International Information and Engineering Technology Association
Advancing the World of Information and Engineering

Revue des Composites et des Matériaux Avancés-Journal of Composite and Advanced Materials
Vol. 32, No. 1, February, 2022, pp. 45-52
Journal homepage: http://iieta.org/journals/rcma

Physical, Thermal and Mechanical Characterization of a New Material Composite Based on Fibrous Wood Particles of Date Palm Tree

Tarek Djoudi[1*], Hocine Djemai[2], Mabrouk Hecini[1], Ahmida Ferhat[3]

[1] Laboratory of Mechanical Engineering (LGM), University Mohamed Khider Biskra, Post box. 145 R.P., Biskra 07000, Algeria
[2] Laboratory of Energy Engineering and Materials (LGEM), University Mohamed Khider Biskra, Post box. 145 R.P., Biskra 07000, Algeria
[3] Research Laboratory of Civil Engineering (RLCE), University Amar Telidji of Laghouat, Post box. G37(M'kam), Laghouat 03000, Algeria

Corresponding Author Email: tarek.djoudi@univ-biskra.dz

https://doi.org/10.18280/rcma.320107

Received: 4 January 2022
Accepted: 20 February 2022

Keywords:
date palm tree, petiole, wood particle composite, mechanical characterization, thermal properties, physical properties

ABSTRACT

The objective of this work is to valorize the waste from date palms tree which is often abandoned in the palm groves The aim is to produce a new composite based on this waste that can be used as an alternative material to the conventional insulators. The approach consists in making a composite material from petiole wood (WPC) in different particle sizes (0 to 1, 1 to 3 and 3 to 5) mm. We then characterized the physical, thermal and mechanical properties of this new material (WPC). The results obtained proved the relative anisotropy of the material and the effect of the particle size distribution on these properties. The composites (WPC) had low density in the range (0.16-0.56) g/cm^3 and also exhibited low thermal conductivity, in the range (0.109-0.122)W/mK°. These weak properties make it possible to use (WPC) as an effective insulator. These characteristics were quite acceptable in comparison with other thermal insulation materials such as cork agglomerate and traditional wood. The interesting mechanical properties of the new composite (WPC) have been shown by the tensile tests and the three-point flexural tests. These results make it possible to valorize these materials (WPC) for possible industrial applications.

1. INTRODUCTION

The availability and price of raw materials are essential to the success of any industrial project, therefore, many researchers are trying to find alternative materials at low cost through the use of natural waste or through recycling.

Date palms tree produce huge amounts of dry palms each year as waste products during their natural growth and during periodic maintenance. This quantity of waste can reach 82 thousand tons per year only in the region of Biskra (Algeria) [1]. Figure 1 shows the main constituents of the date palm tree and the natural evolution of a palm. Recycling and exploiting this waste instead of burning it would help convert this plant waste into real wealth that can be used efficiently while respecting the environment. Indeed, several studies have shown that the association of this waste from date palm tree with construction materials [2-7] and polymers [8-13] gives composite materials with good physical, mechanical and thermal properties. These results also indicate that the mechanical properties of the composite material based on this date palm waste have increased compared to those of the virgin matrix by nearly 50%. In addition, the density and thermal conductivity of the composite decreases as the ratio of these wastes increases. This is due to the good physical, mechanical and thermal properties of this vegetable waste [8, 10, 14]. In addition, other studies carried out have shown that date palm wood has very evident physical, thermal and mechanical properties compared to traditional wood and other vegetal materials [4, 15-17]. The results also showed that wood from date palm petiole exhibits a better thermal insulation ratio compared to other parts of date palm wood, because of its low average density between 0.14 and 0.23 g/cm^3 and its low average thermal conductivity is between 0.058 and 0.098 W/m.K° [18-20]. It was also found that petiole wood particleboard has good interparticle adhesion due to its high lignin content. This was demonstrated in the evaluation study of composite particleboard based on the date palm byproducts produce by thermopressing without any pretreatment. This also showed the effect of molding temperature on the mechanical properties of these particuleboards [21].

In this context, we confirmed the results obtained by studying the physical, thermal and mechanical properties of raw wood in the transverse and longitudinal direction of the fibers. Through these scientific results, it was necessary to take advantage of these distinctive properties of petiole wood and to exploit these materials in the manufacture of insulation boards as alternative materials to cork boards and others (MDF, HDF, etc.). Thus, the purpose of this research work is the implementation and the mechanical, physical and thermal characterization of new composite panels based on the petiole wood particles with a natural matrix produced by the thermopressing molding process which makes it possible to ensure good particle adhesion. This characterization will make it possible to highlight the effect of the particle sizes of the wood used on the thermal, physical and mechanical properties of the material. This identification will make it possible to apply this new material for possible industrial exploitation and thus to recover date palm tree waste.

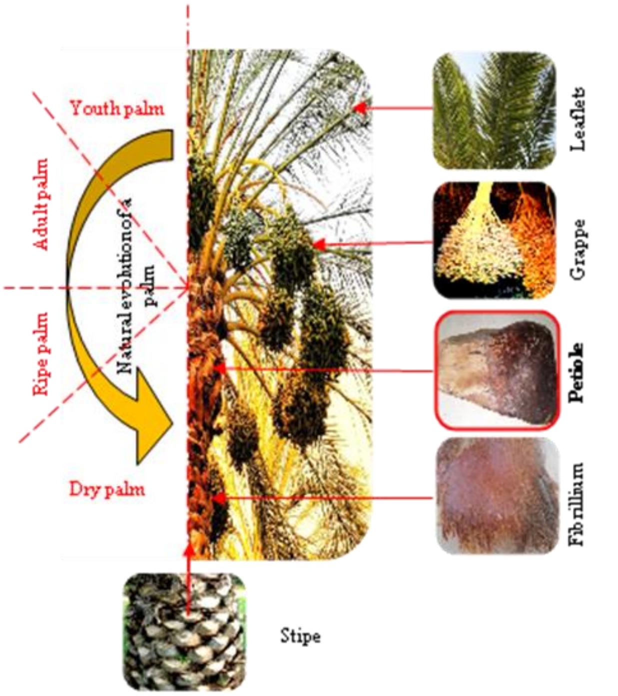


Figure 1. Main constituents of the date palm tree and the natural evolution of a palm

2. MATERIALS

2.1 Fibrous wood

In this work, we used raw fibrous wood from petioles of the same date palm tree. Wood particles were prepared from the wood waste of these petioles by manual cutting for sizes between 1 and 5 mm. The size of less than 1mm is obtained by sieving the crushed wood chips using a blade mill. The size of less than 1 mm is obtained by sieving the crushed wood chips using a blade grinder.

2.2 Matrix

The matrix used is of natural origin based on date palm tree lignin obtained by mixing wood glue (vinyl glue) with wood lignin powder from the petiole. The soft fixing paste (natural matrix) was obtained with a ratio of 1/5 between the lignin of petiole and the vinyl glue.

2.3 Composite material

The petiole wood particle composite plates with a natural matrix were obtained from different particle sizes (0 to 1, 1 to 3 and 3 to 5mm) which are referenced according to these maximum sizes (WPC1, WPC3 and WPC5). The molding of the plates with a mass ratio (wood-particle / natural matrix) of 4/5 was carried out by the use of a disassemblable metal mold subjected to a pressure of 10 bars for 45 minutes at a temperature of 110°C. This thermopressing molding process which ensures good adhesion between the particles and the natural matrix. The composite plates of particles obtained are dried after demolding at a temperature of 70°C. After 72 hours, the specimens are then cut in accordance with the standards for each test.

Figure 2 shows the main preparation steps for composite materials (WPC).

3. SPECIMENS AND TEST METHODS

3.1 Specimens

The test samples were obtained by cutting fibrous wood from the raw petiole (Raw wood), and the plates of different sizes of wood particles (WPC1, WPC2 and WPC5) according to the standards using a wood cutting table. The dimensions of the specimens test are given in Table 1.

3.2 Physical test

3.2.1 Density and water absorption

The density is measured on several samples taken of raw wood and composites according to standard NF B51-005 (AFNOR, 1985a). Specimens at 12% humidity are weighed with an electronic balance (Kern V3.1) with an accuracy of 0.0001g in a chamber conditioned at 20°C and 65% humidity. The volume of specimens is determined on the basis of hydrostatic weighing by soaking in a container filled with propanol. The density (ρ) at 12% humidity, expressed in (kg/m³), is then calculated according to the following formula:

$$\rho_{12\%} = \frac{m_{12\%}}{V_{12\%}} \quad (1)$$

where: $\rho_{12\%}$ is the density at 12% moisture, $m_{12\%}$: the mass at 12% moisture, $V_{12\%}$: the volume at 12% humidity.

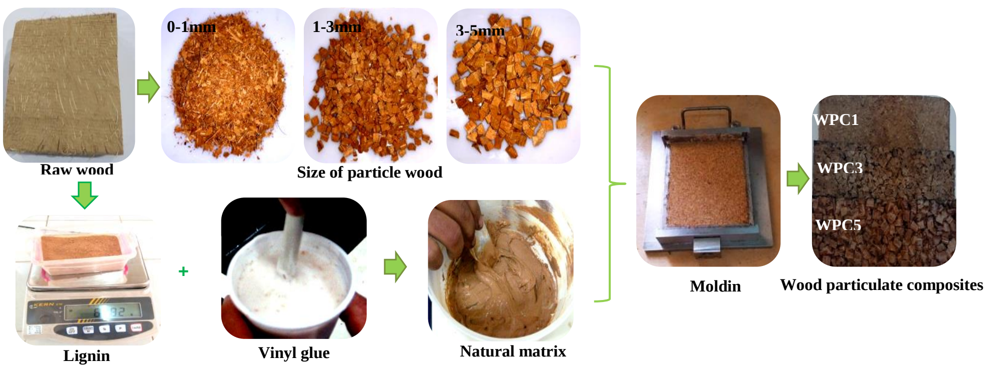


Figure 2. Main steps in preparing composite materials (WPC)

Table 1. Dimensions of the specimens tests

Test		Dimensions			
		Length [mm]	**Width [mm]**	**Height [mm]**	**Standrds**
Physical test	Density	30	30	30	**NF B51-005**
	Shrinkage measuring	40	40	40	-
Thermal test		60	60	30	**HOTDisk TPS500**
Mechanical test	Compression test	30	30	30	**B51-007ISO3132-1975**
	Three-point flexural test	260	40	30	**NF en ISO 178**

The water content or water absorption of petiole wood is determined by the gravimetric method according to standard NF B51-004 (AFNOR, 1985e) in a room conditioned at 20°C and 65% humidity. Raw wood samples and composite materials (WPC1, WPC3 and WPC5) specimens are placed in an oven (BINDER) at a temperature of (110 ± 1)°C. Specimens are weighed every 4 hours until the specimen mass stabilizes. The drying time and temperature were chosen after studying the effect of these parameters on the humidity rate [15]. The water absorption *Hs* is determined by the following formula:

$$H_s\% = \frac{(m_h - m_s)}{ms}.100 \tag{2}$$

where: (*Hs %*) is the water absorption, m_h: the sample mass before drying, m_s: the sample mass after drying.

3.2.2 Raw wood shrinkage

To determine the linear radial (*Rr*), tangential (*Rt*) and longitudinal (*Rl)* shrinkage of the raw petiole fibrous wood, we draw two lines through the center of each specimen surface, one in the radial direction and one in the transverse direction of the fibers (Figure 3). These reference lines allow repeat measurements at the same points and locations. Then the specimens are soaked in a bath of distilled water for three days to achieve the saturation point of the wood. The 0.001mm precision dial indicators are then adjusted by taking the initial dimensions at the center of each sample. The specimens are then dried in a well-ventilated oven at 110°C for 4 hours several times until they are returned to anhydrous state. In the dry state, the radial (*Ra*), tangential (*Ta*) and longitudinal (*La*) dimensions are each time re-measured to determine the linear shrinkage in the three directions. Linear and volume shrinkage, expressed as a percentage (%), are calculated using the following formulas.

$$R_r(\%) = \frac{(R_s - R_a)}{R_s}.100 \tag{3}$$

$$R_t(\%) = \frac{(T_s - T_a)}{T_s}.100 \tag{4}$$

$$R_l(\%) = \frac{(L_s - L_a)}{L_s}.100 \tag{5}$$

$$R_V(\%) = \frac{(V_s - V_a)}{V_s}.100 \tag{6}$$

where: (R_r, R_t and R_l) are the linear shrinkage, (R_a,T_a and L_a) are the dimensions in the dry state, (R_s,T_s and L_s) are the dimensions in the wet state, R_v: the volume shrinkage, V_a: the dry volume, V_s: the wet volume.

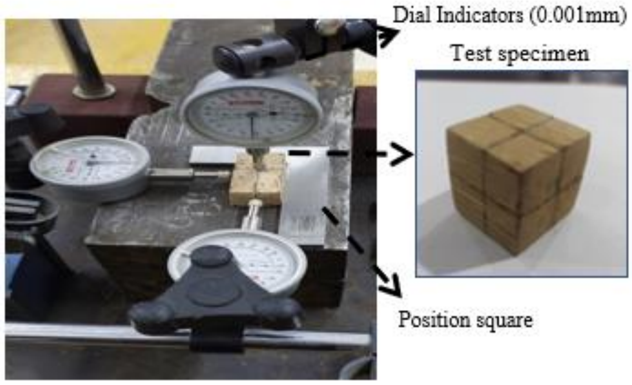


Figure 3. Raw wood shrinkage measuring device

3.3 Thermal test

The thermal properties such as, thermal conductivity, thermal diffusivity and spect heat of raw material (Raw wood), were measured in the two directions of the fibers (RWPT and RWPL) using a HOT Disk TPS500 thermal characterization device with a maximum temperature probe of 60°C under the following climatic conditions 36°C temperature and 60% humidity. In addition, measurements were one-way for the various composites materials (WPC).

3.4 Mechanical test

The mechanical properties were determined for raw fibrous wood (Raw wood) and various composites materials (WPC). Compression tests were performed using an Instron 5969 type universal machine controlled by computer with Bluehill3 software. For the three-point flexural test, we used a computer-controlled TEST-type machine with TesT Winner 950 software. The test speed is constant at 5mm/min. Cells used have a maximum capacity of 5kN. Compression tests were performed in the longitudinal (longitudinal direction) and transverse (Transverse direction) directions of the fibers. The flexural modulus E_f and the flexural stress are determined respectively according to formulas (7) and (8).

$$E_f = \frac{L^3}{4bh^3}\frac{F}{S} \tag{7}$$

$$\sigma = \frac{3FL}{2bh^2} \tag{8}$$

where: (*F*) is the applic load, *L*: the distance between supports, *S*: specimen arrow, *b*: specimen width, *h*: specimen height.

4. RESULTS AND DISCUSSION

4.1 Physical properties

4.1.1 Density

The measurement of the wood density will determine its effect on several physical, thermal and mechanical properties of raw wood. The density of wood is a key factor in the evaluation of construction and insulation materials. In principle and in the literature [8, 13-14], the water content and mechanical properties increase as the density of wood decreases.

Figure 4 and Table 2 showing the variation of the density of raw wood and for different composite materials (WPC) at 12% humidity depending on the size of particle wood.

It can be seen that the density values of the composite materials (WPC) increase as the size of the wood particles decreases. The composite material (WPC1) has the highest density values between (0.48 and 0.55 g / cm^3). The density values of the composite material (WPC5) and the raw wood are identical in the range (0.14 to 0.24 g / cm^3). This is due to the good bond between the small wood particles, as well as the presence of voids between the large wood particles.

Table 2. Physical properties (density) of raw wood and composites materials (WPC)

Physical properties	
Materials	**Density [g/cm^3]**
Raw wood	0.19±0.05
WPC1	0.53±0.03
WPC3	0.23±0.04
WPC5	0.18±0.02

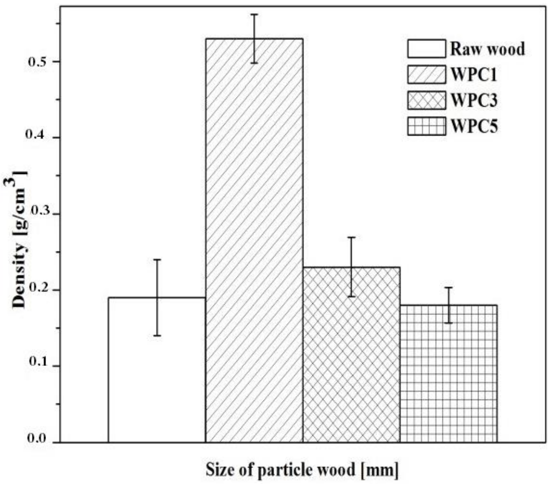


Figure 4. Density of (Raw wood) and composite materials (WPC)

4.1.2 Raw wood shrinkage

The shrinkage measurements of the raw wood allow us to deduce the shrinkage values in different directions as well as the volume shrinkage with its humidity rate. From this we can determine the saturation point and the possible domains for using this type of raw wood.

Figure 5 and Table 3 show the shrinkage of the raw wood according to the different directions of the raw wood: longitudinal (*Rl*), radial (R_r) and tangential (*Rt*), as well as the volume shrinkage (R_V), depending on the variations in the water absorption rate.

Table 3. Physical properties (Shrinkage at saturation point) of raw wood

Physical properties	
Direction of shrinkage	**Shrinkage at saturation point [%]**
R_l	2.25±0.20
Rt	22.19±0.22
R_r	22.81±0.19
Rv	26.9±1.10

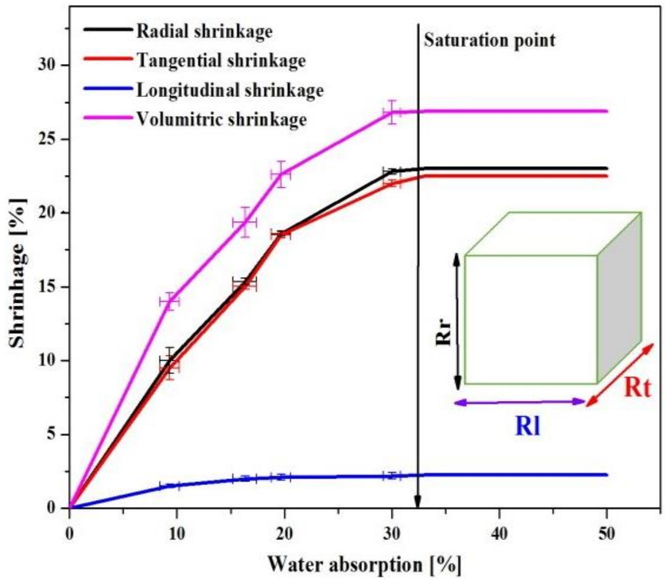


Figure 5. Raw wood shrinkage as a function of water absorption rate

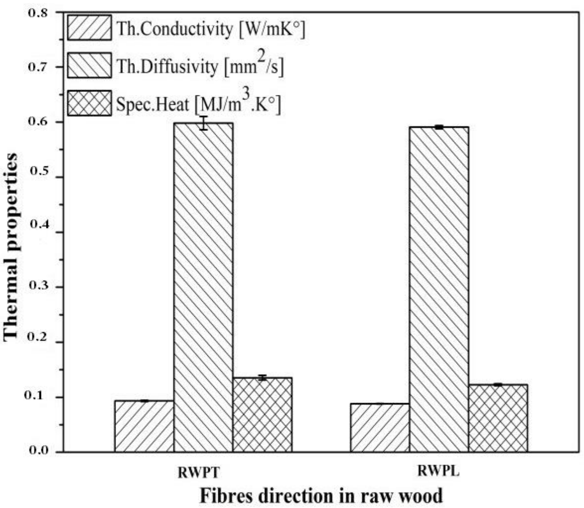
It can be seen that the shrinkage in the radial (*Rr*) and tangent (*Rt*) directions of the raw wood is identical, their value varies between 22 and 22.5%; Contrary to what appears a longitudinal shrinkage (*Rl*) with a very low value of 1 to 2.5%. The value of the very large shrinkage is 25% for the volume shrinkage and the saturation point of raw wood is 33%. In general, the values obtained are higher compared to other classic wood species Mubala, Eyek and Pins [22]. This is due to the wood morphology and the nature of the date palm fibers [2, 15, 18, 23].

4.2 Thermal properties

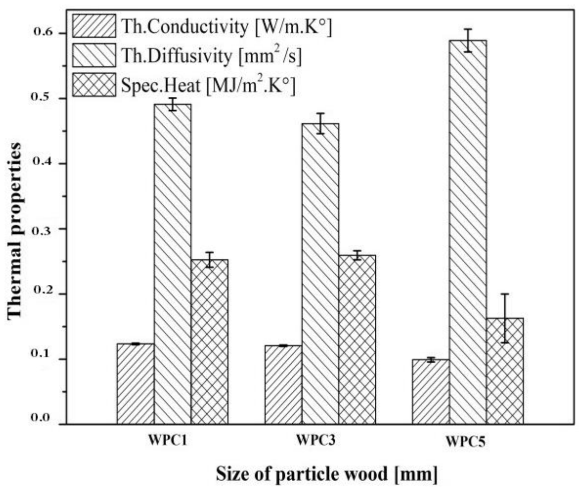
The results obtained by measuring the thermal properties of raw wood and composite materials (WPC) characterize the desired capacity of heat-insulating materials. Thus, the lower the thermal conductivity λ, the more insulating the material will be, in particular when $\lambda \leq 1$.

Figure 6 (a) shows that the orientation of the fiber has no significant influence on the thermal properties of raw wood. Whereas, the effect of particle size on thermal properties of composites (WPC) is well illustrated as shown in Figure 6 (b). This has already been noted in the literature [9, 14, 18, 20].

The thermal conductivity of raw wood and composite materials (WPC) is in the following intervals: 0.087-0.092 and 0.109-0.122 W/mK°. It can be seen that the thermal conductivity of composite materials (WPC) decreases with increasing particle size and becomes very close to the value of raw wood which had the lowest thermal conductivity value of 0.080 to 0.094W/mK°. In general, the wood from the petioles, whether it is raw or in this new composite material (WPC), has good thermal properties and is a good insulator compared to other vegetal materials such as hemp, bananas, sisal, wood and cork [9, 14, 18, 20].



(a) Thermal properties of raw wood



(b) Thermal properties of composite (WPC)

Figure 6. Thermal properties of raw wood and composite materials (WPC)

Table 4 shows the thermal properties obtained by tests on raw wood in the longitudinal and transversal directions of the fibers (RWPT and RWPL) and on the composite materials (WPC).

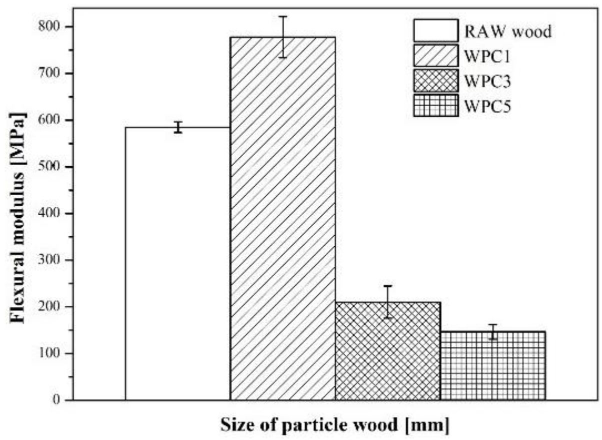
4.3 Mechanical properties

From the mechanical tests carried out, the compression test and the three-point flexural test made it possible to extract the mechanical properties of this new material, such as the modulus of elasticity and the maximum stress indicated in Table 5.

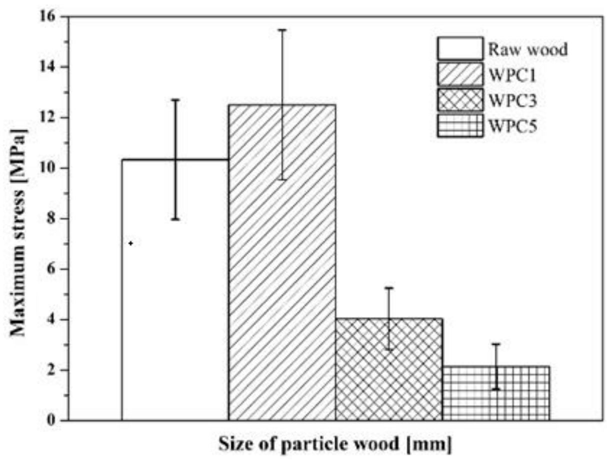
4.3.1 Flexural properties

The results obtained from three-point flexural tests on specimens made of composite materials of different particle sizes (WPC) and raw petiole wood are presented in Figure 7.

Figure 7 shows the effect of wood particle size on the mechanical behavior of these new composite materials (WPC). It is observed that the values of the mechanical properties decrease gradually as the size of the particles increases, thus giving more flexibility to the composite materials (WPC). Flexural modulus and maximum stress respectively increase to (38.98%, 20.64%) for composite material (WPC1) and decrease to (73.20%, 77.96%) for composite material (WPC5) by relative to raw wood. This is due to the good adhesion between the small particles sizes already observed in the literature [9].



(a) Flexural modulus



(b) Maximum stress

Figure 7. Flexural properties of raw wood and composite materials (WPC)

Table 4. Thermal properties of raw wood and composite materials (WPC)

Thermal properties		Materials			
		Raw wood	**WPC1**	**WPC3**	**WPC5**
Thermal	**Conductivity [W/mK°]**	T: 0.093±0.001 L:0.081±0.001	0.123±0.001	0.120±0.001	0.093±0.003
	Diffusivity [mm²/s]	T: 0.598±0.011 L:0.590±0.002	0.491±0.009	00.461±0.015	0.588±0.017
	Spect Heat [MJ/m³K°]	T: 0.135±0.004 L:0.122±0.001	0.252±0.011	0.259±0.006	0.162±0.037

T: tangential direction; L: longitudinal direction

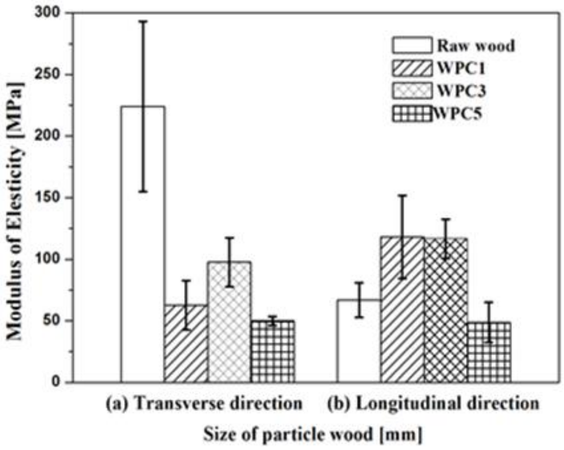
Table 5. Mechanical properties of raw wood and composite materials (WPC)

Mechanical properties			Materials			
			Raw wood	WPC1	WPC3	WPC5
Compression test	Modulus of elasticity [MPa]	CL	224± 69	62.73±19.97	97.56±19.86	49.98±3.61
		CT	67±14	118±33.72	116.58±16.03	48.84±16.29
	Maximum stress [MPa]	CL	3.70± 0.42	1.74±0.85	2.04±0.65	1.94±0.79
		CT	3.85±0.04	2.41±0.06	3.34±0.65	1.79±0.87
Three-point flexural test	Flexural modulus [MPa]		585±10	788±35	200±51	145±18
	Maximum stress [MPa]		10.5±2.5	12.6±2.45	4.01±1.33	2.38±1.66

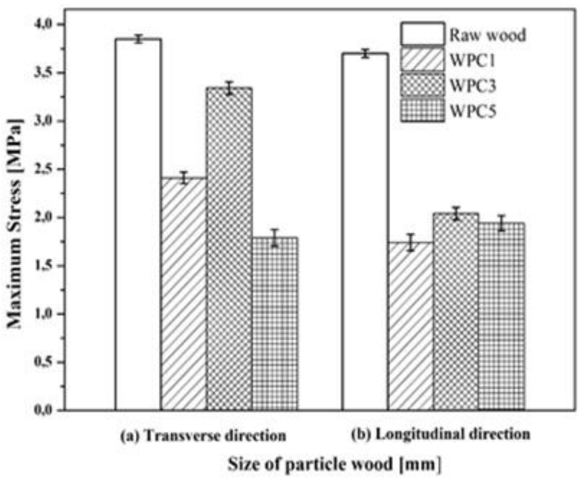
CL: Longitudinal direction; CT: Transverse direction

4.3.2 Compression properties

Figure 8 shows the variation in mechanical properties for compression tests on composite materials (WPC) and raw wood in the longitudinal (CL) and transverse (CT) direction of the fibers.



(a) Compression modulus



(b) Maximum stress

Figure 8. Compression properties of raw wood and composite materials (WPC)

It can be seen from the results obtained that the difference between the mechanical properties of the composite materials (WPC) in the two directions of the test varies as a function of the particle size. Indeed, the values of the modulus of elasticity of raw wood in the transverse direction are very high compared to that in the longitudinal direction. The mechanical behavior of the composite material (WPC5) is similar in both directions of the test, showing the isotropic character of these tested materials.

On the other hand, the results obtained with the tests on composite materials (WPC1 and WPC3) are very different for the two test directions, which shows the anisotropic character of these materials. The mixture (glue/wood particles) being initially isotropic (homogeneous mixture), the anisotropy comes from the implementation (the pressure on the material to be molded). In the large particles case, the wood opposes the processing influence and remains isotropic. In the small particles case, the opposition of the particles is minimal, and the processing directly influences the glue and creates the anisotropy of these composite materials.

We also note that the values of the elastic modulus and the values of the maximum stress obtained by the longitudinal compression tests (CL) for the composite materials (WPC1 and WPC3) are almost identical. The weakest mechanical properties in this test relate to the composite (WPC5) and the raw petiole wood in the longitudinal direction (CL). This is due to the large particle size and interface bonding in the composite, as well as the orientation of the fibers in the raw wood. The values of the mechanical properties obtained by the transverse compression test (CT) on the composite materials (WPC) are in all cases lower than those of raw petiole wood. Composite materials (WPC) exhibit a high modulus of elasticity relative to the modulus of agglomerated cork stressed by compression [24].

5. CONCLUSIONS

The present study examined the physical, thermal and mechanical properties of date palm wood from the region of Biskra, Algeria, as well as the characterization of the new composite material obtained from different particle sizes of date palm waste from this studied petiole wood.

In general, the results obtained show that the raw wood of the petiole has the most advantageous physical, thermal and mechanical properties compared to other composite materials (WPC). Composite material (WPC5) has a low thermal conductivity similar to that of raw wood. This may be due to the very high percentage of vegetal matrix (lignin) in these materials and its low density. Thus, this low thermal conductivity value provided by these materials makes them a good thermal insulator.

As a result of this research work, this study has enabled the scientific and industrial community to identify the feasibility and the limits of the possible use of date palm tree waste in various indusial areas. It is a new, low-cost natural resource that can be harnessed by the composite insulation materials industry. As we have found that the mechanical properties improve with decreasing particle size, the physical and thermal properties, also improve with increasing particle size. These results make to valorize these materials (WPC) for possible industrial applications.

It appears that a complementary study of the influence of the rate of the natural matrix on the physical, mechanical and thermal properties of the composite materials (WPC) is necessary for a future use as a core in sandwich structures and insulation elements.

ACKNOWLEDGMENT

This research work was supported by the General Direction of Scientific Research and Technological Development (DGRSDT), Algeria.

REFERENCES

[1] Itdas, (2012). Report on the situation of the agricultural sector. Technical Report. Technical Institute for the Development of Saharan Agronomy, Biskra, Algeria.

[2] DJOUDI, T. (2019). Elaboration and characterization of biosourced composites based on date palm fibers. Ph.D Thesis. University Mohamed Khider Biskra, Algeria.

[3] Djoudi, A., Khenfer, M., Bali, A., Kadri, E., Debicki, G. (2012). Performance of date palm fibres reinforced plaster concrete. International Journal of Physical Sciences, 7(21): 2845-2853. https://doi.org/10.5897/IJPS11.1553

[4] Siham, A. (2015). Study and development of a composite based on the fibrous material of the date palm Phoenix dactylifera L. Ph.D thesis. University of Boumerdes, Algeria.

[5] Atiki, E., Taallah, B., Feia, S., Almeasar, K.S, Guettala, A. (2021). Effects of incorporating date palm waste as a thermal insulating material on the physical properties and mechanical behavior of compressed earth block. Journal of Natural Fibers, pp. 1-18. https://doi.org/10.1080/15440478.2021.1967831

[6] Koadri, Z., Benyahia, A., Deghfel, N., Belmokre, K., Nouibat, B., Redjem, A. (2019). Study of the effect of the alkaline treatment time of palm fibers on the mechanical behavior of materials based on red clay from the M'sila region. Matériaux & Techniques, 107(4): 404. https://doi.org/10.1051/mattech/2019031

[7] Amara, I., Mazioud, A., Boulaoued, I., Mhimid, A. (2017). Experimental study on thermal properties of bio-composite (gypsum plaster reinforced with palm tree fibers) for building insulation. International Journal of Heat and Technology, 35(1): 576-584. https://doi.org/10.18280/ijht.350314

[8] Djoudi, T., Hecini, M., Scida, D., Djebloun, Y., Djemai, H. (2021). Physico-mechanical characterization of composite materials based on date palm tree fibers. Journal of Natural Fibers, 18(6): 789-802. https://doi.org/10.1080/15440478.2019.1658251

[9] Masri, T., Ounis, H., Sedira, L., Kaci, A., Benchabane, A. (2018). Characterization of new composite material based on date palm leaflets and expanded polystyrene wastes. Construction and Building Materials, 164: 410-418. https://doi.org/10.1016/j.conbuildmat.2017.12.197

[10] Djebloun, Y. (2018). Contribution to the characterization of composite materials reinforced with plant fibres. Ph.D thesis. University Mohamed Khider Biskra, Algeria.

[11] Hammood, A.S. (2015). Effect of erosion on water absorption and morphology for treated date palm fiber-reinforced polyester composites. Int J Mech Mechatron Eng, 15(6): 108.

[12] Zadeh, K.M., Ponnamma, D., Al-Maadeed, M.A.A. (2017). Date palm fibre filled recycled ternary polymer blend composites with enhanced flame retardancy. Polymer Testing, 61: 341-348. https://doi.org/10.1016/j.polymertesting.2017.05.006

[13] Berkouk, A., Meghezzi, A., Chelali, H., Soltani, M.T. (2021). Mechanical, morphological, thermal and dynamic study of composites of unsaturated polyesters-date palm leaf fiber DPLF. Revue des Composites et des Matériaux Avancés-Journal of Composite and Advanced Materials, 31(6): 317-323. https://doi.org/10.18280/rcma.310602

[14] Almi, K. (2018). Développement et caractérisation de matériaux à base du bois de palmier dattier adaptés aux applications de développement durable en Algérie. Ph.D thesis. University Mohamed Khider Biskra, Algeria.

[15] Djoudi, T., Hecini, M., Scida, D., Djebloun, Y., Guerira, B. (2018). Physical and mechanical characterization of wood and fibers from a date palm tree. Matériaux & Techniques, 106(4): 403. https://doi.org/10.1051/mattech/2018056

[16] Temam, G., Derfouf, S., Guerira, B., Hadid, M. (2017). Structural and mechanical characterization of the wood of the date palm cluster. Knowledge Courier, 24: 115-120.

[17] Guettaf T. (2017). Modeling of the mechanical behavior of date palm constituents. Ph.D thesis. University Mohamed Khider Biskra, Algeria.

[18] Agoudjil, B., Benchabane, A., Boudenne, A., Ibos, L., Fois, M. (2011). Renewable materials to reduce building heat loss: Characterization of date palm wood. Energy and Buildings, 43(2-3): 491-497. https://doi.org/10.1016/j.enbuild.2010.10.014

[19] Al-Oqla, F.M., Sapuan, S. (2014). Natural fiber reinforced polymer composites in industrial applications: feasibility of date palm fibers for sustainable automotive industry. Journal of Cleaner Production, 66: 347-354. https://doi.org/10.1016/j.jclepro.2013.10.050

[20] Tlijani, M. (2016). Contribution to the thermophysical characterization of bio-insulating materials: recovery of palm wood waste. Ph.D thesis. University of Paris-Est, France.

[21] Saadaoui, N., Rouilly, A., Fares, K., Rigal, L. (2013). Characterization of date palm lignocellulosic by-products and self-bonded composite materials obtained thereof. Materials & Design, 50: pp.302-308. http://dx.doi.org/10.1016/j.matdes.2013.03.011

[22] Burgers, A. (2016). Physico-mechanical characterization of "flawless" wood for mechanical design: Application to pines in the French Mediterranean region. Ph.D thesis. Montpellier University, France.

[23] Benmansour, N. (2011). Study of the performance of renewable and local products suitable for thermal insulation applications in buildings. Ph.D thesis. University of Batna, Algeria.

[24] Djemai, H. (2017). Contribution to the study of damage in sandwich composite materials. Ph.D thesis. University Mohamed Khider Biskra, Algeria.

NOMENCLATURE

WPC	wood particle composite (Composite materials)
RWPT	transversal thermal properties of raw wood
RWPL	longitudinal thermal properties of raw wood
CL	longitudinal test compression
CT	transversal test compression

Greek symbols

λ	thermal conductivity, W/mK°.