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Impact du comportement hydrophile des fibres de Bambusa Vugaris traitées dans un composite fibres/époxyde en fonctionnement dans le revêtement de maison

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Research Article

Keywords: "Bambousa Vulgaris", acetylation of fibers, water absorption, hydrophilic behavior, hygrothermal behavior

Posted Date: September 29th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-3381642/v1

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Additional Declarations: No competing interests reported.

Impact of hydrophilic behaviour of Bambusa Vugaris Fibers treated in a Fibers/Epoxide composite in operation in house siding

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- **AUTHOR'S DELEGATIONS**

Thanks : our thanks go first to my family, then to my supervisors for the success of this research.

Declaration of interest : we declare that no competing interests exist.

Funding: The authors received no funding for this work.

- **ABSTRACT**:

The aim of this study is to study the hygrothermal behavior of bamboo fibers extracted by the alkaline method (3% soda) and treated with acetylation for potential use in house and fence siding. 10 g of 5-year-old fibers of "bambusa vulgaris" was soaked in 400 ml of glacial acetic acid, with 50 ml of catalyst (sulphuric acid) for 4 h at 30 ° C. After extraction by the « Improved Hydrophilic Extraction Method » and treatment in the laboratory, the diameter and lateral area observed with a magnification of 2, a 16x eyepiece and a 40x lens using an optical microscope equipped with a Balow lens, show that the fibers were smoothed to more than 3.57%; The absorption studied over three temperature ranges (30 °C, 50 °C and 70 °C), shows that it has decreased by about 20% and can grow with temperature to the limit of 37% after 48 hours of quenching; The composite was manufactured in three types of structure; increasing the

rate of treated fibers reduces the hydrophilic character of the composite, it becomes completely hydrophobic from 15%; Increasing the level of treated fibres reduces the hydrophilic character of the composite; and damage to the composite due to the hydrophilic effect of the treated bamboo fibers is less significant..

- **KEY WORDS** : "Bambousa Vulgaris", acetylation of fibers, water absorption, hydrophilic behavior, hygrothermal behavior.

I- INTRODUCTION

Bamboo is a technological plant in the sense that all its components can be applied (*Dobo Pierre, 2020 ; Aniket Baksy,2013*) especially in the field of buildings such as facings and of house fencing (*Dieudonné Abessolo, 2020*) (Figure 1).



***Figure I**: Bamboo stem – Bamboo fibers – Bamboo wood siding*

Although bamboo fibers have been studied by several researchers (*Allaoua F. and A. Merzouga, 2019 ; Quang Minh Do, 2016*), just like other natural fibers (*Shaker K. et al, 2020*). The characterization of bamboo fibers is still an axis of exploration. Bamboo fibers, are very effective in strengthening polymer composites. They have been accredited with the possibility of being used in the technique of fiber concrete (*Shaker K. et al, 2020 ; Cabrillac R., 1992*); however, their hydrophilic nature is a problem with their characteristics, thus leading to rapid aging of the composites. The main constituent of bamboo, cellulose (46 to 58%), which ensures the mechanical characteristics (*J. Wu, D. Yu, C., 2000*) loses its hydroxyl groups (-OH) in replacement of hydrogen ions (H2). The fracture stress decreases to 30% (*Shaker K et al., 2020 ; Jakovljević S., Lisjak D., 2017*). This hydrophilic character can also be responsible for caused by interfacial embrittlement between the fibers and the matrix (*Ebanda E. Dieudonné, 2022* ; *Kushwaha P. K. and R. Kumar, 2009*). Several treatments have been created to solve

the problem of hydrophilicity of plant fibers; in this case, the treatment with soda and acetylation of the fibers (*Do Thi Vi Vi, 2011*).

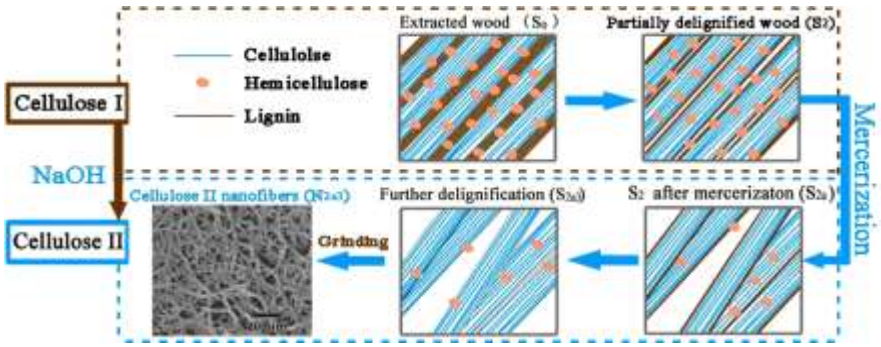


***Figure II** : graphical depiction of the conversion of cellulose I to cellulose II.*

In this work, it is then a question of verifying that the treatment of Bambusa Vulgaris fibers, to reduce their hydrophilic character, may or may not have an impact on the hygrothermal behavior and damage of the fiber/epoxide composite in operation in the structure of house siding and fences.

II- MATERIALS AND METHODS

II-1- **MATERIALS**

II-1-1- **bamboo fibers pretreated with soda (3%) and treated with acetylene**

The 5-year-old "bambusa vulgaris" fibres, of the "graminae" species harvested in a swampy and warm area on the coast of Cameroon were chosen, and the upper and outer part of the Bamboo thatch was used because it has the best mechanical characteristics (Sikame Tagne N. *et al.*, 2021 ; Fokwa D. , F. Ngapgue, 2012). These fibers underwent extraction by the IHEM method by press (DMCN Art-150 machine, 8000 N/m2) and chemical (3% caustic soda), followed by acetylation.

II-1-3- A composite resin, SR5550 epoxy (Topcoat Epoxy Resin), with a density of 1.145 g/cm3 at 20 ◦C (pycnometer), is recommended in Wood and Epoxy systems. The epoxy resin was mixed with the SR5503 hardener density of 1 g / cm3 (recommended for lamination and bonding); The hardener volume/resin dosage is 1/3 (recommended by the manufacturer). With this mixture, a density of 1.109 g / cm 3 is obtained.





Figure III*: Epoxy resin and its hardener;* ***Figure IV****: Acetone ONYX Bricolale*

II-1-4- DIY ONYX acetone, a degreaser that plays the role of the compatibilizing agent (CA); Its content as an additive or filler in the composite material created, is of the order of less than 2%, almost negligibl

II- 2- METHOD

II-2-1- The extraction of bambusa vulgaris fibres has done by the IHEM method (Ebanda Ebanda D.,2022). The method used (with pre-treatment of 3% caustic soda and a press machine of the Chinese brand DMCN Art-150, 8000N/ m2) was chosen and justified in order to reduce the hydrophilic character.

II-2-2- Treatment of bambusa vulgaris fibers with acetylation:

10 g of alkalinet reated fibers were soaked in 400 ml of glacial acetic acid (Melting point 16.7°C) with 50 ml of catalyst (sulfuric acid) for 4 h at 30 ° C, all covered in a beaker by a metal film to minimize hydrolysis; they were then settled, washed in distilled water up to neutral PH, and dried at room temperature in the shade for 48 hours.





Figure V *: Fiber quenching.* ***Figure VI*** *: Overview of acetic acid residue after fiber settling.*

II-2-3- Manufacture of the Mold:

It is made of sheet metal formed in reinforced steel and obtained, in contact molding, from a model that is most often made of wood. This mold is made of several elements; It has undercut parts. The good

surface finish of the mold is produced by a special gel Coat for molds that allows the realization of 700 to 1000 pieces with a mold when it is properly maintained. The release treatment (here butter) allows its use for more than ten pieces without any intervention. After that, a light polishing and re-processing will be required to ensure both easy demolding and a beautiful surface appearance of the casting.



Figure VII *: Mold manufacture*

- Implementation of the epoxy/fibers composite material of "bambusa vulgaris"

The structure of the composite is band-shaped. Its dimensions are 150 x 45 x 5 mm^3 according to the AM3734 standard.

II-2-4- Measurement

- Mass water intake of acetylation-treated fibers

The fibers were weighed and the mass m0 (/100) raised; then immersed in demineralized water over three temperature ranges (30°, 50° and 70°C), for a variation time (t) after 72 hours; then cleaned on the surface with an absorbent cloth and weighed again. We obtain a final mass mt. The water intake is determined by the expression :

$$Wabs = (mt - m0)/m0 \times 100 \quad (1)$$

- Young's Module of Acetylation-treated fibers

$$E = \frac{\Delta\delta}{\Delta\varepsilon} \quad (2)$$





***Figure VIII** : LDW traction machine. **Figure IX** : Manufacture of specimens for tensile testing.*

- Determination of the density of the material to be used.

- For untreated fibers : (R+F) : ⇒ Ff = 10% : $\rho_{C1} =$ 1,137 g/cm^3⇒ Ff = 15% : $\rho_{C1} =$ 1,155 g/cm^3

⇒ Ff = 20% : $\rho_{C1} =$ 1,171 g/cm^3

- For acetylated fibers : (R+FT) : ⇒ Ff = 10% : $\rho_{C1} =$ 0,965 g/cm^3⇒ Ff = 15% : $\rho_{C1} =$ 0,908 g/cm^3

⇒ Ff = 20% : $\rho_{C1} =$ 0856 g/cm^3

The ideal mass M_C of the composite to be developed is determined:

$$M_{Ci} = V_c \times \rho_C. \quad (3)$$

The following table shows the fractions and characteristics of the different components and the composite:

Table 1: The characteristics of the composite to be created

COMPOSITE (C)	ρ_f (g/cm^3)	ρ_{EP} (g/cm^3)	F_f %	F_{EP} %	ρ_C (g/cm^3)	V_{Ci} (cm^3)	M_{Ci} (g)	m_f (g)
			10	90	1,137		38,37	3,86
R +F	1,494		15	85	1,155		38,98	5,85
		1,109	20	80	1,171	33,75	39,52	7,91
			10	90	0,965		32,57	3,26
R = FT	0,447		15	85	0,908		30,64	4,60
			20	80	0,856		28,89	5,78

- Hygrothermal analysis of the Epoxy/bambusa vugaris fiber material created

The composites obtained were subjected to a wetting/drying test to measure their characteristics in relation to their hydrophilic behavior. We have recompacted the following steps:

- A quantity of water is poured into the beaker and its height indicates H0;
- The initial Epox/Fib composite is weighed on a digital balance (mass: M_C), and then immersed in distilled water contained in the beaker;
- The whole is covered by a metal body to avoid the phenomenon of hydrolysis, and left to wet for three days (72 hours);

- Then the specimen is removed and suspended above the beaker for one minute to let the unsaturated drops of water run completely;
- The removed composite is weighed again (mass: M_{CS});
- Subsequently, it is dried in the open air for 24 hours, and weighed again (mass: M_{CT});
- After drying for 24 hours, the composite is again immersed in another beaker for 24 hours and weighed once more (mass: M_{AS}).

The composite was soaked in distilled water contained in a cylindrical graduated beaker, diameter DB. The water level was read before, during, and after immersion of the composite.

<u>After tempering:</u>

The following characteristic masses are obtained:

- ΔM : the change in mass of the composite measures, substituted in water, after soaking:

$V_{CS} \Rightarrow \Delta M = \rho_C \times V_{CS}$ or $V_{CS} = V_2 - V_0$; (4)

- M_S : the saturation mass, which corresponds to the difference in mass of the composite obtained at the end of quenching, compared to that of departure: $M_S = M_{CT} - M_C$ (5)

M_{AS} : mass of the composite after drying from one day to 300, obtained by simple weighing on a digital balance of precision 0.001. M_T : mass of moisture content,

after drying: $M_T = M_{CS} - M_{AS}$

(6)

The ratio indicating the level of hydrophilicity. According to Hadjer Rabii (2014), When subjected to a wetting and drying cycle, the material is hydrophilic if MT / Ms < 5 (MT is mass at the time t, after wetting and Ms the mass of water saturation)

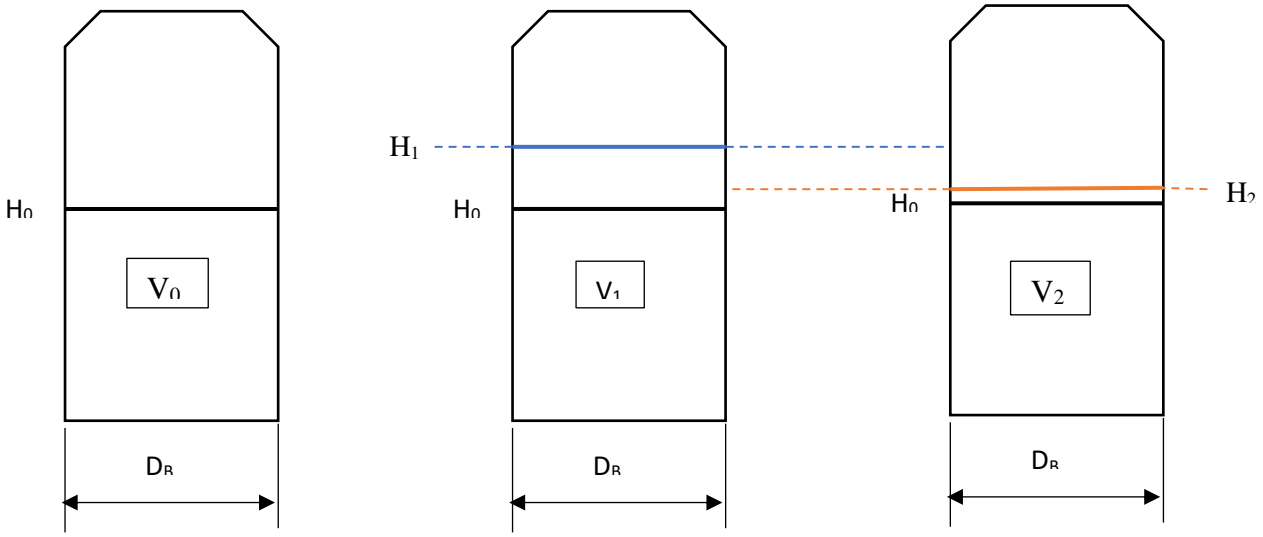


***Figure X**: Illustrative diagram of the evolution of the mass of the composite*

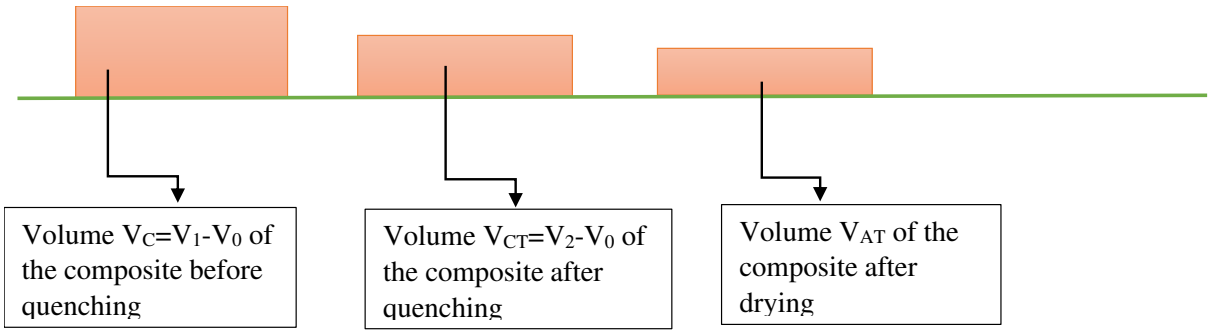


***Figure XI** : Illustrative composite submission diagram*

It is observed that:

$V_C > V_{CT} > V_{AT}$. $M_T = M_C - M_{AT} \Rightarrow \Delta M = \rho_C \times V_{CS}$ (7)

This experiment is done on each type of specimen and repeated four times to ensure better representativeness in each case.

III- RESULTS AND DISCUSSIONS

III-1- Appearance of Bambusa vulgaris fibers obtained.

The overview of bambusa vulgaris fibers extracted to 3% soda and then treated with acetylene gave the following images:





***Figure XII**: Overview of fibers after extraction;* ***Figure XIII**: Overview of fibers after Acetylation.*

Acetylated fibers have a much clearer and finer image than the former. The weighing of 100 fibers, of the same length (20mm) treated with acetylene made it possible to observe an average mass M0 of 0.0026 g per fiber. There is a clear decrease of 77.19% in mass compared to that of untreated fibers (0,014 g). This suggests that fibers that have undergone an acetylation treatment appear less hydrophilic and more suitable for the development of a polymer matrix composite.

III-2- Mechanical characteristics of Bambusa Vulgaris fibers obtained.

III-2-1- Diameter of Bambusa vulgaris fibers before acetylation

The diameters found after extraction of 3% soda range from 0.10 to 0.27 mm, with better overall concentrations of 22.2% (for d= 0.155 mm) and 25.2% (for d= 0.140 mm), compared to the fibers of "Bambusa vulgaris not treated" by *Adzo Dzifa Kokutse* (0,153 mm ; 0,158 mm ; 0,154 mm ; 0,162 mm), much higher that those observed in the literature. The reduction of the diameter leads to a standardization of the surface finish, thus creating a great increase in contact angle, which reduces the hydrophilic character of the fibers.Le diamètre après l'acétylation.

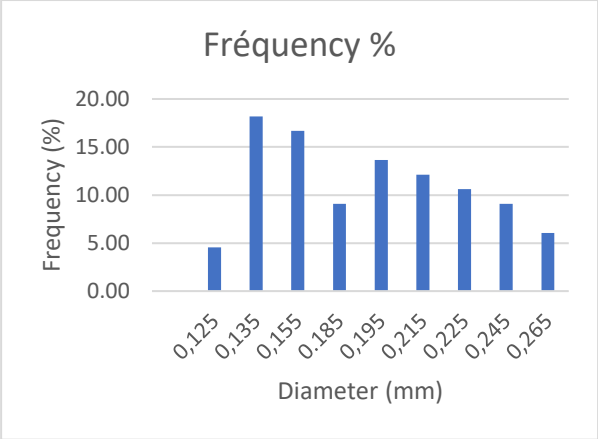


***Figure XIV**: Strip diagram of the bambusa vulgaris fibers obtained treated with acetylation.*

The largest concentration (18.18%) of diameter on 100 acetylation treated fibers is 0.135 millimeters. The fibers were sufficiently smoothed to cover more than 3.57% of those extracted (0.140 millimeters), including the highest concentration of 25.2%. Hence, an increase in contact angle.

III-3- Mechanical characteristics

III-3-1- Density of bambusa vulgaris fibers obtained after acetylation

Four experiments on specimens of "bambusa vulgaris" fibers have done ;

average density is PB = 447 kg/m3.

III-3-3- Water mass gain after acetylation of Bambusa Vulgaris fibers is obtained. The acetylated and weighted fibers of mass m0 (/100) recorded chronologically made it possible to obtain the following table and diagram: With ***Wabs = (mt -m0)/m0 x 100*** (8)

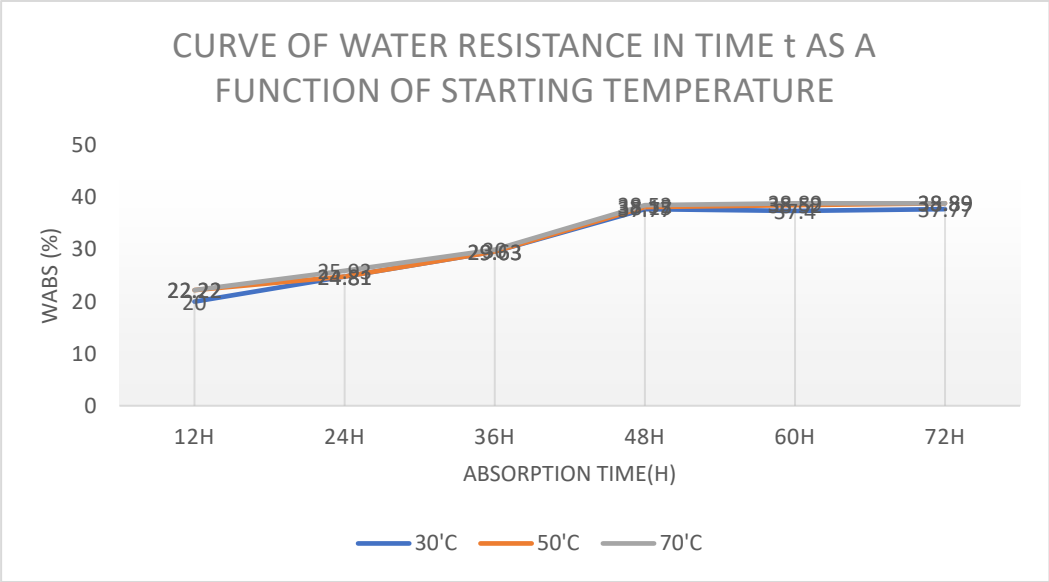


Figure XV *: Diagram of water mass gain of acetylated fibers after 72 hours.*

Water mass gain, which drops to about 20%, has been reduced by more than 45.55% compared to untreated water intake (45% on average in the literature). So decrease in porosity and fragility. It also tends to stabilize after 48 hours (around 37%). It is also noted that the water mass content is influenced by temperature, it believes in the same sense as this one.

III-3-4- Le Module d'Young of bambusa vulgaris fibers obtained

From the Excel 2010 software, the Stress-Strain curves have been plotted and the fracture stress (δrup) was calculated, then young's modulus (E) was deduced into the elastic zone.

Young's modulus is high as much as the diameter of the fibers is small, and the fiber tends to resist breakage when it appears thicker.

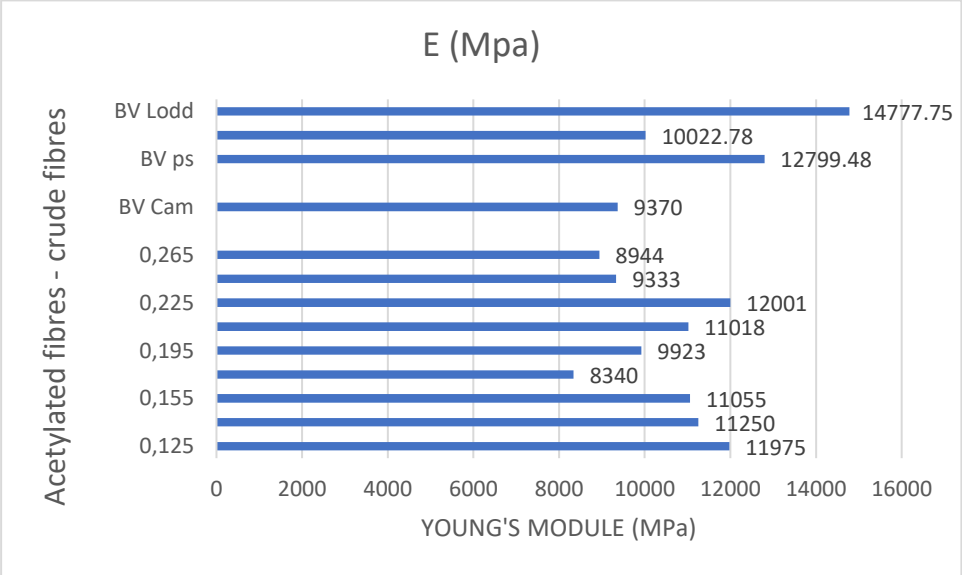


Figure XVI: *Diagram of Module d'Young of acetylated fibers as a function of diameters and crude fibers.*

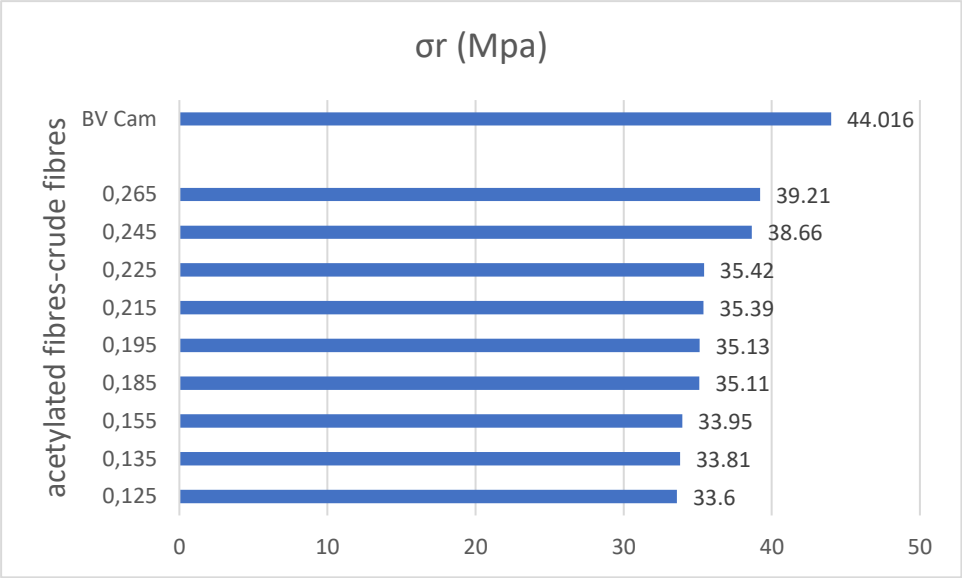


Figure XVII: *Diagram of the fracture stress of acetylated fibres as a function of diameters and crude fibers.*

Acetylation treatment promotes the reduction of the diameter for a less hydrophilic behavior of the fibers compared to those found in the literature; but the elastic resistance is not improved. The stress at break also shows a slight decrease. The value of the diameter increases in the same direction as the fracture stress.

Table 2: Table comparing the characteristics of the treated fibres in relation to the others.

Type de fibers (Localization)	***Species***	***Φ (µm)***	***E(MPa)***	***Content of water (%)***	***Density (Kg/m^3)***	***Linear density (Tex)***
Untreated. (*Togo, Africa*) [30]	Bambusa vulgaris var. striata Lodd. ex Lindl	16,17	10022,78	not defined	725,33	not defined

	Bambusa vulgaris Schrad. ex J.C. Wendl.	15,44	12799,48	not defined	555,46	not defined
	Oxytenanthera abyssinica (A.Rich.) Munro	15,82	not defined	not defined	not defined	not defined
	Bambusa Sp	15,32	14777,75	not defined	750,75	not defined
Untreated. (*Cameroon*) [29]	Bambusa Vulgaris fibers (Slender)	16,17	not defined	31,10	1820	not defined
	VALLEY (oxytenanthera abyssinica)	15,9 - 28	not defined	23,75	937	not defined
	UPHILL (arundinaria alpina)	19,8 - 22,8	not defined	42,30	1110	not defined
Untraited (*Cameroon*) [28]	Bambuseae	not defined	9505	8,91– 10,00 (Dry)	not defined	18.29– 28.54 (Lengh : < 50 mm)
Traited (*Grenoble, France*) [13]	*Đằng Ngà*	5 – 17	3829	not defined	not defined	not defined
	Phú Thọ	5 – 18	2826	not defined	not defined	not defined
	Mỏ Đá	7 – 18	3866	not defined	not defined	not defined

Traited (*Cameroon*)	*experienced bambusa vulgaris fibres* (our study)	13,5	12000	20-38,89 (72 hours) Dynamic at 30°, 50° and 70°C)	447	11,25–21,25 (Lengh : 100mm)

This table shows that the treatment of fibers influences their characteristics on hydrophilicity, for bamboos in general, and bamboo vulgaris in particular. Untreated fibres of Bambuseae appear to have the right characteristics, but the absorption is spontaneous and does not take into account the temperature elevation, which is an element that influences the phenomenon. Bamboo fibers Bambusa vulgaris var. striata Lodd, Schrad, and Bambusa Sp have an appreciable Young's Module ; most of the influential parameters with a hydrophilic character have not been studied on other bamboos. Only the treated Bambusa vulgaris fibers seem to show clearly, through their characteristics, that the hydrophilic character of the fibers has decreased. The diameter and density are decreased, the linear density is increased, and the young's module is respected.

III-4- Implementation of the Composite

- The following curves show the evolution of the fiber content during the manufacture of the composite

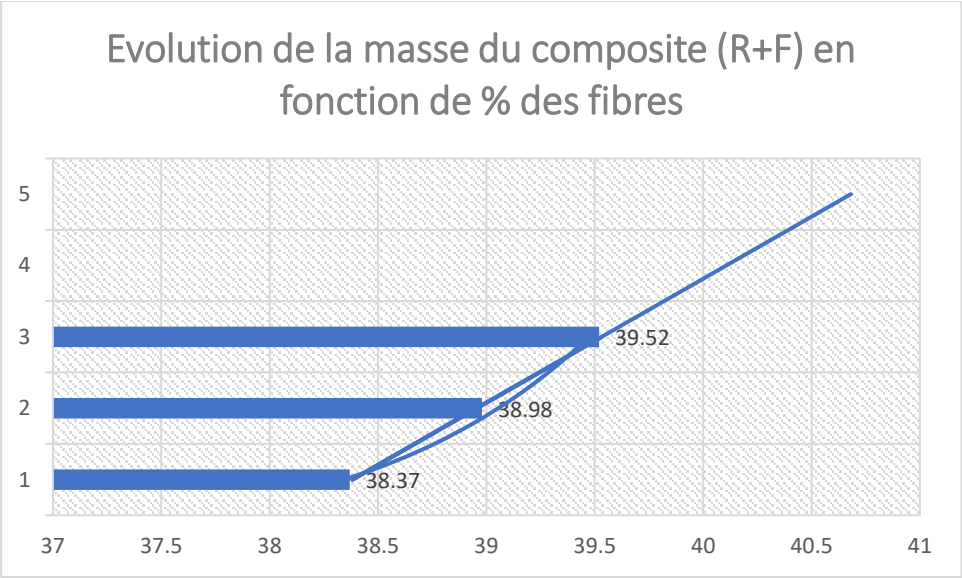


Figure XVIII *: Evolution of the mass of the reinforced composite of untreated fibres (R + F) as a function of the % of fibers*

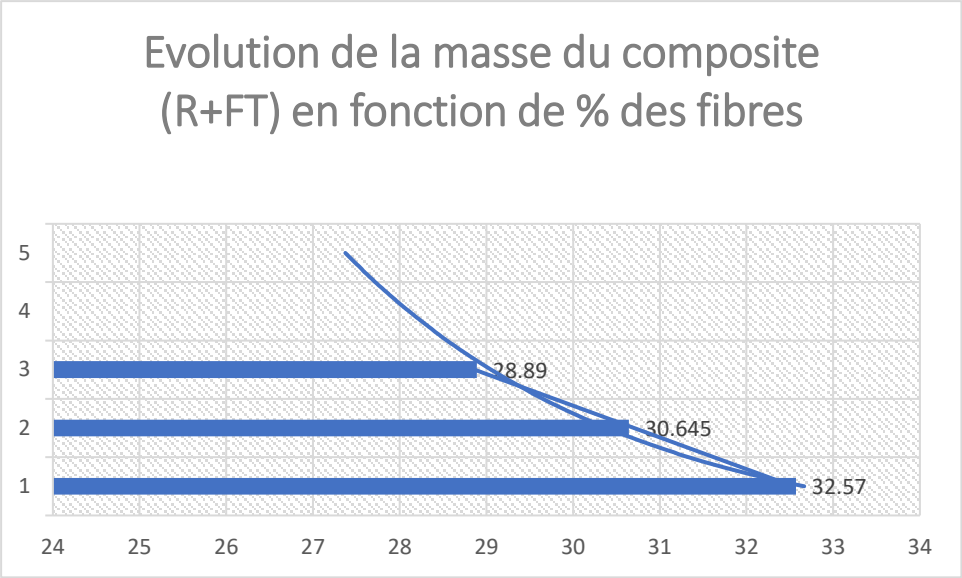


Figure XIX*: Evolution of the mass of the reinforced composite of acetylation-treated fibres (R + FT) as a function of the % of fibers*

- It is observed that The mass of the composite increases with the rate of untreated fibers, while this is not the case in composites reinforced with bamboo fibers treated with acetylation. This is due to the decrease in fiber density during acetylation.
- Implementation protocol for the manufacture of the material epoxy/ bambusa vulgaris fibers

We used the "molding and demoulding" method. We proceeded by impregnating the mattes of fibers to 10, 15 and 20%. The structuring of the composite developed was conditioned by the arrangement of the fibers; Three cases were tested:

- First case: The fibers are long and arranged randomly;

The long fibers are directly mixed in a container with the resin using a spatula. The whole mixure (resin + long fibers + ketone) is already impregnated before being poured into the mold. (see figure, steps 2; 3; 4 and 5).

The following table presents the different stages of implementation of our material with long fibers in random:

Table 3: The different stages of implementation of our material Epoxy / bambusa vulgaris fibers.

N°	STAGES	PICTURES	OBSERVATIONS
1	A release agent (here butter) is embalmed in the iron mold of parallel pipedic shape and on its lid; then the Coat gel is applied with a brush.		Coat gel consists of a layer of epoxy resin. It is the outer skin of the piece, which is the layer serving both as appearance and protection.
2	The fiber mats and the resin-hardener mixture are weighed according to the content of the different components, using an electric balance witch a precision of 0.01 grams.	 	The respective contents of the epoxy and its hardener are, respectively, 2/3 and 1/3 according to the manufacturer's specifications.
3	Then, in a plastic container using a spatula, the mixture is made: fibers + resin + hardener by adding 2% of the acetone to prevent rapid hardening during impregnation.		The mixture is done in the shade, with a temperature of less than 10 ^{0}C.

4 The mixture of fibers + resin + hardener arranged randomly is poured into the prepared molds.



5 Once the mixture is deposited in the mold, we proceed to the display of the whole in the reserved space.





We operate for a few minutes of hardening, allow. the homogenization of the fibers in the composite.

6 The whole is covered and hermetically blocked by the counter-molds, for compaction, using two ear nuts.







The pressure of the lid is determited by the level of clamping.

P = F/S

The normal force F = 25200N, according to the standard of the ISO metric thread technical form (Screw M10 x 1.5); Resistance class

8.8 ;

stress rate = 90%; Coefficient= 0.15)

S= 150 x 45 mm2.

Hence P = 3.36. 106 Pa

7 The whole is allowed to polymerize for 24 hours at ambient temperature of the day; Then the demolding is carried out.





8 We obtain an echatillon of composite of epoxy / bambusa vulgaris fibers



9 Finally, the composite material is machined with a grinding wheel, to give it the desired shape





The composite this is obtained numbered according to its state of treatment and its fiber content

2- Second case : The fibers are short and arranged randomly

The short fibers are cut to the length of 10 millimeters, and directly mixed in a container with the resin using a spatula. The whole mixture (resin + long fibers + ketone) is already impregnated before being poured into the mold (see figure, steps 2'; 3'; 4' and 5').



Figure XX*: The steps 2"; 3" ; 4" and 5" of the implementation of the composite with long fibers at random.*

3- Third case: The fibers are long and stretched

A layer of fiber reinforcement of desired thickness, put in the form of a matte with long cut wires, is stretched and glued into a rectangular frame of the mold to form a unidirectional structure. The resin is mixed with its separate hardener and poured into the mold before and after the deposit of the fibers for impregnation. (see figure, steps 2"; 3"; 4" and 5").



Figure XXI *: The steps 2"; 3" ; 4" and 5" of implementation of the composite with the stretched fibers.*

- Comparison of the different composites obtained.



Figure XXII*: Comparison of the different composites obtained*

By simple observation, we revealed that the first and third cases have some imperfections, especially those related to the density and compactness of the fibers in the composite; The spaces between the fibers are irregular, theses causes a great inhomogenization of the material. However, composites witch

short fibers (first case) have poor mechanical stress, due to the bonds that have beencut on their size. In the rest of our work, we opted for the first case (the fibers are long and arranged in random)

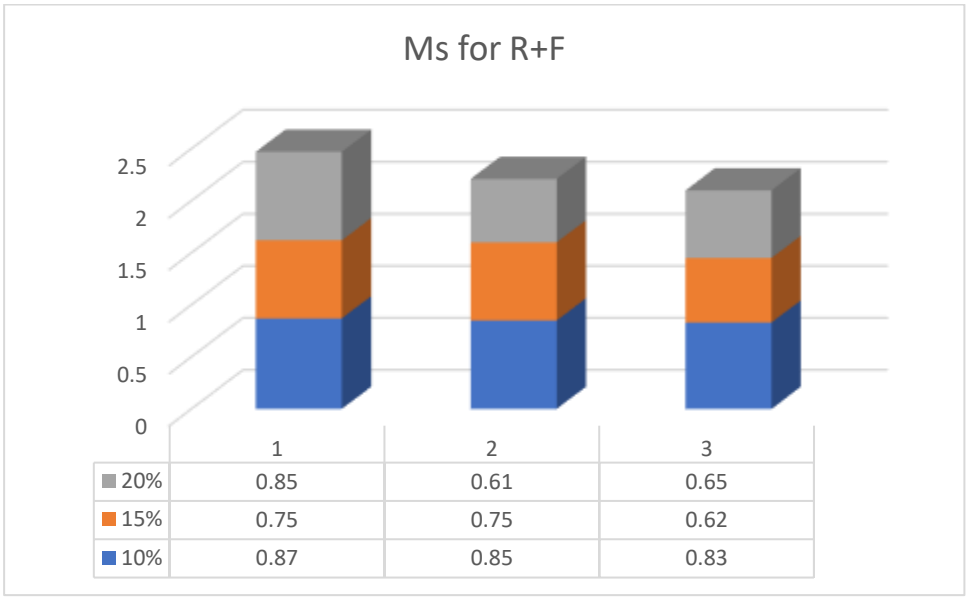
- Proportions of the different components of the material to be developed (with untreated fibres and those treated with acetylation)

A series of three (03) samples of composites created were analyzed in three ranges (10%, 15% and 20%) of fiber content on the two classes of composites obtained, those with untreated fibers (R + F) and those with acetylation treated fibers (R + FT). Hence the illustration of the following tables:



***Figure XXIII**: Composites material created, epoxy matrix reinforced with bamboo fibers treated with acetylation or not.*

The following figures shows the states that characterize the Epoxy/Fiber composite created, subjected to the wetting/drying cycle after three days of quenching and one day of drying.



	1	2	3
20%	0.85	0.61	0.65
15%	0.75	0.75	0.62
10%	0.87	0.85	0.83

***Figure XXIV**: Evolution of Ms in relation to fibre content for (R + F).*

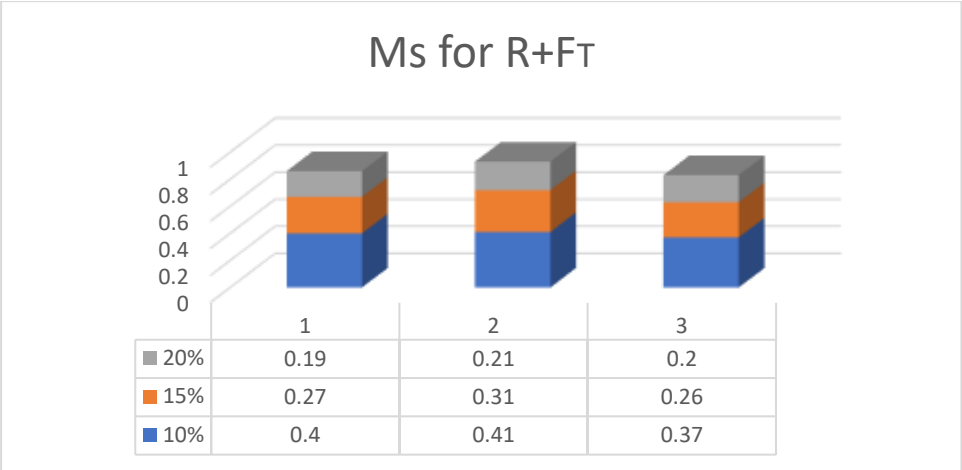


***Figure XXV**: Evolution of Ms in relation to fibers content for (R + FT).*

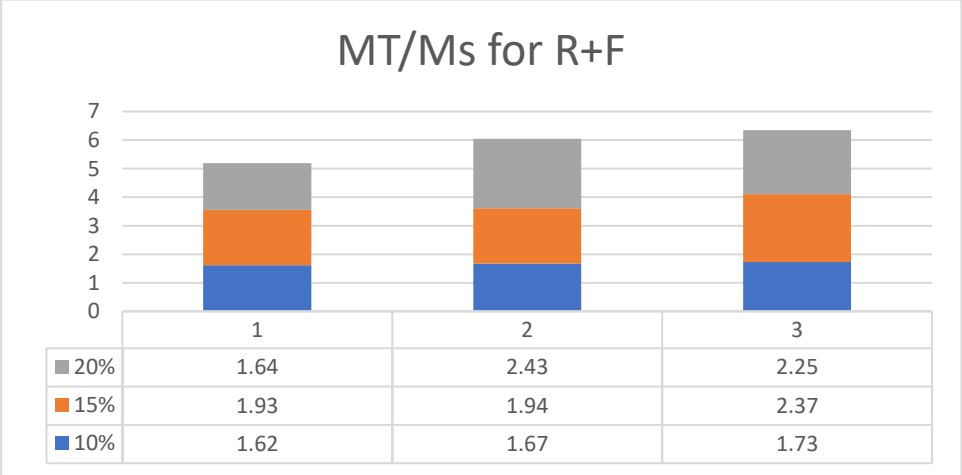


***Figure XXVI**: Evolution of Mt/Ms in relation to fibers content for (R + F).*

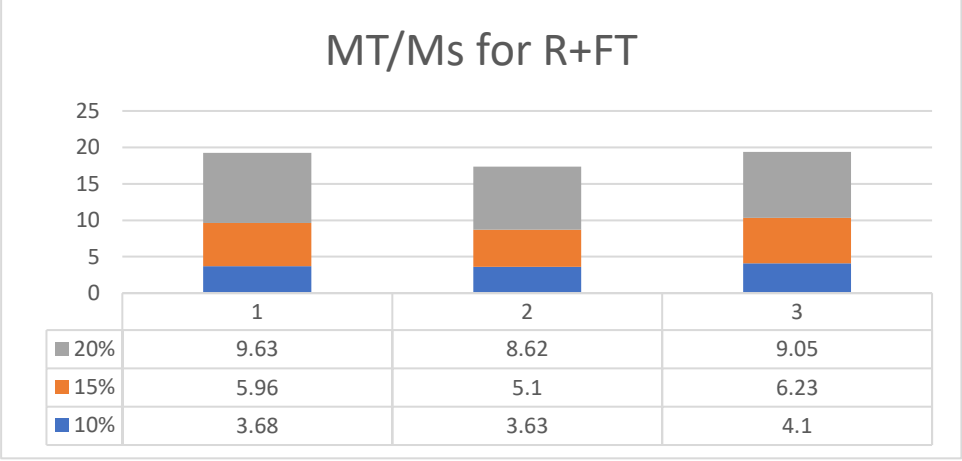


***Figure XXVII**: Evolution of Mt/Ms in relation to fibers content for (R + FT).*

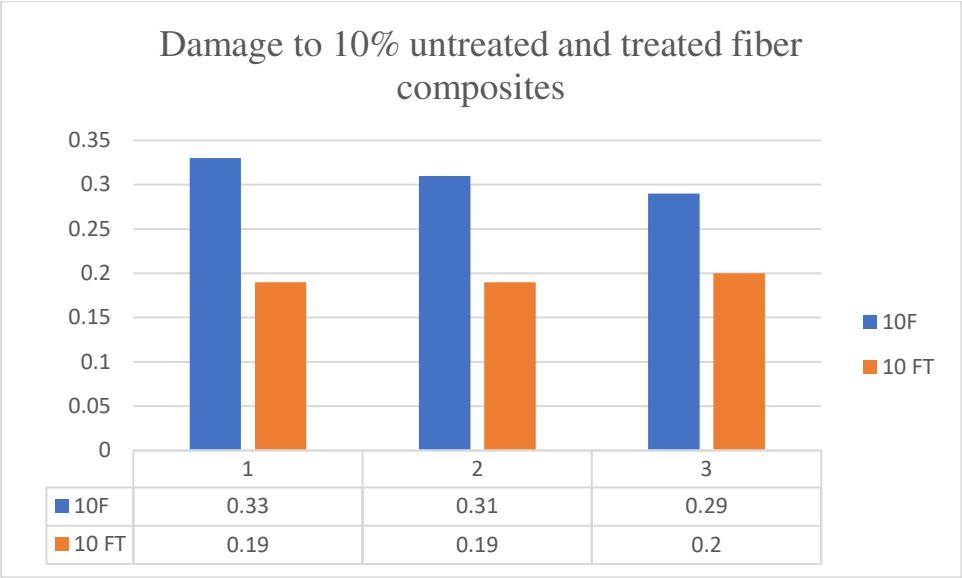


Figure XXVIII: *Comparison of damage between composites of untreated fibers (R + F) and fibers treated with acetylation at the same content of 10%.*

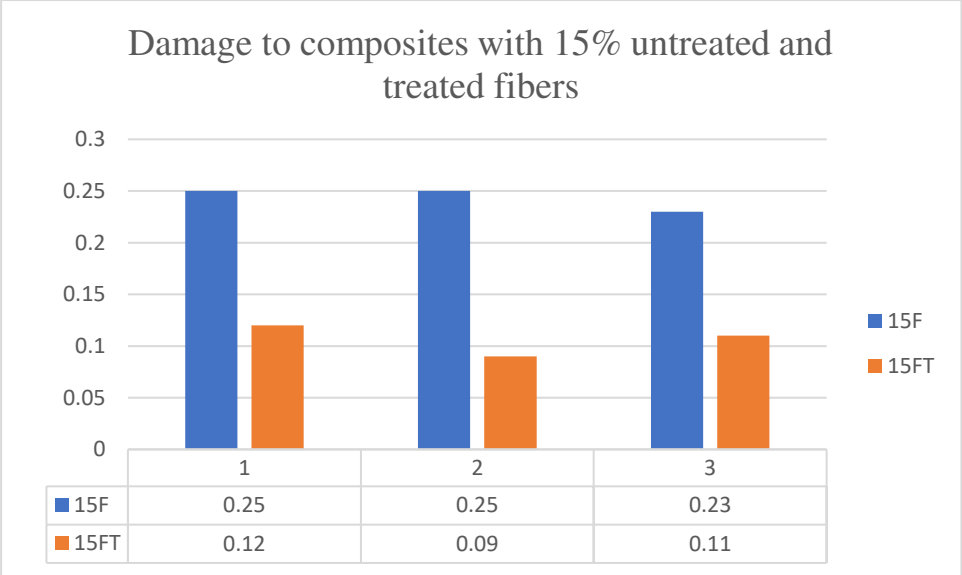


Figure XXIX: *Comparison of damage between composites of untreated fibers (R + F) and fibers treated with acetylation at the same content of 15%.*

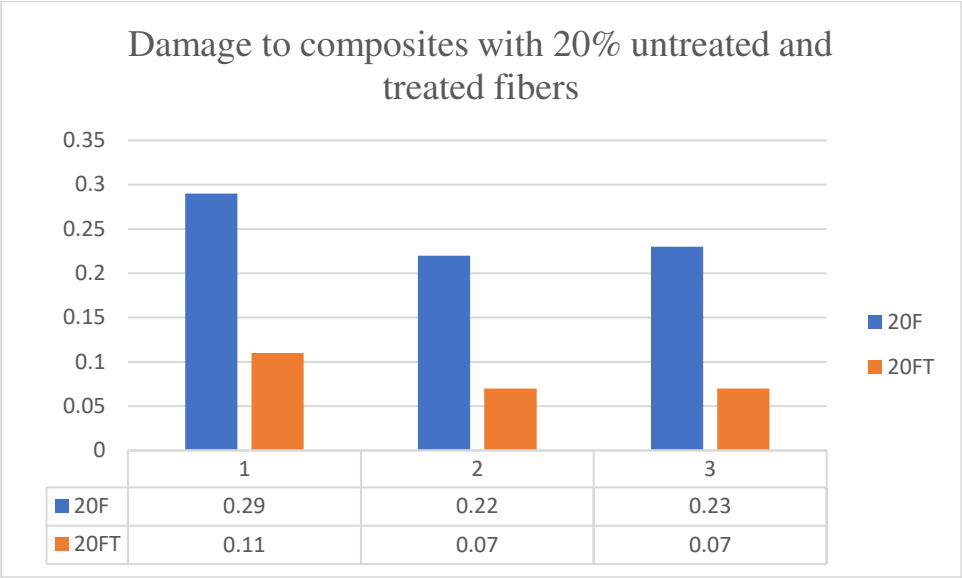


***Figure XXX**: Comparison of damage between composites of untreated fibers (R + F) and fibers* treated with acetylation at the same content of 20%.

The different curves observed above showed that:

- The fiber content in the Epoxy/Bamboo Fiber composite increases with its hydrophilic character while the MS saturation mass decreases in composites in composites for non-acetyled fibers (R+F+AC). This phenomenon is not the same in composites with acetylation-treated fibers (R+FT+AC).
- The increase in the fiber rate automatically leads to a decrease in hydrophilic character in composites with acetylation-treated bamboo fibres (R+FT+AC). The composite is downright hydrophobic froat 15%.
- The damage is much greater in composites reinforced with untreated fibers, than in those reinforced with acetylation treated fibers; It is also lower as much as the fiber content is high.

- **CONCLUSION AND OUTLOOK :**

Bamboo fibers are reputed to be very hydrophilic. Here, the study on hydrophilicity took into account several influential parameters, such as the origin, species, age, and size of the bamboo, their position in the bamboo, their mode of extraction, their treatment, and the conditions of hybrid solicitation to absorption and temperature variation at the same time. It was a question in this article, to characterize bamboo fibers that have undergone pre-treatment (extraction at 3% NaOH) and acetylation treatment,

to check if they can be used in a polymer composite, for facings and house fences. Fibers become less complex and smoother due to a decrease in diameter and density. This allows for better interfacial contact with the polymer matrix. The fibers are less rigid thanks to pre-treatment with a NaOH content of less than 5%. Mechanical characteristics such as Young's modulus and fracture stress are preserved, but still need to be improved. The maximum absorption limit of 38.89% regardless of temperature and duration, and the behavior of the tested composite when subjected to wetting and drying lead us to believe that it can be concluded that the "bambusa vulgaris" fibers treated here, are likely to be used in the development of a polymer matrix composite, to improve performance and longevity at work, in the structures of house siding and fences.

This work highlights the following originalities:

- - The NaOH content of less than 5% during the extraction of Bambusa Vulgaris fibers reduces their hydrophilic character, without increasing their rigidity, contrary to previous studies where the NaOH content is more than 5%;
- The quenching of the fibres at three temperature levels shows that the hybrid mechano-thermal stress increases the hydrophilic character at high temperatures, but has a limit after 72 hours;
- The arrangement of the fibres during the preparation of the composite shows that the mechanical characteristics are better in the case of the fibers long ranged in random.

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• AUTHORS CONTRIBUTIONS

All authors contributed to the design and design of the study. Material preparation, data collection and analysis were carried out by EBANDA Ebanda Dieudonné, NKONGHO Anyi Joseph MBANGUE Nzengwa Ekmon. The first draft of the manuscript was written by EBANDA Ebanda Dieudonné. Supervision was done by NGUIYA Severin and all authors commented on previous versions of the manuscript. All authors have read and approved the final manuscript

• .**DATA AVAILABILITY :** Not applicable