Archimedes' principle. The oven dried fiber samples ( $M_F$) weighed on an analytical balance with an accuracy of 0.01 g. Then the fiber was wrapped in paraffin of volume $V_P$ and density 0.88 g/cm$^3$. The paraffin-coated fiber is then immersed in the water in the measuring cylinder. The volume of water displaced in the measuring

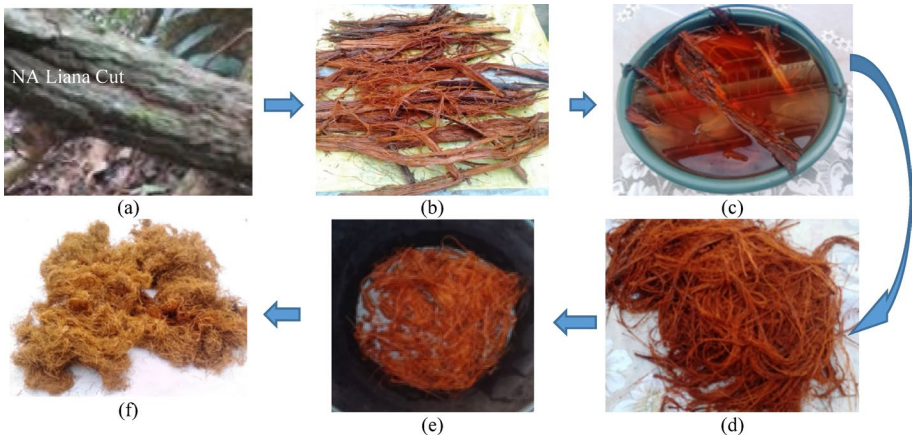


**Fig. 4** Extraction by water retting: (**a**) harvested NA liana; (**b**) liana obtained after manual beating; (**c**) liana immersed in a container; (**d**) liana removed from water after retting and dehusked; (**e**) washing of the fiber obtained; (**f**) fiber obtained after natural drying

cylinder corresponds to the volume of paraffin-coated fiber $V_{(P+F)}$. The fiber volume $V_F$ is calculated by Eq. (1)

$$V_F = V_{(P+F)} - V_p \tag{1}$$

Where $V_F$: the volume of the fibre, $V_P$: volume of paraffin, $V_{(P+F)}$: volume of paraffin-coated fiber.

The calculation of apparent density is determined by Eq. (2):

$$d_F = \frac{M_F}{V_F} \tag{2}$$

Or $d_F$ apparent density in g/cm$^3$,

#### *2.2.2 Water absorption rate*

For this test, 5 specimens for each sample were used. The experimental protocol for determining the water absorption rate begins with drying in an adjustable oven at 105 °C for 24 hours [17]. These samples were latter, weighed ( $m_0$) on a 0.01 g precision balance and placed in jars of distilled water. In order to control the variation in mass of each sample, weighing was done ( $m_1$) at regular intervals of 10-minutes over a period of 1 h 40 min. Eq. (3) was used to calculate the water absorption rate of NA fibers.

$$Abs\ (\%) = \frac{m_1 - m_0}{m_0} \times 100 \tag{3}$$

where $m_0$ initial sample mass at time zero, $m_1$ final sample mass at time t, Abs (%) water absorption rate.

#### *2.2.3 Moisture content*

Five (05) specimens of each sample, were used. The protocol followed was that of Baley et al. [5]. The initial sample mass ($m_i$) was weighed on a balance (accurate to 0.01 g). The weighed samples were then placed in an oven at 105 °C for 24 hours. The final mass ( $m_f$) after oven drying was measured and the moisture content was determined using Eq. (4).

$$H\ (\%) = \frac{m_i - m_f}{m_i} \times 100 \quad (4)$$

With $m_i$: initial specimen mass; $m_f$ final specimen mass and H (%): moisture content.

### 2.3 Chemical and thermal characteristics

#### *2.3.1 Thermal analysis*

Analyses by ATG/DTG and DSC on samples obtained by biological extraction (RUF) and by chemical extraction (NAF) were obtained according to a precise protocol. The RUF and NAF samples (5 mg) are ground to a fine powder of approximately 315 µm. The resulting powder is introduced into the crucible of a LINSEIS STA-PT 1000 thermogravimetric analyzer, equipped with a high-resolution 0.1 mg balance, an oven with a maximum calcination temperature of 1000 °C and a very rapid cooling system. The powder is temperature-mounted in the furnace at a constant heating rate of 10 °C/min up to the maximum temperature of 600 °C under a flow of nitrogen at the same temperature and a flow rate of 50 ml/min. The mass loss of the samples is recorded on a computer, controlled by Platinum Evaluation v1.0.182 software, which enables digital data to be acquired, then ATG curves and its DTG derivative, as well as DSC curves to be plotted using the digital data collected.

#### *2.3.2 Fourier transform infrared spectroscopy*

Chemical functional groups of the dried (105 °C for 30 min) and ground (315 µm) NA fiber samples were obtained by ATR- FTIR on a Perkin – Elmer device. The experiments were done at room temperature (about 24 °C). The device was connected to a computer equipped with a software which processes the FTIR data recorded.

### 2.4 Tensile test

Tensile tests were carried out on 10 mm long NA fiber specimens, in accordance with standard NF T25 501-2, on a SHIMADZU testing machine, model LDW – 1, made in Japan, equipped with a 1 kN force cell, and a maximum movable jaw speed of 2 min/min controlled by a computer for acquisition and processing of measured parameters (Fig. 5). The diameter of the NA fiber was obtained by making three to five measurements along each fiber mounted on the tensile testing machine by an optical microscope equipped with a camera.

## 3 Results and discussion

### 3.1 Physical properties

#### *3.1.1 Diameter of NA fiber*

NAF samples of NA fiber had the highest diameter (468 µm) compared to RUF samples which had a diameter of 439 µm and MEF samples which had a diameter of 426 µm (Fig. 6). The diameter of the NA fiber is close to that of the plant fibers of the same species as in the literature (Table 1), in particular *Rhecktophyllum camerunense* (RC) fiber (70–350 µm) reported by Betene et al. [10] and *Neuropeltis acuminatas* (NA) fiber (504 µm) from Obame et al. [15].

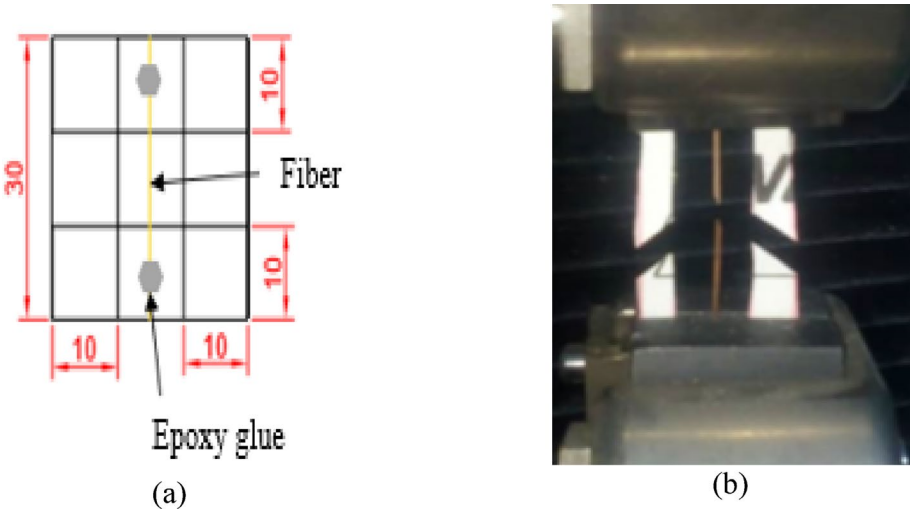


**Fig. 5** Preparation, mounting and fracture of a specimen during tensile testing: (**a**) specimen preparation; (**b**) NA fiber fracture

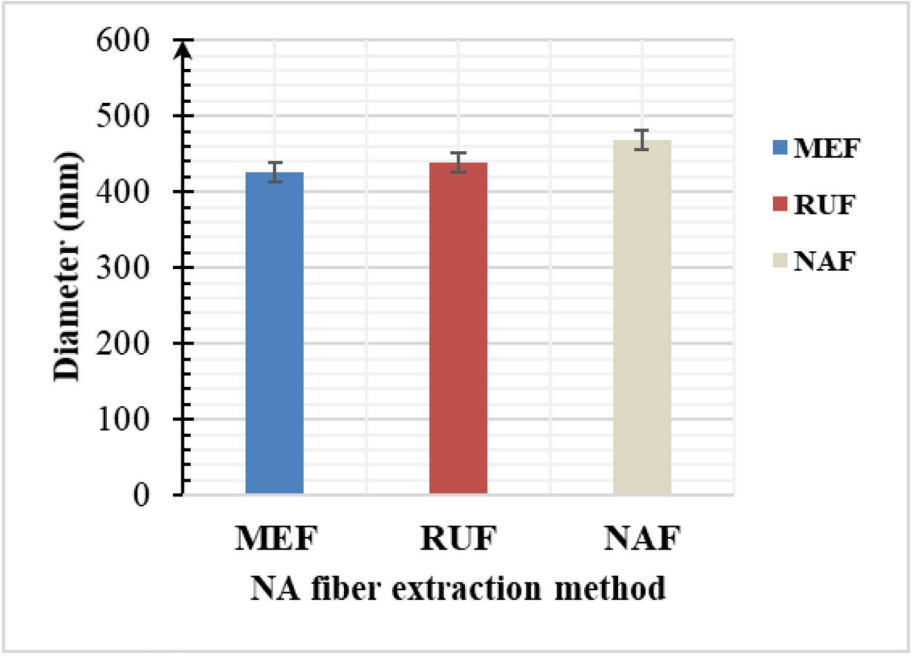


**Fig. 6** Diameter of NA fiber for different extraction methods

#### *3.1.2 Apparent density of NA fiber*

The apparent density values of NA fibers vary depending on the extraction method used (Fig. 7). The chemical method (NAF) produces high-density fibers (0.74 g/cm$^3$), compared to 0.30 g/cm$^3$ for the biological method (RUF) and 0.24 g/cm$^3$ for the mechanical method (MEF).

The increase in density in the case of NAF can be explained by the action of soda (NaOH), which reduces the volume of 'coarse' pores by extracting amorphous compounds (lignin, hemicellulose), leading to a more compact structure. On the other hand, MEF fibers, obtained by manual beating, retain a more aerated internal structure, which explains their low density. Despite this low density, the MEF method is considered more

**Table 1** Degradation temperature of the different compounds still present in the fiber after extraction

| Samples | Temperature (°) | Interpretation |
|---|---|---|
| **RUF** | 71 | Evaporation of water molecules |
| | 285 | Degradation of hemicelluloses |
| | 335 | Degradation of cellulose fiber |
| | 416 | Degradation of lignin |
| | 461 | Presence of Inorganique compounds |
| **NAF** | 67 | Same interpretation of RUF |
| | 329 | |
| | 414 | |
| | 483 | |

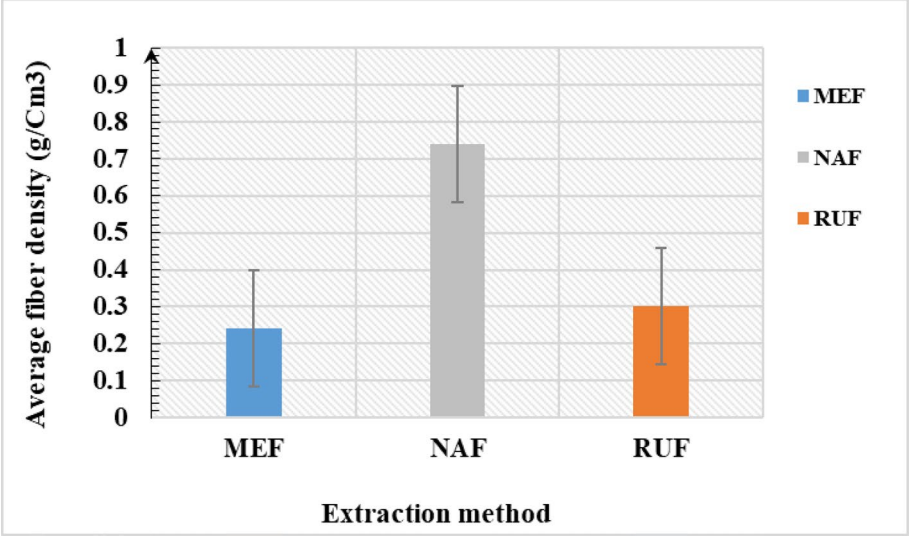


**Fig. 7** Apparent density of NA fiber for different extraction methods

favourable for the development of lightweight composites, as it better preserves fiber integrity, promotes impregnation by the matrix, and improves interfacial adhesion. These results suggest that the extraction method directly influences the apparent density, and therefore potentially the final performance of the materials in which these fibers would be incorporated.

Comparatively, the density values of NA fibers are similar to those of other natural fibers such as *Rhecktophyllum camerunense* or *Ananas comosus* stems, confirming their potential as bio-based reinforcements (Table 1).

#### *3.1.3 Water absorption rate of NA fiber*

The results presented in Fig. 8 show a notable variation in the water absorption rate of NA fibers depending on the extraction method. NAF samples absorb water rapidly and reach the highest absorption rate of 294%, reflecting a more porous and open structure. This behaviour is attributable to the alkaline action of NaOH, which promotes the breakdown of cell walls and exposes more hydrophilic hydroxyl groups [18].

Conversely, MEF fibers, obtained by manual beating, show slower and lower absorption, reaching only 171%, while RUF samples show an intermediate rate of 198%. This suggests that MEF fibers retain a more compact structure that is less accessible to water,

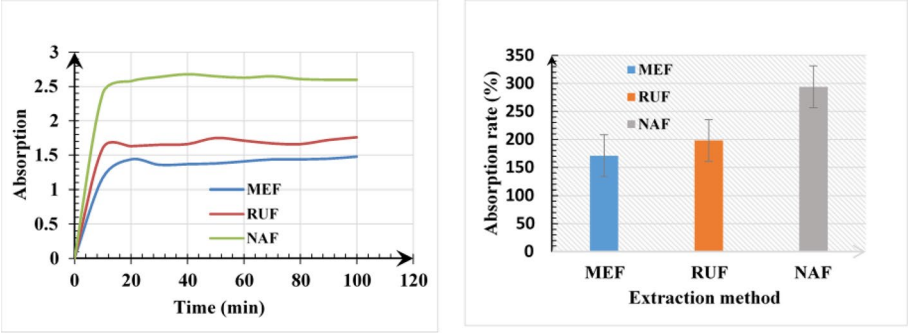


**Fig. 8** Water absorption rate of NA fiber: (**a**) water absorption kinetics; (**b**) absorption rate as a function of extraction method

which could be beneficial for applications requiring better dimensional stability in humid environments. From an application perspective, excessive absorption rates can compromise the dimensional stability and mechanical properties of composites, particularly in humid environments [19]. Thus, although NAF fibers absorb more water, their compatibility with hydrophobic matrices may be less favourable without additional surface treatment. In this respect, MEF fibers offer an interesting compromise between performance and water stability.

Compared to commonly used plant fibers, these values remain within a typical range: the absorption rate of NA fibers is close to that of sisal fibers (190–250%, Souck et al., [20]) and *Rhecktophyllum camerunense* fibres (198.17%, Betene et al., [8]). This confirms the potential of NA fibres as bio-based reinforcements, while highlighting the decisive influence of the extraction method on their hygroscopic behaviour.

We should point out that Fig. 8(b) shows the average values obtained from repeated measurements, while Fig. 8(a) may show individual or representative curves.

#### *3.1.4 NA fiber moisture content*

The moisture content of NAF (12.97%) samples is higher than both the moisture contents of RUF (11.53%) and MEF (11.49%) samples (Fig. 9). It should be noted that the moisture content of the NA fiber is close to those of other plant fibers in the literature (Table 1), including banana trunk pseudo fiber (12.4%) [9], AC fiber (12.21%) [8] and jute fiber (12–13.7%).

### 3.2 Thermal properties

Thermogravimetric Analysis (TGA/DTG) and Differential Scanning Calorimetry (DSC) of NA fiber are performed on NAF samples called treated fiber and RUF samples called untreated fiber.

#### *3.2.1 Thermal degradation curves (TGA) and their derivatives (DTG)*

TGA curves (Fig. 10) show that NA fiber samples break down into several phases: five phases for untreated fibers and three phases for treated fibers [21]. This thermal behavior is typical of conventional plant fiber [22]. The first noticeable change begins at 30 °C and ends at 120 °C for untreated fibers and from 30 °C up to 125 °C for treated fibers. This is due to the evaporation of their structural moisture. The mass loss recorded in this

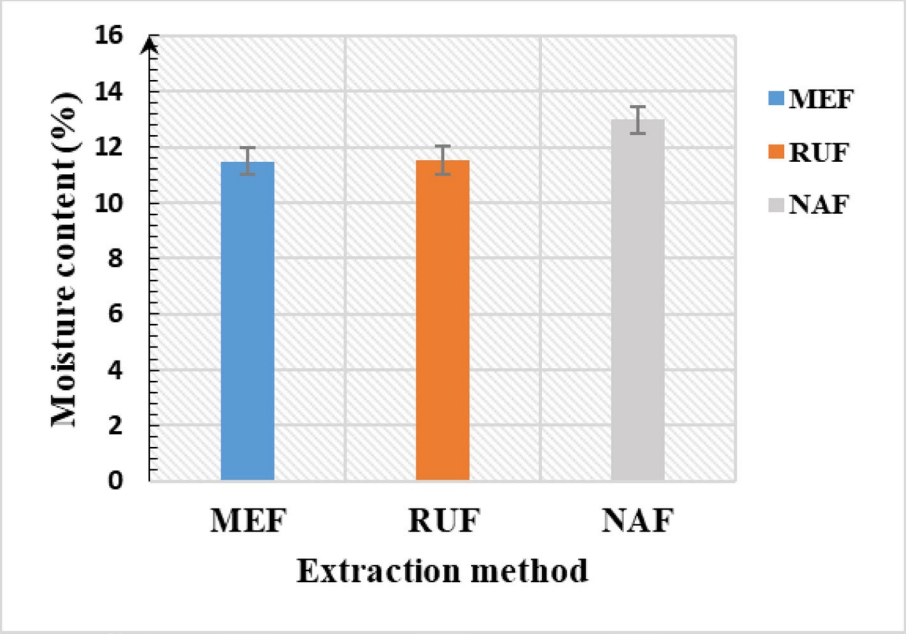


**Fig. 9** Moisture content of NA fiber

first phase is 7.54% for the untreated fiber sample and 9.89% for the treated fiber sample. After dehydration of these two samples, the mass change is found to be constant up to 225 °C for the treated fiber samples and 210 °C for the treated fiber sample [23].

The thermal stability zone thus identified provides information on the service temperature of these two *Neuropeltis acuminatas* fiber samples.

In the second phase, a mass loss of 26.67% was recorded between 225 °C and 305 °C for RUF fiber sample (call the untreated fiber), and a mass loss of 52.61% was recorded between 210 °C and 380 °C for NAF fiber sample (call the treated fiber) [24]. This mass loss is attributed to the thermal decomposition of hemicelluloses and pectin between 150 °C and 250 °C, followed by that of cellulose between 240 °C and 380 °C [25]. The third phase indicates lignin decomposition in both samples studied. For the untreated samples, a mass loss of 43.47% was observed at 380 °C, while for the treated samples, a mass loss of 29.96% was observed 505 °C. For treated fibers, due to ash formation the variation is really small [17]. In the fourth phase, the ATG content is 7.54% and a mass loss of 24.63% is observed at 461 °C [26]. In the fifth phase, for untreated fiber samples, due to ash formation, the variation is very small as well, with an ATG content of 5.31%. Table 1 shows the degradation temperature of the various compounds.

#### *3.2.2 Differential scanning calorimetry*

The DSC curves (Fig. 10) for the two samples are almost similar. The first exothermic peak is concave for both NA fiber samples and is associated with the loss of water from the fibers, observed at 71 °C for the RUF samples and 67 °C for the NAF samples [27]. We can therefore associate these events with incomplete drying of the NA fiber prior to differential scanning calorimetry. The three convex exothermic peaks probably correspond to the degradation of hemicelluloses, cellulose, and lignin for the untreated and treated NA fiber samples.

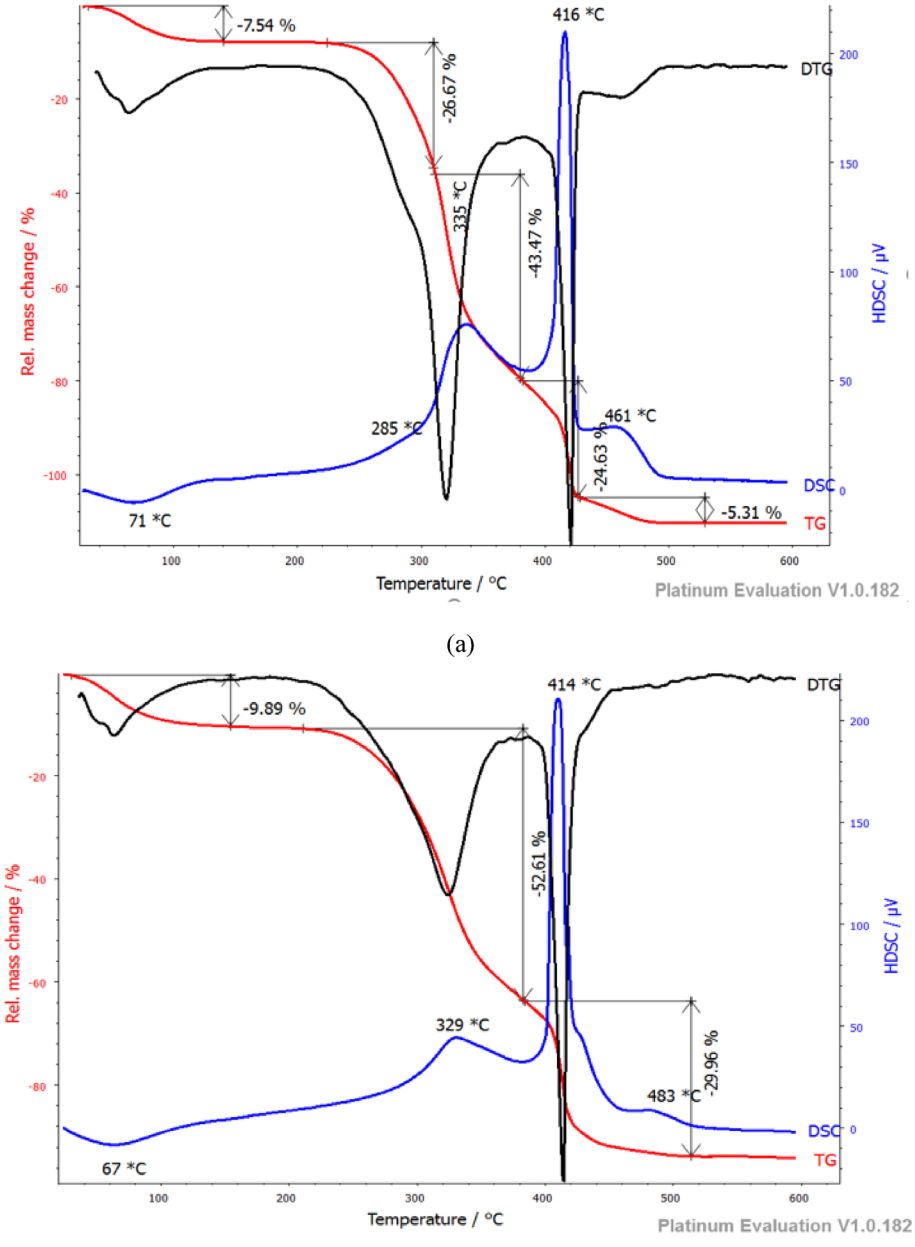


**Fig. 10** Thermal degradation curves TGA/DTG and DSC curves of *Neuropeltis acuminatas* fiber: (**a**) untreated fiber; (**b**) fiber treated with NaOH

### *3.2.3 Infrared spectrometry (FTIR) of NA fiber*

The infrared spectrometry (FTIR) shown in Fig. 11 was performed on the MEF, RUF, and NAF samples of NA fiber to identify the functional groups of the different chemical components present in the fiber, and to verify whether all the functional groups of contaminants and impurities were removed after extraction.

Figure 11 showed the FTIR spectrum of the three different fibers. The assignments of the vibration bands were carried out based on literature and are reported in Table 2. The vibrational bands emerging at 3256 and 2800 $cm^{-1}$, respectively, correspond to the stretching vibrations of the ether bond groups -OH, ethylenic -CH initially present in the cellulose fibers [28–30]. The bands observed in all NA spectra in the region of

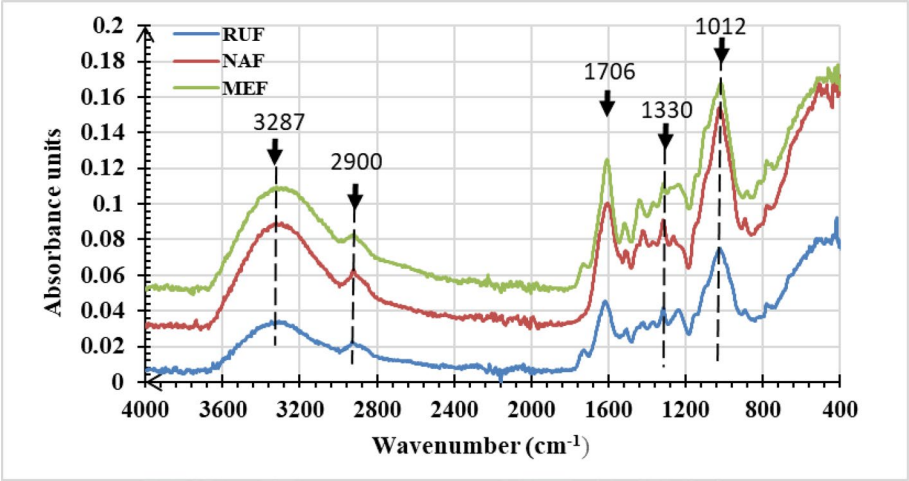


**Fig. 11** FTIR spectra of fiber FTIR spectra of different fibers treated by mechanical (MEF), chemical (NAF) and retting processes (RUF)

**Table 2** Assignment of the main FTIR vibration bands spectra NA fibers

| Wavenumber ($cm^{-1}$) | | | | Band assignment | References | Interpretations |
|---|---|---|---|---|---|---|
| Reference range | RUF | NAF | MEF | | | |
| 3400 – 3256 | 3341 | 3259 | 3263 | O–H valence vibration of fibers cellolosic | [29, 30] | Broad peak, more intense in RUF > MEF > NAF, indicating increasing hydroxyl group or moisture content |
| 2980 – 2800 | 2913 | 2907 | 2920 | C–H stretching vibration (aliphatic bonds) | [32] | the presence of longer aliphatic chains |
| 1740 – 1700 | 1604 | 1579 | 1599 | C = O stretching in lignin and hemicellulose | [33] | Peak aromatic structure characteristics |
| 1600 | 1308 | 1325 | 1322 | O–H valence vibration of water | [4] | Peak of water vibration |
| 1056 | 1038 | 998 | 1008 | C | [34] | Peak of ether bonds in tree fiber |

1603, 1587 to 1611 $cm^{-1}$ correspond to the OH group of the absorbed water molecule. However, the vibrational frequency of NAF of water molecule decreased slightly, which highlights the quality of the chemical process compared to the reinforcing and mechanical process. The disappearance of the band emerging at 1708 $cm^{-1}$ characteristic of the carbonyl group (C = O) on the NAF spectrum of the fibers confirms that the chemical treatment has eliminated more impurities (hemicellulose, lignin) than the mechanical and retting treatments [28, 31]. The absence of the band at 1500 $cm^{-1}$ characteristic of phenolic group in RUF, NAF and MEF shows at least the effectiveness of three processes on the removal of phenolic groups (Lignin). The peak at 1011 $cm^{-1}$ corresponds to the stretching vibration of the pyranose C-O-C cycle in cellulose fibers in three spectra. Such a result shows the processes used have allowed the elimination not only of contaminants but also most of the impurities.

### 3.3 Mechanical properties of NA fiber

In this section, we present the results of uniaxial tensile tests carried out on samples of NA fiber. Figure 12a shows the stress-strain curves obtained. This curve (Fig. 12a) shows three zones: first (ε range 0–0.018%), a relatively linear zone corresponding to the

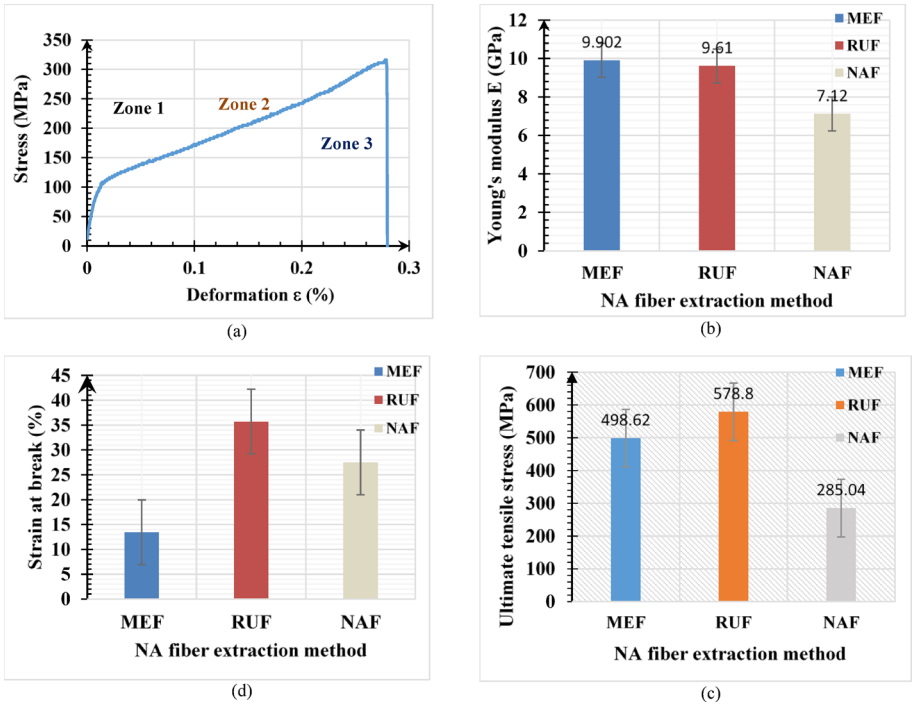


**Fig. 12** Behavior of tensile specimens: (**a**) stress-strain curve; (**b**) modulus of elasticity; (**c**) Ultimate tensile stress; (d) strain at break

reorientation of the micro-fibrils in the tensile direction; second (ε range 0.018–0.28%), a linear zone corresponding to the mechanical behavior of the fiber; and third (ε > 0.28%), a zone corresponding to fiber breakage. Young's modulus is determined by evaluating the slope of the linear zone 1 of each specimen (Fig. 12b, c, and d),

The typical tensile behavior of the three samples (MEF, RUF, and NAF) shown in (Fig. 12a) is the same for all 10-mm tensile-tested specimens. The mechanical properties of NA fiber revealed that the NA fiber samples obtained by the MEF method had better mechanical properties (modulus of elasticity and ultimate tensile strength) than those obtained by the RUF method, which in turn had better mechanical properties (modulus of elasticity and ultimate tensile strength) than the samples obtained by the NAF method (Fig. 12b, c and d). In the case of treatment in an alkaline solution of 5% NaOH (NAF), our mechanical resistance results obtained experimentally are close to the those obtained by Obame et al. [15] on the same of NA fiber.

The low tensile strength and modulus of elasticity of NAF samples can be explained by the fact that they have undergone chemical treatment (using alkaline solution at a concentration of 5% NaOH), which has modified the structure of these samples [35]. We also note that the mechanical characteristics of NA fiber are similar to those of other plant fibers in the literature (Table 3), in particular Sisal fiber of Subbiah et al. [36] and RC fiber of Betené [8].

## 4 Conclusions

The characterization was carried out on the three NA fiber samples. The physical characterization consisted in determining the water absorption rate, the moisture content and the apparent density. The chemical and thermal characterization was done by:

**Table 3** Physical and mechanical characteristics of *Neuropeltis acuminatas* (NA) fiber for three extraction processes : mechanical extraction method by manual beating (MEF), the biological extraction method by simple water retting (RUF) the chemical extraction method (NAF)

| Fibers | Extrac. method | Fiber diameter (µm) | density (g/cm³) | Water absorption rate (%) | Moisture content (%) | Young modulus E (GPa) | Strain at break A (%) | Tensile strenght Rm (MPa) | References |
|---|---|---|---|---|---|---|---|---|---|
| **NA (MEF)** | | **426** | **0,24** | **171** | **11,49** | **9,902** | **13,43** | **498,62** | **This study** |
| **NA (RUF)** | | **468** | **0,30** | **198** | **11,43** | **9,61** | **35,7** | **578,80** | **This study** |
| **NA (NAF)** | | **439** | **0,74** | **294** | **12,97** | **7,128** | **27,5** | **285,04** | **This study** |
| Banana pseudo trunk | Bio-extraction in cold wate | 0,84 | 1,03 | - | 12,4 | 0,26 | 2,8 | 743,9 | [9] |
| NA | Wet retting | 504 | 1,23 | 102,7 | - | 2,8 | 34,8 | 104 | [14] |
| AC | Wet retting | - | 1,256 | 188,64 | 12,21 | - | - | - | [8] |
| RC | Wet retting | 174 | 0,757 | 198,17 | 9,37 | - | - | - | [8] |
| NA | Wet retting | - | 0,843 | 276,16 | 10,36 | - | - | - | [8] |
| Banana pseudo trunk | Cooking in water | - | 1,02 | 14,52 | - | - | 2,82 | 816,6 | [4] |
| Pine-apple stem | Water retting | 42,3 | 0,9 | - | - | 33,6 | - | 1072 | [7] |
| Jute | Water retting | - | 1,3 – 1,41 | 281 | 12–13,7 | 36,14 | 3,71 | 350 | [28] |
| Hemp | Chemical retting | 42 | 1,1–1,45 | - | 6,2–12 | - | 4 | 2000 | [37] |

thermogravimetric analysis (ATG/DTG), Differential Scanning Calorimetry (DSC) and the Fourier Transform Infrared Spectroscopy (FTIR).

The relatively high tensile strengths, comparable to those of conventional fibers, are as follows: 498.62 MPa for MEF, 578.80 MPa for RUF and 285.04 MPa for NAF. The relatively low apparent densities (MEF ≈ 0.24 g/cm³, RUF ≈ 0.30 g/cm³ and NAF ≈ 0.74 g/cm³) could contribute to reducing the weight of composite materials. The water absorption rate of the fibers is influenced by the extraction processes, covering a range of values from 171.94% (for MEF) to 294.06% (for NAF), reflecting the interaction of soda ash on the opening of the plant fibers pores.

The results obtained show that fibers obtained by the biological method (RUF) have mechanical and physical properties that are interesting for use as reinforcement in composite materials for applications such as aerospace, automotive, construction, sports and the textile industry (production of fabrics, ropes and nets). RUF fibers have moderate moisture content and water absorption, which could influence their dimensional stability and durability in humid environments.

However, it is important to note that fiber performance may vary depending on the targeted properties, such as tensile strength, stiffness, thermal and chemical stability. Furthermore, it would be interesting to study the effect of the RUF extraction method on the adhesion at the fiber/matrix interface of a composite in order to better understand the interface mechanisms and optimise the performance of composite materials.

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**Author contributions**
Conception: DONFACK and FOKAM. Experimental design: FOKAM, CHENGOUE and KENMEUGNE Carrying out measurements: DONFACK and CHENGOUE Manuscript composition: DONFACK, FOKAM and DEHOMBREUX

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**Data availability**
The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

**Code availability**
Not Applicable

## Declarations

**Ethics approval and consent to participate**
This plant material (NA) was wild. We declare that the collection of plants used in this research work complies with national guidelines. The permissions is not applicable.

**Consent for publication**
Consent to Publish declaration: not applicable.

**Permissions to collect the plants**
Not Applicable. No permissions and/or licences for collection of plant specimens NA.

**Competing interests**
The authors declare no competing interests.

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