Scientific Research Publishing

Journal of Minerals and Materials Characterization and Engineering, 2020, 8, 341-352
https://www.scirp.org/journal/jmmce
ISSN Online: 2327-4085
ISSN Print: 2327-4077

Elaboration and Characterization of Composite Materials Reinforced by Papaya Trunk Fibers (*Carica papaya*) and Particles of the Hulls of the Kernels of the Winged Fruits (*Canarium schweinfurthii*) with Polyester Matrix

Ze Eric Parfait[1,2,3,4*], Noah Pierre Marcel[2,5], Nnomo Elobi Didine[2], Nfor Clins Wiryikfu[1,4], Betene Ebanda Fabien[2,5], Ngahiyi Abbé Claude Valery[3], Atangana Ateba[2]

[1]Local Materials Promotion Authority, Yaoundé, Cameroon
[2]Department of Mechanical Engineering, Higher Technical Teacher Training College Douala, University of Douala, Douala, Cameroon
[3]Department of Industrial Construction Technology, National Advanced School of Engineering of Douala, University of Douala, Douala, Cameroon
[4]Laboratory of Civil Engineering and Mechanics, Department of Mechanical Engineering, National Advanced School of Engineering Yaoundé, University of Yaoundé I, Yaoundé, Cameroon
[5]Mechanical Laboratory, Higher Technical Teacher Training College Douala, University of Douala, Douala, Cameroon
Email: *ericparfaitze@gmail.com

How to cite this paper: Parfait, Z.E., Marcel, N.P., Didine, N.E., Wiryikfu, N.C., Fabien, B.E., Valery, N.A.C. and Ateba, A. (2020) Elaboration and Characterization of Composite Materials Reinforced by Papaya Trunk Fibers (*Carica papaya*) and Particles of the Hulls of the Kernels of the Winged Fruits (*Canarium schweinfurthii*) with Polyester Matrix. *Journal of Minerals and Materials Characterization and Engineering*, **8**, 341-352.
https://doi.org/10.4236/jmmce.2020.85021

Received: July 9, 2020
Accepted: August 2, 2020
Published: August 5, 2020

Abstract

In this work we determine the physical and mechanical properties of local composites reinforced with papaya trunk fibers (FTP) on one hand and particles of the hulls of the kernels of the garlic (PCNFA) in the other hand. The samples are produced according to BSI 2782 standards; by combining fibers and untreated to polyester matrix following the contact molding method. We notice that the long fibers of papaya trunks improve the tensile/compression characteristics of composites by 45.44% compared to pure polyester; while the short fibers improve the flexural strength of composites by 62.30% compared to pure polyester. Furthermore, adding fibers decreases the density of the final composite material and the rate of water absorption increases with the size of the fibers. As regards composite materials with particle reinforcement from the cores of the winged fruits, the particle size (fine ≤ 800 μm and large ≤ 1.6 mm) has no influence on the Young's modulus and on the rate of water absorption. On the other hand, fine particles improve the flexural strength of composite materials by 53.08% compared to pure polyester; fine particles increase the density by 19% compared to the density of pure polyester.

Keywords

Physical and Mechanical Characterization, Composite, Fibers, Papaya Tree Trunk, Particles, Shells, Kernels, Garlic Fruits

1. Introduction

The need of new materials is a permanent concern in many industrial sectors. Environmental protection being a global concern, the integrating new ecological materials is a necessity. Currently synthetic fibers are largely dominant in the industrial sector. However, their use raises many problems due to the emission of harmful compounds and a high production energy [1]. Papaya and aiele are widespread crops in sub-Saharan Africa country because of their fruit [2] [3] [4]. As the current recycling of synthetic fiber composites has offered no ecological solution, the use of natural reinforced composites seems/proves to be an alternative for environmental protection [5]. As a result, natural components are a growing contribution to the development of composite materials. The choice of fibers in the composite depends on their sensitivities and their mechanical, thermal and physical properties. Among the fibers used, mention may be made of: Pineapple, abaca, sisal agave, alfa, hemp, kenaf, agave sisal fibers and fibers of textile palm [6] [7] [8] [9]. The study on the unsaturated polyester/doum palm fiber composite shows that the nature, morphology, arrangement and type of the fibers play a major role in the absorption phenomena of the composite. The behavior of the composite with a fiber content exceeding 10% goes from a linear behavior with fragile rupture to an almost linear behavior with a progressive rupture of the fibers which limits the progression of cracks within the composite [7] [8]. In composite materials with particle reinforcement in general, the interface has good properties [6]. The present work aims to valorize the waste of local agriculture through the exploitation of fibers (papaya trunks) and stones (the winged fruits).

2. Materials and Methods

2.1. Elaboration of the Composite Material

2.1.1. Process for Obtaining Short and Long Fibers from Papaya

The fibers of the papaya tree trunks are obtained in a long process as shown in **Figure 1**.

We used the male papaya trees after the second flowering. The papaya tree trunks were cut into 40 cm long pieces, then cut longitudinally. The elements thus acquired were soaked in water without additive for a period of one month as shown in **Figure 2**. The extraction of our papaya trunk fibers is done by retting as shown in **Figures 2(c)** and **Figure 3** [10].

The folds thus obtained were immersed in hot water (70˚C) mixed with a molar concentration sodium hydroxide for two days then we extract the fibers. **Figure 3** shows the process for obtaining papaya fibers.

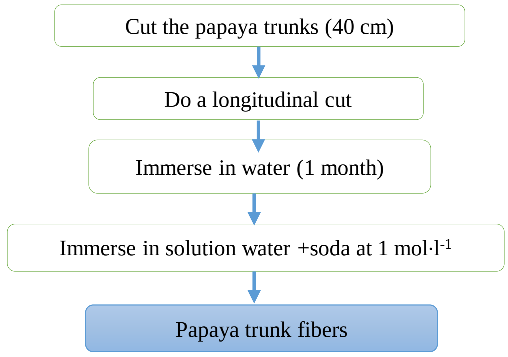

Figure 1. Process for obtaining fibers from papaya tree trunks [Author].

(a) (b) (c)

Figure 2. (a) Trunk of papaya tree cut; (b) Trunk of papaya cut longitude; (c) Soaked papaya trunk [author].

(a) (b) (c) (d)

Figure 3. (a) Honeycomb structure of the papaya tree; (b) Papaya fibers after extraction; (c) Long papaya fibers; (d) Short papaya fibers [author].

2.1.2. Process for Obtaining Particles from the Seeds of the Garlic

The cores obtained are illustrated by Figure 4.

The kernels of the pili fruit are crushed in order to extract the fines. The empty cores are grounded and sieved with 800 μm and 1.60 mm sieves (Figure 5) to obtain the corresponding particles (Figure 6) [10] [11].

The particle sizes obtained are as follows ≤ 800 μm (fine particles) and ≤1.60 mm (large particles) as shown in Figure 6.

2.1.3. Implementation of Samples

The samples with reinforced rate of 30% are used because it the composite exhibits poor characteristics [12]. Table 1 gives the dimensions and the proportions of the elements used the polyester resin is mixed with 1% hardener [11].

2.1.4. Preparation of Test Pieces/Samples

The test pieces shaped according to standard BSI 2782 are parallelepipedic block of 150 × 10 × 10 (mm). The main steps in shaping our test pieces are given in Figure 7.

The samples obtained and classified by type of reinforcement are shown in Figure 8.

3. Results and Discussion

3.1. Physical Characterization

3.1.1. The Density

To determine the density of our composite material, we calculate the apparent density for each of the samples using Equation (1).

$$\rho_a = \frac{P_r}{v_r} \tag{1}$$

with: ρ_a: apparent density; P_r: mass of reinforcement; v_r: the reinforcement volume.

For each formulation, the experimental density of the composite is obtained by averaging Equation (2) for each test piece [13].

$$\rho_{\exp} = \frac{P_e}{\Delta v - \frac{m_p}{\rho_p}} \tag{2}$$

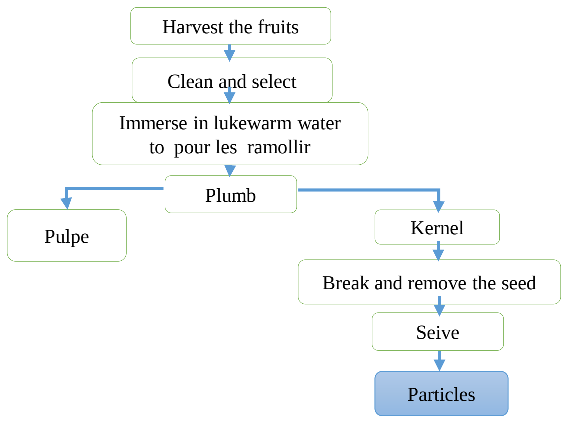

Figure 4. Process for obtaining particles from the kernels of garlic [Authors].

(a) (b) (c)

Figure 5. (a) Standardized sieve; (b) vibrating machine; (c) Screening [Authors].

(a) (b)

Figure 6. (a) Fine particles (≤800 μm); (b) Large particles (≤1.60 mm) [Authors].

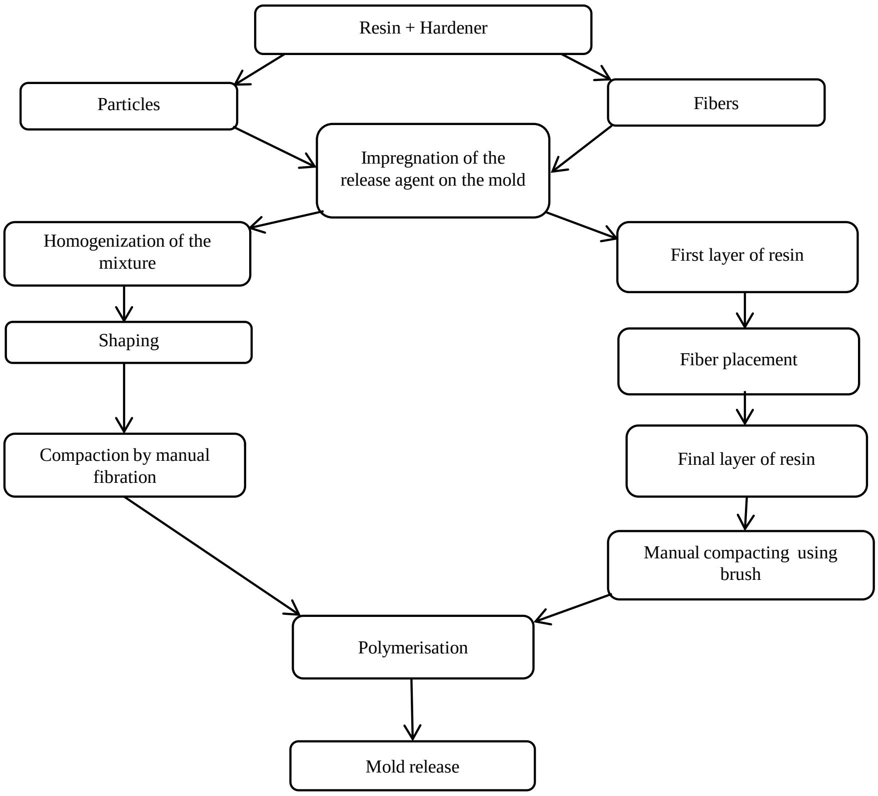

Figure 7. Sample molding steps [Authors].

Figure 8. (a) Pure polyester; (b) Long fibers; (c) Short fibers; (d) Large particles; (e) Fine particles [Authors].

Table 1. Dimensions and proportions of the elements.

Fiber-reinforced composites		Composites with particle reinforcement	
Long fibers	150 mm	Fine particles	≤800 µm
Short fibers	≤5 mm	Large particles	≤1.60 mm
Reinforcement rate		30%	

with: $\rho_{\exp}$: experimental density; P_e: mass of test piece; m_p: paraffin mass; ρ_p: paraffin density; Δv variation of water volume.

Finally, the analytical density of the composite material ρ_{an} (in Kg/m^3) of each sample for each formulation was determined using Equation (3)

$$\rho_{an} = \rho_r V_r + \rho_m V_m \tag{3}$$

The densities of the reinforcements are $\rho_r = 1125$ Kg/m³, the density of the matrix is $\rho_m = 1140$ Kg/m³; V_r : volume fraction of reinforcements; V_m : volume fraction of matrix; ρ_m : analytical density (Table 2, Figures 9-11).

Table 2. Densities.

Reinforcement type	ρ_a Kg/m³	ρ_{exp} Kg/m³	ρ_{an} Kg/m³
Pure polyester	1140	1140	1140
Short fibers	1038	1037	1135.5
Long fibers	1086	1058	
Particles ≤ 800 µm	1186	1408	1183.5
Particles ≥ 1.6 mm	1295	1284	

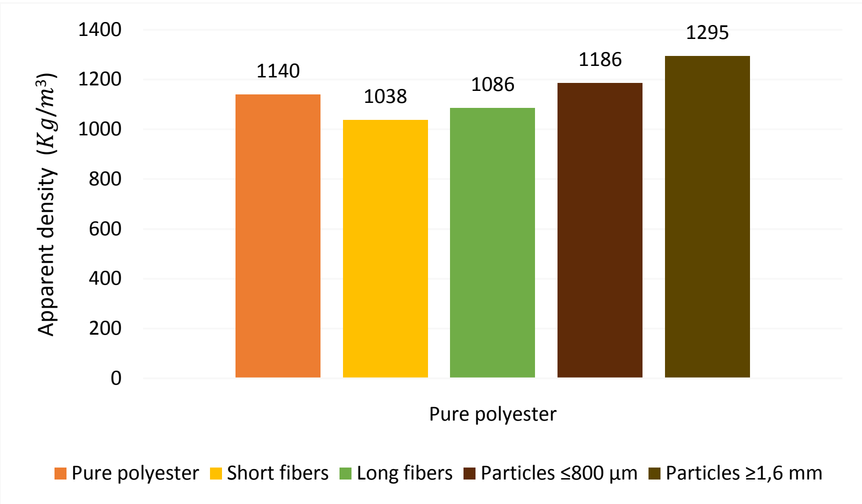

Figure 9. Apparent density as a function of reinforcement type.

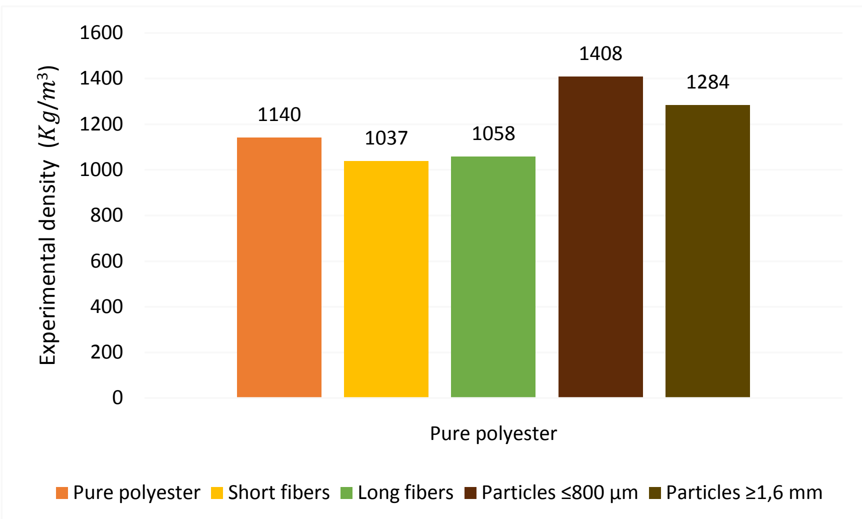

Figure 10. Experimental density as a function of reinforcement type.

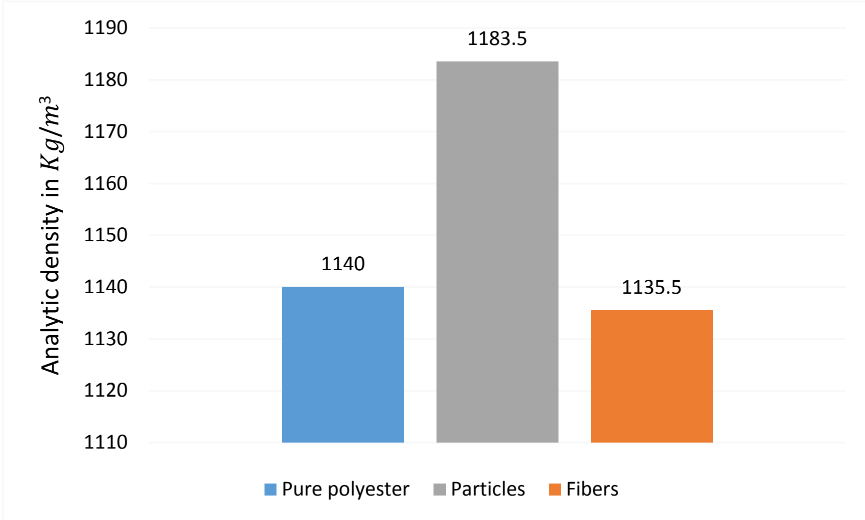

Figure 11. Analytic density as a function of reinforcement type.

From these histograms, it appears that the density of the papaya fiber-reinforced composites is comprised/varies between [1047.5; 1062 Kg/m^3] the addition of papaya trunk fiber to the polyester reduces the density of the latter and for composites with particle reinforcement of the kernels of fruit of the wing is between [1240.5; 1346 Kg/m^3] the addition of black fruit kernel particles in the polyester increases the density value of the latter. In addition, the length of the fibers (long or short) and the particle size of the kernels of fruit of the pili have a negligible influence of the order of on the density (of the order of 0.02% to 0.05% for the composites with reinforcement of fibers of trunk of papaya and of the order of 0.08% to 0.09%).

3.1.2. The Rate of Water Absorption

The amounts of water absorbed by our composite materials reinforced with papaya trunk fibers and particles of the seeds of the garlic shown by **Figure 12** are determined by Equation (4).

$$\%H = \frac{M_o - M_f}{M_o} \times 100 \quad (4)$$

The water absorption curves of the various composites reinforced with papaya trunk fibers (long and short) and particles of the seeds of the winged fruit (large and fine) are similar to room temperature, the one given by Fick's law of diffusion in a binary medium [14]. The following observations are made:

- For composites with particle reinforcement of the kernels of garlic, the particle size does not influence the rate of water infiltration.
- In the case of composites with a reinforcement of trunk fibers from papaya trees, the longer the fibers, the less water the material takes up.
- Composites with short fiber reinforcement take more water than composites with particles of garlic kernels which absorb more than those with long fiber reinforcement.

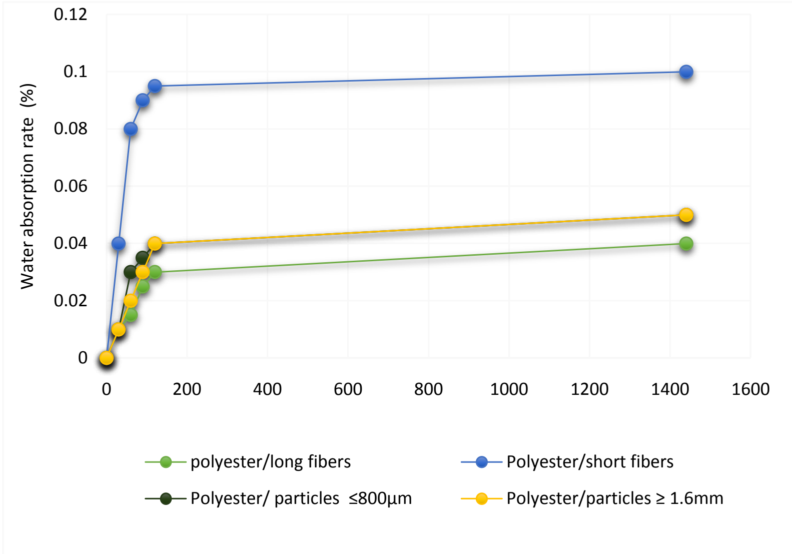

Figure 12. Water absorption rate according to the type of reinforcement.

3.2. Mechanical Characterization

The mechanical properties are obtained from the three-point compression and bending tests of different composite samples.

3.2.1. Compression Test

The samples for each formulation are submitted to compression test carried out with a PERRIER 14570 200 KN. Equation (5) is used to determine the Young Modulus/the elasticity modulus [7] [11] [15] [16].

$$E = \frac{FL_0}{S_0 \Delta L} \tag{5}$$

The comparative study of the average values of the Young's moduli obtained during the compression test helped us to plot the histogram of **Figure 13**.

From **Figure 13** we see that:

- The Young's modulus of long fiber reinforced composites is greater than that of short fibers.
- The length of the fibers influences the mechanical behavior of the composites, composites with long fiber reinforcements have better behavior in the elastic range compared to those with short fiber reinforcement.
- The Young's modulus of fine particle reinforcement composites is greater than that of medium black fruit core particles. The mechanical characteristics of composites with reinforcement of black fruit kernel particles fluctuate with the particle size distribution (of the interstices in the material).
- Reducing the particle size of the particles improves their behavior in the elastic range.

3.2.2. Bending Test

The three points bending test is carried out using a CBR press (CONTROLS T1004) and Equation (6) and Equation (7) enable us to determine the modulus

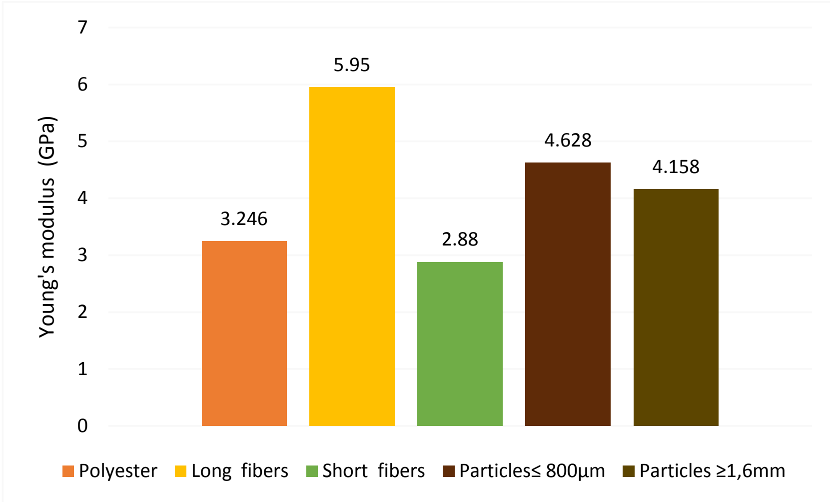

Figure 13. Young's modulus according to the type of reinforcement.

of elasticity in bending (MEF) and modulus of resistance to bending (MRF) respectively [8] [11] [17] [18].

$$\text{MEF} = \frac{\alpha L^3}{4be^3} \quad (\text{MPa}) \tag{6}$$

$$\text{MRF} = \frac{3LF_{Rup}}{2be^2} \quad (\text{MPa}) \tag{7}$$

with: L: distance between supports; b: width of the test piece; e: thickness of the test piece; α: slope of the straight line determined by the plot of the force-deformation curve in the elastic domain; F_{Rup} : force measured at break.

The results are presented in **Table 3**.

The comparative study of flexural elasticity modules (FEM) and flexural resistance modules (FRM) of fiber and particle reinforced composites is given in **Figure 14** and **Figure 15** respectively [11] [19] [20].

These histograms reveal that:

- The elastic modulus of flexion does not vary with the size or the type of reinforcement because the difference between the different values of modules is minimal;
- The multidirectional nature of composites with short fiber reinforcement gives it a modulus of flexural strength significantly higher than the composites one with long fiber reinforcement (report 1.27);
- The resistance modulus of composites with fine particle reinforcement (≤800 µm) is 2.27 times higher than the composites with medium particle reinforcement (≥1.6 mm). This difference may be caused by the particle size and the presence of a gap in large-particle composites which is not completely homogenized with the resin.

4. Conclusions

The aim of this paper was to determine some physical and mechanical properties of composites reinforced with papaya fiber. These fibers are made of short, long and shell of kernels of winged fruits.

The tests carried out show that:

- The long fibers improve the characteristics in traction/compression of the composites while short fibers improve the flexural strength of composites.

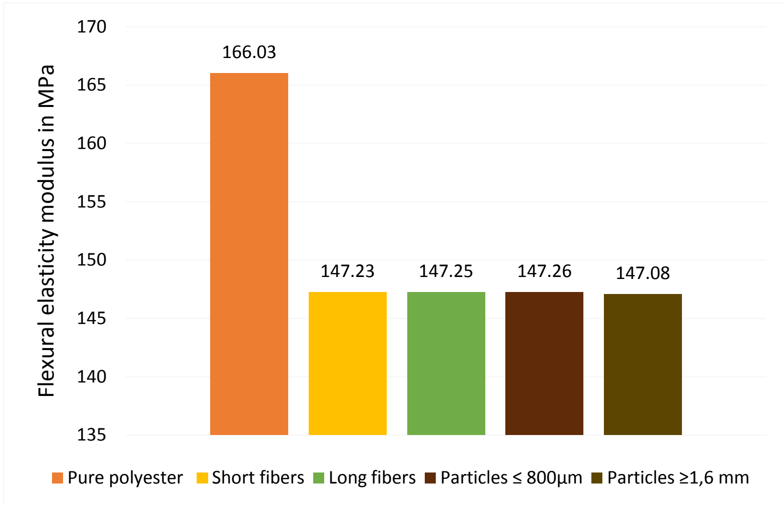

Figure 14. Flexural modulus according to the type of reinforcement.

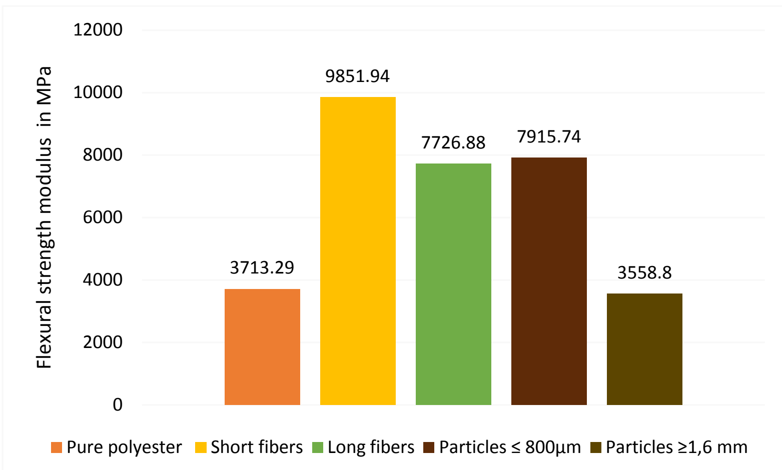

Figure 15. Flexural strength module depending on the type of reinforcement.

Table 3. Values of MEF and MRF according to the type of reinforcement.

Reinforcement type	FEM (MPa)	FRM (MPa)
Polyester	166.03	3713.29
Short fibers	147.23	9851.94
Long fibers	147.25	7726.88
Particles ≤ 800 μm	147.26	7915.74
Particles ≥ 1.6 mm	147.08	3558.8

- The addition of fibers decreases the density of the final composite material and the rate of water absorption increases with the length of the fibers.
- The particle size (fine particles ≤ 800 µm and large particles ≥ 1.6 mm) of composite materials reinforced with the cores of winged fruits has no influence on the Young's Modulus and therefore no effect on the mechanical behaviour (regarding tension and compression)
- The size (fineness) of the particles of the kernels of the fruit of the wing improves the bending resistance of the composite materials and increases have a density of 19% relative to the density of the polyester.
- The rate of water absorption is not influenced by the size of the particles.

Acknowledgements

- The laboratory of Civil Engineering of the NASEY.
- The Local Materials Promotion Authority (MIPROMALO).

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Gornet, L. (2008) Generalities on Composites Materials, Engineering School.

[2] Agbo Nzi, G., Chatigre kouamé, O. and Simard, R.E. (1992) *Canarium schweinfurthii* Engl.: Chemical Composite of Fruit Pulp. *JAOCS*, **69**, 317-320. https://doi.org/10.1007/BF02636058

[3] Agbo Nzi, G. and Chatigrekouamé, O. (1996) Amélioration de l'extraction de la matière grasse du fruit de *Canarium schweinfurthii* Engl. Par ajout d'enzymes. Sciences des aliments.

[4] TFTC (Tropical Forest Technical Center), Mémento of the Forester (1998) Africa Technical. 3th Edition, French Ministry of Cooperation, France, 565 p.

[5] Kempe, A., Göhre, A., Lautenschläger, T., Rudolf, A., Eder, M. and Neinhuis, C. (2015) Evaluation of Bast Fibres of the Stem of *Carica papaya* L. for Application as Reinforcing Material in Green Composites. *Annual Research & Review in Biology*, **6**, 245-252.

[6] Seyni, A., Le Bolay, N. and Molina-Boisseau, S. (2009) Advantage of Using Vegetable Fillers in Composites Co-Ground Materials, Chemical Engineering Laboratory—UMR CNRS, France, 176-184.

[7] Yyuhazri, M., Phongsakorn, Y., Haeryip Sihombing, P.T., Jeefferie, A.R., Puvanasvraran Perulmal, A.M. and Rassiah, K. (2011) Mechanical Properties of Kenaf/Polyester Composites. *International Journal of Engineering and Technology*, **11**, 127-131.

[8] Sathishkumar, T.P., Navaneethakrishnan, P., Shankar, S., Rajasekar, R. and Rajini, N. (2013) Characterization of Natural Fiber and Composites—A Review. *Journal of Reinforced Plastics and Composites*, **32**, 1457-1476. https://doi.org/10.1177/0731684413495322

[9] Mohammed, L., Ansari, M.N.M., Pua, G., Jawaid, M. and Islam, M.S. (2015) A Review on Natural Fiber Reinforced Polymer Composite and Its Applications. *International Journal of Polymer Science*, **2015**, Article ID: 243947.

https://doi.org/10.1155/2015/243947

[10] Ntenga, R. (2007) Multi-Scale Modeling and Characterization of the Elastic Anisotropy of Plant Fibers for Reinforcement of Composites Materials. Université Blaise-Pascal—Clermont-Ferrand II, University of Yaoundé, Yaoundé.

[11] Otiti, S.B. and Ngok, O.-J. (2017) Crépin Constant, Implementation and Behavioral Studies of a Polyester Matrix Composite Reinforced by Kernels Fruit: Application to the Manufacture of Soles. Higher Technical Teacher Training College Douala, University of Douala, Douala.

[12] Yeow, T.K. and Lik, W.T. (2015) Epoxy EFB Palm Fibre Mat Composites—The Effects of Fibre Weight Fraction on Mechanical Behavior. *ARPN Journal of Engineering and Applied Sciences*, **10**, 6578.

[13] Mohanty, A.K., Misra, M. and Hinrichsen, G. (2000) Biofibres, Biodegradable Polymers and Biocomposites: An Overview. *Macromolecular Materials and Engineering*, **276**-**277**, 1-24.
https://doi.org/10.1002/(SICI)1439-2054(20000301)276:1<1::AID-MAME1>3.0.CO;2-W

[14] Yang, H.-S., Kim, H.-J., Park, H.-J., Lee, B.-J. and Hwang, T.-S. (2006) Water Absorption Behavior and Mechanical Properties of Lignocellulosic Filler-Polyolefin Bio-Composites. *Composite Structures*, **72**, 429-437.
https://doi.org/10.1016/j.compstruct.2005.01.013

[15] Saaidia, A., Bezazi, A., Belbeh, A., Bouchelaghem, H., Zanache, N. and Scarpa, F. (2001) Characterization of Bio-Composites Jute/Polyester by Using the Statistical Method of Weibull and Analysis of Variance. *ANOVA*, 22*nd French Congress of Mechanics*, Lyon, 24-28 August 2015.

[16] Jain, S., Jindal, U.C. and Kumar, R. (1993) Development and Fracture Mechanism of the Bamboo/Polyester Resin Composite. *Journal of Materials Science Letters*, **12**, 558-560.

[17] Ahmed, M., *et al.* (2016) A Study of Factors Affecting the Flexural Tensile Strength of Concrete. *Journal of King Saud University Engineering Sciences*, **28**, 147-156.
https://doi.org/10.1016/j.jksues.2014.04.001

[18] Lomelí-Ramírez, M.G., *et al.* (2014) Bio-Composites of Cassava Starch-Green Coconut Fiber: Part II—Structure and Properties. *Carbohydrate Polymers*, **102**, 576-583.
https://doi.org/10.1016/j.carbpol.2013.11.020

[19] Rokbia, M., Osmani, H., Imad, A. and Benseddiq, N. (2011) Effect of Chemical Treatment on Flexure Properties of Natural Fiber-Reinforced Polyester Composite. *Procedia Engineering*, **10**, 2092-2097. https://doi.org/10.1016/j.proeng.2011.04.346

[20] Peças, P., Carvalho, H., Salman, H. and Leite, M. (2018) Natural Fibre Composites and Their Applications: A Review. *Journal of Composites Science*, **2**, 66.
https://doi.org/10.3390/jcs2040066