Journal of Materials and Environmental Science
ISSN : 2028-2508
CODEN : JMESCN

J. Mater. Environ. Sci., 2020, Volume 11, Issue 7, Page 1121-1128

http://www.jmaterenvironsci.com

Influence of extractions techniques on the physico-mechanical properties of banana pseudo-stem fibers

A. Mbouyap Chengoué [1], T. Tchotang [1], C. Bopda Fokam [1], B. Kenmeugne [1]

[1] *Laboratoire Engineering Civil et Mécanique de l'Ecole Nationale Supérieure Polytechnique (ENSP) de l'Université de Yaoundé 1-Cameroun*

Received 28 April 2020,
Revised 18 June 2020,
Accepted 20 June 2020

Keywords
- ✓ *Banana pseudo-stem,*
- ✓ *Biomaterials,*
- ✓ Cellulosic fiber,
- ✓ Composite reinforcement
- ✓ Fiber extraction process,

chengoueanatole1@gmail.com
Phone: +237691994598

Abstract
Banana fibres generally come from different constituent parts of the banana, but they are more abundant in the pseudo- stems or trunks of the banana. This paper presents an experimental study of the impact of the extraction processes on the physico-mechanical properties of banana pseudo-stems fibers used as reinforcement in composite materials. On the basis of a bibliographic synthesis, we selected three fibers extractions processes: Soaking in cold caustic soda, cooking in water and water retting. A characterization study was carried out on fibers resulting from the various extractions processes. The results show that the physico-mechanical characteristics of the fibers vary according to the extraction process. Also the highest physical characteristics are obtained by extraction after cooking in water with a maximum density of 1,02g/cm^3 and a maximum absorption rate of 15.17% for water retting. In a second step, it appears that the extraction method after cooking in water gave the best tensile mechanical properties of the fiber which are; tensile strength: 816.6 MPa and elongation at break: 2.83%. These results show that the fibers of the banana pseudo-stem have properties similar to other natural fibers studied in the literature review.

1. Introduction
The natural fiber market is booming with many industrial opportunities. Today, plant fibers are sought for their many environmental, technical, economic and health benefits of which industries could take advantage: renewable raw material, biodegradable and low density, neutral carbon footprint, energy saving, flexibility, low cost, a possible eradication of the allergy or health problem of the operators on the production lines, etc. These fibers are abundant in the world and are of different varieties: hemp, linen, cotton, jute, kenaf [1, 2, 3]. Also, they are characterized by a wide field of application. While they have previously been used in traditional sectors such as textiles and the paper industry, they are now used in new sectors including the automotive industry, construction and geotextiles [4]. Tanweer and al. [5] evaluated the possibility of applying banana waste in treating waste water. The study covered the application of banana rejects (fruit peels, pseudo-stem, trunks, and leaves) as raw materials to make adsorbent its use to combat environmental pollutants like heavy metals, pesticides, organic pollutants and many other pollutant gases. It was clear from this study that banana rejects made adsorbents have high ability to remove various pollutants.

Thomas Sango and al. [6], studied the multi-scale structure of the banana pseudo-stem and the morpho-mechanical properties of the extracted long fibres. The authors identified the chemical composition of the fiber: 13.4% extractives, 6% pectins, 14.7% linen, 28% hemicelluloses and 38% cellulose. Tensile tests carried out on fibers with diameters in the range 40-140 µm showed the following mechanical properties: Young modulus: 6.3-26 GPa; nominal stress at break: 140-768 MPa. William Jordan and al. [7] have shown that treated banana fibers can improve the properties of banana fiber-reinforced composites. This study was aimed at two distinct chemical treatments purposely to increase the interfacial bonding between banana fibers and a matrix: peroxide treatment and permanganate treatment. The influence of the chemical treatment on tensile properties of single banana pseudo-stem fibers was analyzed, with peroxide treatment enhancing the tensile properties and permanganate treatment having an inconclusive effect. Marwan and al. [8] did experimental studies on compressed earth block with banana fibers resisting flexure and compressive forces. From their studies, they have thus proposed innovative banana-Compressed earth block having ordinary compressed earth block ingredients plus banana fibers. From the results obtained, they notice general trends in the strength characteristics of different mixtures when different lengths of banana fibers are added to the compressed earth block.

It is in this context that we focused on the valorization of banana pseudo-stem, by studying the physical-mechanical properties of fibers derived from agricultural by-products: banana's pseudo-stems of Cameroon. According to the FAO, 75% of the natural fiber production market is concentrated in South-East Asia, particularly India and Bangladesh through jute, coconut fiber or kenaf [1, 4]. Europe produces 10% while the rest of the world including Africa is at 15%.

To position itself in this new sector of activities in view of its intrinsic potential, many African countries and more particularly Cameroon, conducts studies on plant fibers [9, 10]. In Africa, the by-products of agriculture or the agro-food industry such as leaves, trunks, skins, bagasse, cake, sawdust are generally dumped into nature [11, 12]. These by-products clog the farmer or industrial sites. Moreover, their decomposition produces methane: a greenhouse gas harmful to the atmosphere, like the banana pseudo-stem. Regarding the varieties of banana Grande-Naine cultivated in Cameroon, these works are still embryonic.

To achieve these results, we proceeded as follows: all the pseudo-stem samples were collected in an agricultural field. These pseudo-stems are from scraps left by the farmer after harvesting the bunch of banana. In addition to the valorization of banana fibers, the specificity of this paper is the comparative study of the impact of a new process of banana fiber extraction by cooking in water and the classical techniques of water retting and soaking in caustic soda.

2. Material and experimental techniques

2.1. Biomaterial used in this study

The biomaterial under study in this article is the banana pseudo-stem of the Grande-Naine variety (see Figure 1a and 1b), species "MUSA" of Cameroon. All samples of the pseudo-stem were self-harvested in a private agricultural field in Yaoundé, Mfoundi department of Cameroon

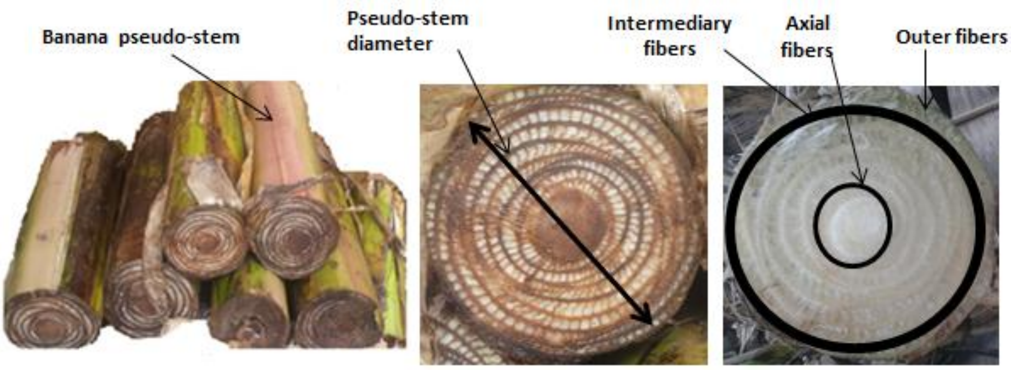

Figure 1 : (a) banana pseudo-stem, (b) banana pseudo-stem cross-section

2.2. Fiber extraction equipment

The main materials used for the extraction of pseudo-stem fibers are illustrated in Figure 2, namely: knife, board, scale, plastic bag, scissors, hot plate, oven, tube, beaker, thermometer, heating pot with thermostat, distiller, gloves, muffler, etc.

2.3. Description of the various fiber extraction processes

Based on a bibliographic synthesis, we have used three (03) methods of extraction in this article. Before extraction, the preparation phase consists of manually separating the leaf samples from the pseudo-stem of the banana. The banana stem leaves are then placed in a container containing cold water for the retting extraction technique. For the extraction technique by cooking, the samples are placed in a heating pot containing boiling water. For the caustic soda extraction technique, samples are placed in a container containing a cold caustic soda solution. After extraction, the fibers are washed and dried in the open air. The parameters of each extraction process are presented in Table 1. In Figure 3, pictures of fibers extracted from pseudo-stem of banana are presented.

Figure 2 : Equipment: (a) tube, (b) beakers, (c) scale balance of accuracy 0.001, (d) heating pot

Table1: Extraction Processes [4,5-7]

Extractions Processes	Parameter	Min value	Max value
Extraction by soaking in a solution of cold caustic soda	Mass of cold caustic soda	5g	10g
	Volume of water	1000 ml	1000 ml
	Duration	48 hours	168 hours
Extraction after cooking in water	Temperature	60°C	100°C (boiling)
	Duration	30 minutes	3 hours
Extraction water retting	Volume of water	800 ml	800 ml
	Temperature	25°C	37°C
	Duration	1 month	4 months

Figure 3 : Pictures of banana fibers after different process of extraction

2.4. Tensile test machine

The tensile machine (see figure 4) used is available in the LAMMA (LMMA: Laboratory of Mechanics and Adapted Materials) of higher technical teacher training college of Douala university - Cameroon. The machine is equipped with two jaws (one mobile and the other fixed). The single-fiber tensile test fixture is carried out according to ASTM D3822-07 with care to eliminate any scratches and burrs of the metal jaws (gluing of a small paper frame, see figure 4c). Ten samples are tested for each extraction method.

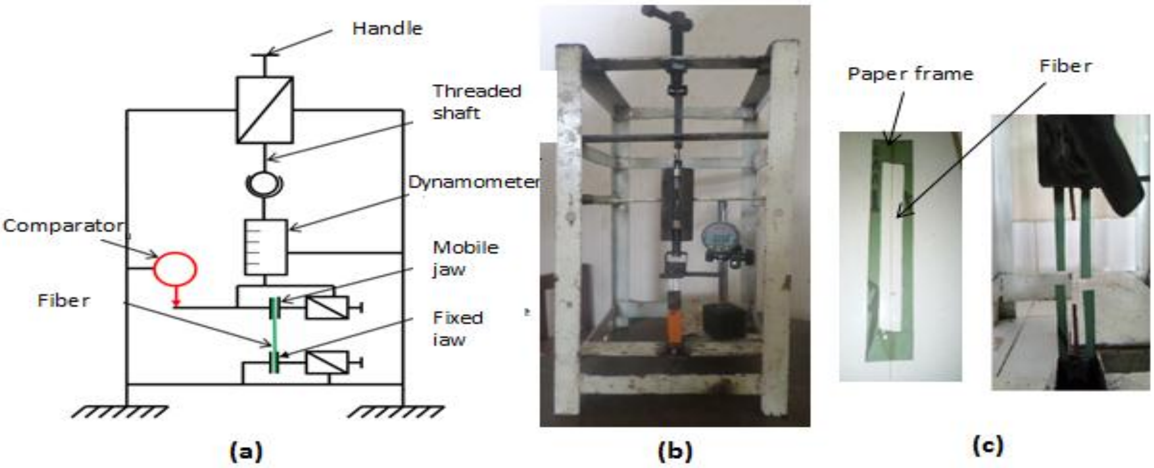

Figure 4 : Experimental single-fiber tensile test fixture: (a) kinematic schematic of the tensile machine, (b) picture of tensile machine, (c) picture of the fixture set-up for the fiber tensile test

3. Results and discussion

In addition to the description of plant fiber characterization test protocols, the results presented the effect of the extraction process of banana pseudo-stem fibers on the quality of the fibers obtained. This influence of the extraction process is quantified through the production yield, mainly the physical and mechanical characteristics.

3.1. Study of the yields of extraction processes

In this section, the study consists to identify the most productive extraction process in fiber, considering the different parameters: the yield and complexity of the tools. The yield is calculated as a ratio of the mass of banana pseudo-stem fibers obtained after extraction to the mass of the initial (or natural) sample (see Table 2). From the analysis in Table 2, it appears that the yield varies from one process to another. Maximum yields are obtained when it is cooked in water [50% -62%] and minimal yields for the extraction process after soaking in cold caustic soda [35% -50%].

Table 2: Summary of different extraction processes (5 tests by method of extraction)

Extraction processes	Soaking solution	Soaking time	Temperature	Appearance of fibers	Yield (%)
Extraction after water retting	water	1 month	37°C	Smooth, tender Color: whitish	45 – 55
Extraction after cooking in water	water	2 hours	100°C	Smooth, tender Color: whitish	50 – 62
Extraction after soaking in a solution of cold caustic soda	Water + NaOH	120 hours	Room temperature March	smooth Color: dark brown	35 -50

3.2. Physical properties of banana fiber

3.2.1. Density of fibers

Density is defined as the ratio of the mass to the volume. It is determined as indicating in equation (1) below:

$$\rho = \frac{m}{V} \qquad (1)$$

With: ρ: density (g/cm^3), m: mass of fibers (g), V: volume of fibers (cm^3).

The density was measured immediately after extraction and oven drying of the fibers. Although the source of the banana pseudo-stem samples is identical. Evertheless, we studied the influence of the extraction process on the density of the fibers obtained... According to Figure 5, the method of extraction after cooking in water has the highest density of 1.02 g/cm^3.

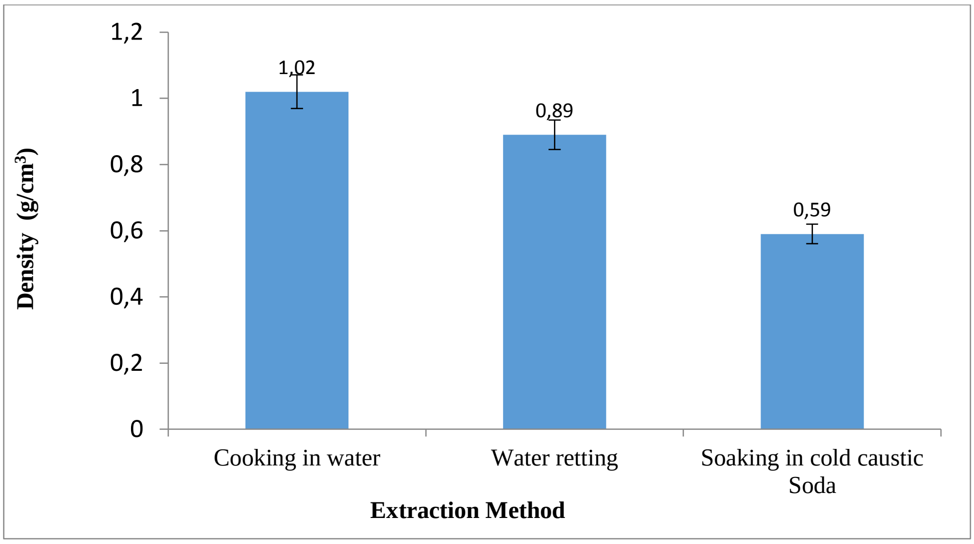

Figure 5 : Evolution of the density according to the process

3.2.2. Determination of the rate of water absorption

In this part, we carried out a comparative study, the amounts of water present in the fibers for the various extraction processes (Figure 6). This is quantified by the "absorption rate" of water and corresponds to the following equation (2):

$$Absorption_{water} = \frac{m_1}{m_2} \times 100 \qquad (2)$$

With: m_1 : Initial mass of fiber bundle (g) just after extraction; m_2: Final mass of fiber bundle (g) after drying.

The dry mass of the fibers is obtained by drying in the open air (exposure to natural sunlight) and then in the oven at 105°C for 24 hours. The rate of water absorption varies from 13.64% to 15.17%. It varies from one process to another. It is maximum for the process water retting and minimal for the extraction process after soaking in cold caustic soda.

3.3. Mechanical Properties of the fibers

In this section of the study, we present the results of mechanical tensile properties of banana pseudo-stem fibers. Firstly, it will be necessary to determine the extraction process offering the best mechanical property to the fibers. Secondly, the mechanical properties of banana pseudo-stem fibers will be compared with the usual plant fibers. The mechanical characteristics presented here are all derived from the tensile test according to ASTM D3822-07, With desired parameters as follows: the tensile strength (MPa) and elongation at break (or fracture strain).

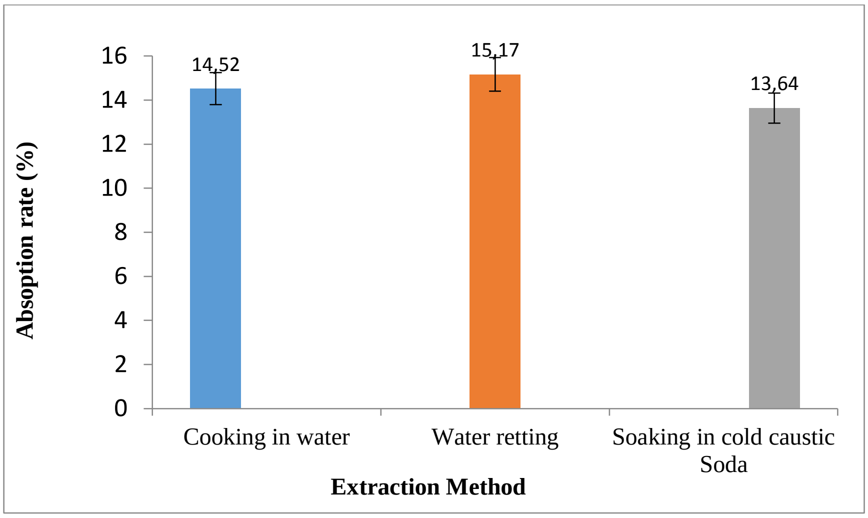

Figure 6 : Evolution of the absorption rate according to the process

3.3.1. Comparison of mechanical properties by extraction processes

Figures 7 represent the mechanical properties (tensile strength and elongation at break) of fibers obtained after extraction for different process used. We find that the extraction process that produces overall fibers of better mechanical characteristics is the extraction by cooking in water. Globally, we obtain the following mechanical characteristics for this process: tensile strength: 816.6 MPa and elongation at break: 2.83%.

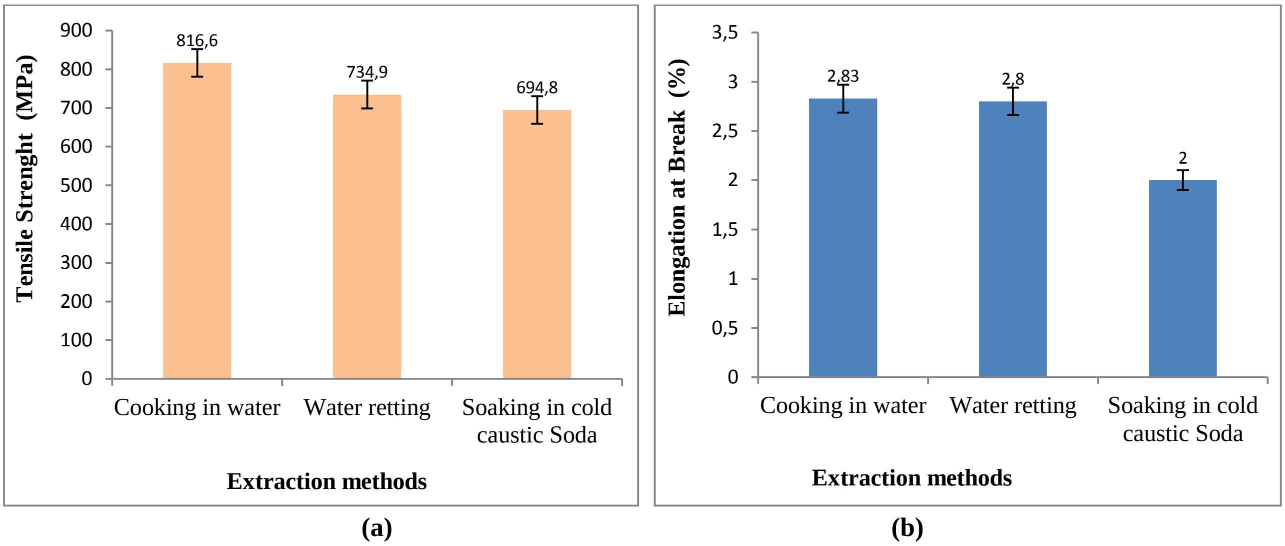

Figure 7: Comparison of tensile mechanical properties of fiber extraction processes: (a) Tensile strength Rm, (b) elongation at break

3.3.2. Comparison of mechanical properties with the usual plant fibers

Considering only the mechanical properties resulting from the boiling extraction process, we will carry out a comparative study with the other fibers in the literature review [1-3, 6, 12, 13]. In this literature, the authors used mechanical extraction techniques and water retting. The comparisons of the different characteristics are made with the maximum magnitudes and presented on the histograms in figure 8. From the interpretation of figures 8, 9 and 10 we can see that banana fibers have equivalent or even identical properties to a large number of common natural fibers.

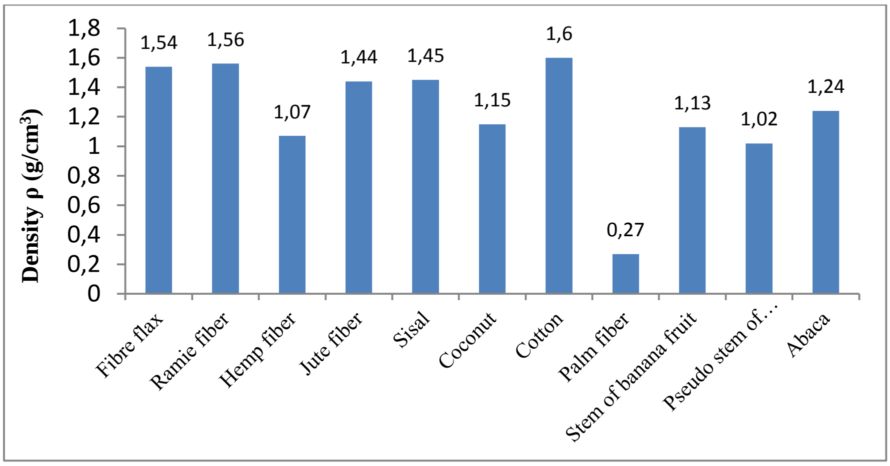

Figure 8: The density of pseudo-stem fibers with usual fibers [1-3, 6, 12, 13]

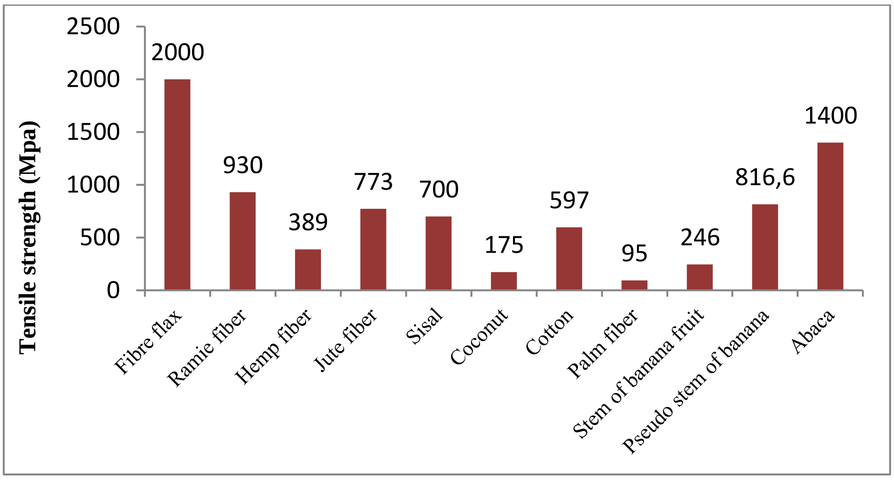

Figure 9 : The tensile strength of pseudo-stem fibers with usual fibers [1-3, 6, 12, 13]

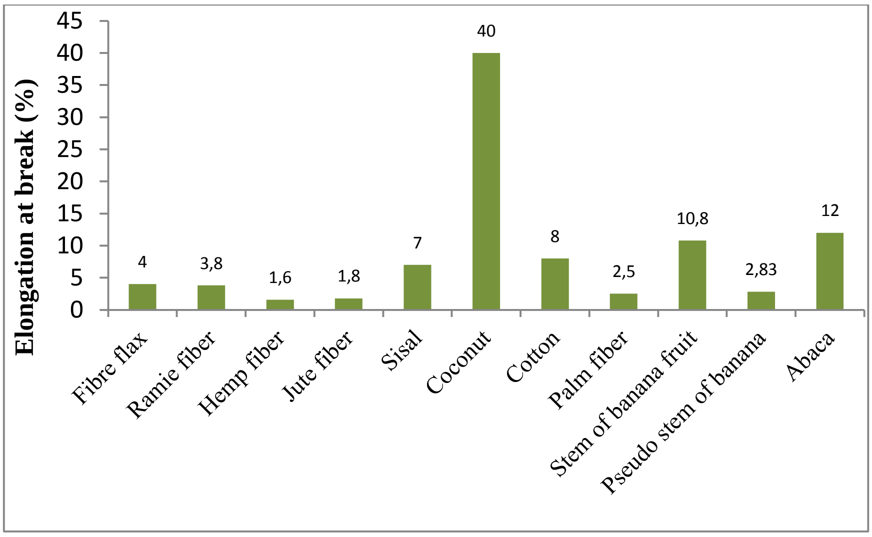

Figure 10 : The elongation at break (or fracture strain) of pseudo-stem fibers with usual fibers [1-3, 6, 12, 13]

Conclusion

In this paper, we were presenting the impact of the extraction process to the mechanical properties of banana pseudo-stem fibers. Thus, we proceeded to the choice of the pseudo-stem of banana to extract fibers, then, we experimented three methods from the literature review, namely: soaking in the cold caustic soda, cooking in water and water retting, which allowed us to get fibers.

The results show that the extraction process after cooking in water has a maximum density of 1.02 g/cm^3 and a maximum absorption rate of 15.17% for water retting. Extraction after cooking in water revealed the best tensile characteristics of the fiber: tensile strength: 816.6 MPa and elongation at break: 2.83%.

References

1. P. Bono, A. Duc, M. Lozachmeur, A. Day, Matériaux : les nouveaux champs de recherche et développement pour la valorisation des fibres végétales techniques (lin fibres et chanvre), Oilseeds et fats Crops and Lipids OCL 22(6) (2015) 613, https://doi.org/10.1051/ocl/2015041
2. S. Amziane, F. Collet, M. Lawrence, C. Magnion, V. Picandet, Round robin test for hemp shiv characterisation: part 1 Evaluation of initial water content and water absorption, Bio-Aggregates Based Building Materials, v. 23, springer, The Netherlands-Amsterdam, ISBN 978 -94-024-1030-3 (2017) https://doi.org/10.1007/978-94-024-1031-0
3. K.L. Pickering, A. Efendy, A review of recent developments in natural fibre composites and their mechanical performance, Compos. Part A 83 (2016) 98–112. http://dx.doi.org/10.1016/j.compositesa.2015.08.038
4. C. Meirhaeghe, Evaluation de la disponibilité et de l'accessibilité de fibres végétales à usages matériaux en France, ADEME – Fibre Recherche Développement (2005).
5. A. Tanweer, M. Danish, Prospects of banana waste utilization in wastewater treatment: A review, Journal of Environmental Management, 206 (2018) 330-348, https://doi.org/10.1016/j.jenvman.2017.10.061
6. T. Sango, A. M. Cheumani Yona, L. Duchatel, A. Marin, M. Kor Ndikontar, N. Joly, J.M. Lefebvre, Step–wise multi–scale deconstruction of banana pseudo–stem (Musa acuminata) biomass and morpho–mechanical characterization of extracted long fibres for sustainable applications, Industrial Crops & Products 122 (2018) 657–668, https://doi.org/10.1016/j.indcrop.2018.06.050
7. J. William, P. Chester, Improving the Properties of Banana Fiber Reinforced Polymeric composites by Treating the Fibers, Procedia Engineering, 200 (2017) 283–289.
8. M. Marwan, N. Uddin, Experimental analysis of Compressed Earth Block (CEB) with Banana fibers resisting flexural and compression forces, Case Studies in Construction Materials, 5 (2016) 53–63, http://dx.doi.org/10.1016/j.cscm.2016.07.001
9. R. Medjo Eko, D. Engelbert Offa, T. Yatchoupou Ngatcha., S.M. Lezin, Potential of salvaged steel fibers for reinforcement of unfired earth blocks, Construction and Building Materials, 35 (2012) 340-346, http://dx.doi.org/10.1016/j.conbuildmat.2011.11.050
10. E. Mboumboue, D. Njomo, Biomass resources assessment and bioenergy generation for a clean and sustainable development in Cameroon, Biomass and Bioenergy, 118 (2018) 16–23. http://dx.doi.org/10.1016/j.biombioe.2018.08.002
11. S. Mukhopadhyay, R. Fangueiro, Banana Fibers — Variability and Fracture Behaviour, Journal of Engineered Fibers and Fabric (2008) 39-45, http://dx.doi.org/10.1177/155892500800300207
12. Z.A. Ghani, M.S. Yusoff, N.Q. Zaman, M.F.M.A. Zamri, J. Andas, Optimization of preparation conditions for activated carbon from banana pseudo-stem using response surface methodology on removal of color and COD from landfill leachate, Waste Manage 62 (2017) 177-187. http://dx.doi.org/10.1016/j.wasman.2017.02.026
13. C. Baley, Fibres naturelles de renfort pour matériaux composites, vol. A.M 5130, Technique de l'ingénieur, Réf. AM 5130, p22 (2013)

(2020) ; http://www.jmaterenvironsci.com