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Mechanical Characterization of Date Palm Nut Powder Reinforced Composite Material from Bechar Algeria Region

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ABSTRACT

This study explores the mechanical properties of composites obtained by mixing date palm powder with an epoxy resin. Tensile and bending tests were carried out to evaluate the mechanical performance of these composite materials. The results show that the addition of date palm date powder significantly influences the mechanical properties of the epoxy resin. The tensile tests reveal a variation in the tensile strength and the modulus of elasticity as a function of the proportion of powder incorporated. Similarly, the bending tests demonstrate a modification of the bending strength and of the rigidity of the composite. These results suggest that date palm date powder can act as a natural reinforcement, modifying the mechanical properties of epoxy resin. This study opens up interesting perspectives for the use of these composites in light and durable applications, in particular in the automotive, aeronautical or construction materials sectors.

1. INTRODUCTION

Reinforced composite materials by the nut powder date palm dates are encouraged by its economic and ecological impact. Indeed, the natural character of these nuts allows it to promote a sustainable industry. These types are used to consider the use of reinforcement in composite materials and as insulation elements. Their mechanical characteristics are similar to synthetic fiber composites with lower density and low cost.

The use of certain nuts requires chemical analyzes, to improve their adhesion and their dispersion in the matrix.

Nature provides a source of momentum from natural materials in the form of untapped residues. The industry needs these materials at present because of the undesirable effects on the environment. Among these sources were found the date walnuts of date palms which will be used as reinforcement in composite materials.

After the Industrial Revolution, the problems of materials, construction in general, blocked several researchers; this was always the object that made scientific research crucial to ensure the growth of industrial development. Seeking to improve its quality, the race to cut out the potting of the composite material is very fierce [1]. Date palms are among the sources that produce huge quantities of nuts and dates every year in the form of waste that is abandoned during its growth and natural evolution [2].

The use of eco-composite materials has increased in recent years in a number of industrial sectors [3].

Plant fibers have valuable mechanical, physical and chemical properties, as well as economic and environmental benefits [4].

Biosourced materials encompass several areas such as thermal insulation, industry, building and packaging. The interest of these materials relates to their mechanical, physical and thermal properties, the latter exist in other plant materials used for composite materials, namely jute [3, 4], flax [5], kernaf [6], hemp [7-20], rachis [7], abaca [9], sisal [9, 10], etc., as well as certain economic and environmental advantages [11].

Some researchers have used date-tree fibers as reinforcement in composite materials and have found good results by applying various fillers.

Worldwide, date palm fibers are one of the most produced fibers and comparatively 42% more than coconut fiber and 10% and 20% more than sisal, hemp, respectively [12], the use of date palm petiole and rachis as a reinforcement in gypsum and mortar composites to study thermal conductivity and mechanical properties [13, 14].

This study focuses on the mechanical characterization of a biocomposite material consisting of date palm date nut powders and an epoxy resin. Tensile and bending tests will determine the mechanical characteristics and the breaking strength.

2. MATERIALS AND METHODS

2.1 Materials

Materials constituting the epoxy laminate:

The materials of study are composite materials based on a powder reinforcement of date nuts, date palm and thermosetting resin, (Epoxy).

2.1.1 Date palm nut powder

The reinforcing materials are date palm nuts from the Bechar region (Algeria). These nuts are dried in the natural state more than a year.

Then cleaned with distilled water to get rid of the impurities, then dried. The objective of the drying process is to reduce the water content present in the internal structure of the date nuts.

The walnuts are then ground with a mill and sieved at 0.05 mm to obtain date palm nut powder.

2.1.2 Resins

The matrix used is an epoxy resin which is now widely used in industry. It is a thermosetting polymer adhesive formulated from 2 main components:

·An epoxy resin

·A hardener

It is the polymerization (or crosslinking) reaction between the two components once mixed (5% of the hardener) that has given the epoxy resins their unique strength and adhesion. They are very effective structural resins which can be used in a great many cases.

2.1.3 Chemical characterization of date palm powder

Table 1 presents the biochemical composition of raw date nuts for two varieties, Deghlet-Nour and Ghars, showing the percentages of various components including moisture, lipids, proteins, sugars, cellulose, minerals, and other unspecified materials.

Table 1. Biochemical composition of raw date nuts [13]

Dosing Elements	Deghlet-Nour (%)	Ghars (%)
Humidity	15.76	9.00
Lipid	4.39	5.15
Proteins	10.71	13.25
Total sugars	11.75	8.88
Reducing sugars	6.50	4.70
Crude cellulose	37.00	33.00
Ash	1.74	2.14
Sodium	0.20	0.26
Potassium	0.67	0.77
Calcium	0.23	0.32
Phosphorus	0.32	0.45
Magnesium	0.06	0.07
Materials not specified	10.67	21.39

2.2 Methods

2.2.1 Specimen preparation procedure

At the heart of our modest study, we project the manufacturing process of laminated composite material test specimens. Our approach involves the production of specimens by stratification, carried out by extraction of the date nuts in Figure 1(a), then the cleaning of the latter with distilled water and drying, grinding of the date nuts and the sieving of the date palm date nuts to a particle size of 0.05 mm in Figure 1(b), with a mixture of epoxy resin and this powder powder powder at a content of 5%, 10% and 15% to manufacture the test pieces of laminated composite material, as shown in Figures 2 and 3.

The implementation of the stratification follows the method of "molding by casting the two materials in a mold", as illustrated in Figure 3. The resulting experiments are exposed to ambient temperature for more than one week in order to guarantee the complete polymerization of the resin, as can be seen in Figures 4 and 5.

Figure 1. (a) Date palm nuts, (b) Powder date palm nuts

Figure 2. Weighing of date palm nut powder and epoxy resin

Figure 3. Use for molding tensile test specimens

Figure 4. Bending test specimens

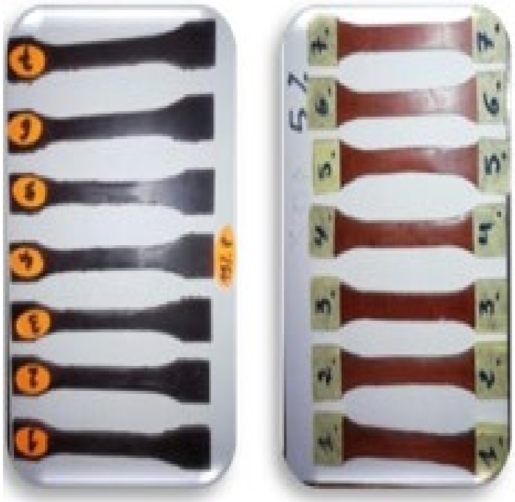

Figure 5. Tensile test specimens

2.3 Equipment used

The test bench used GUNT with hydraulic drive with direct stress generation, can generate both jogging powers and compressive forces. The bottom navigation can be moved standard from the bearings for coarse height adjustment. Cylindrical housings are located on the navigators allowing easy change of accessories. The numerous accessories allow the realization of tests of jogging, compression, Brunel hardness, bending, shearing and stamping. It is also possible to analyze disk springs and coil springs. The test stress and elongation of the test specimens are measured standard from the sensors and then displayed. The measurement values are transmitted to a PC, in order to be exploited there by means of supplied software. The cells used have a maximum capacity of 50 KN.

3. EXPERIMENTAL METHOD

3.1 Tensile test

The tests were carried out on the GUNT test bench at a displacement speed of 1 mm/min. The Cinque test specimens tested have a geometry of length L=250 mm, a width b=25 mm and a thickness e=3.5 mm according to French standard NF T57-101 (Figure 6(a)). The ends of the test pieces are manually hatched with a saw to prevent sliding during the experiment, as shown in Figure 6(b).

Figure 6. (a) Tensile test, (b) Tensile specimen

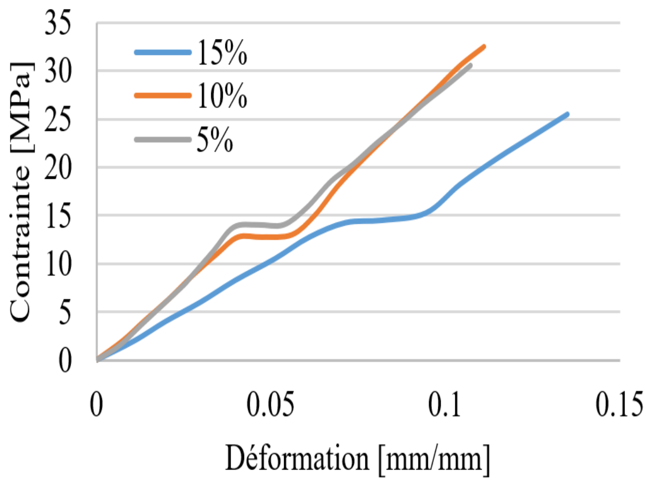

Figure 7. Evaluation of stress as a function of elongation

The stress-strain curves in Figure 7 illustrate the tensile test results for specimens containing various percentages of date palm nut powder.

Table 2 summarizes the maximum stress values associated with the strains (E%), demonstrating a nearly identical consistency with Young's modulus.

Table 2. Tensile test results for powder content (5%, 10% and 15%)

Percentage of Powder Content [%]	σmax [MPa]	E mm/mm	E [GPa]
5%	30.5±3.6	0.107±1.1	2.84±2.3
10%	32±2.5	0.111±2.8	2.95±2.6
15%	25.5±3.45	0.135±2	2.01±2.7

3.2 Three-point bending test

The three-point static bending test is carried out on five test specimens in accordance with French standard NF T57-104.

These test pieces have the following dimensions: a length (L) of 100 mm, a width (b) of 15 mm, a thickness (e) of 3.5 mm, and a distance between the bearing points (d) of 56 mm. The test speed is maintained at about 2 mm/min, as illustrated in Figure 8.

Table 3. Mechanical properties obtained from three-point bending tests

Percentage of Powder Content [%]	σmax (N/mm²)	E mm/mm	E (MPa)
5%	59.42±5.12	0.48±0.45	128.79±2.7
10%	68.57±5	0.51±0.37	142.53±2.6
15%	54.85±5.30	0.46±0.45	93.202±2.8

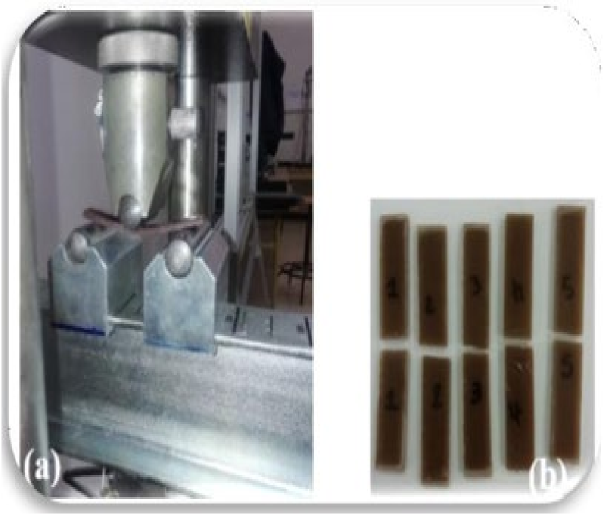

Figure 8. Mechanical bending analysis: (a) Experimental set-up, (b) Test specimens under test

By analysing the load-displacement curves resulting from the three-point bending test, the mean values of the elastic and rupture mechanical characteristics were determined from the results presented in Table 3.

4. RESULTS AND DISCUSSION

The curves of Figure 7 show that the addition of 10% by mass of date nut powder leads to superior mechanical performance compared with the other contents evaluated. The modulus of elasticity increases significantly between 5% and 10%, suggesting that in this range the powder contributes positively to the reinforcement of the polymer matrix, probably through an improvement in structural cohesion and charge transfer.

However, beyond this threshold, mechanical performance declines, as shown in Figure 9, which shows a drop in the modulus of elasticity to 15%. This behavior indicates saturation or poor dispersion of the loads, reducing the effectiveness of the reinforcement. Therefore, a 10% rate is an optimal compromise between rigidity and toughness.

Optimization of charge dispersion (10%):

Homogeneous dispersion: At 10%, the date nut powder is probably well dispersed in the matrix, avoiding agglomerates. A uniform distribution allows a better transmission of stresses to the matrix/load interface, which improves the mechanical strength.

Optimal contact surface: This ratio offers an ideal balance between the interfacial surface and the volume of the matrix, which promotes effective adhesion. Lower percentages (e.g. 5%) do not provide sufficient reinforcement.

Optimum mechanical reinforcement (10%):

Bridging effect: Well-dispersed particles at 10% can impede crack propagation by forcing crack deflection, which increases the energy required for fracture (toughness).

Chemical compatibility: The date nut powder contains functional groups (Table 1) capable of interacting with the matrix (by hydrogen or covalent bonding). Adhesion is maximized at this rate, which improves tensile strength.

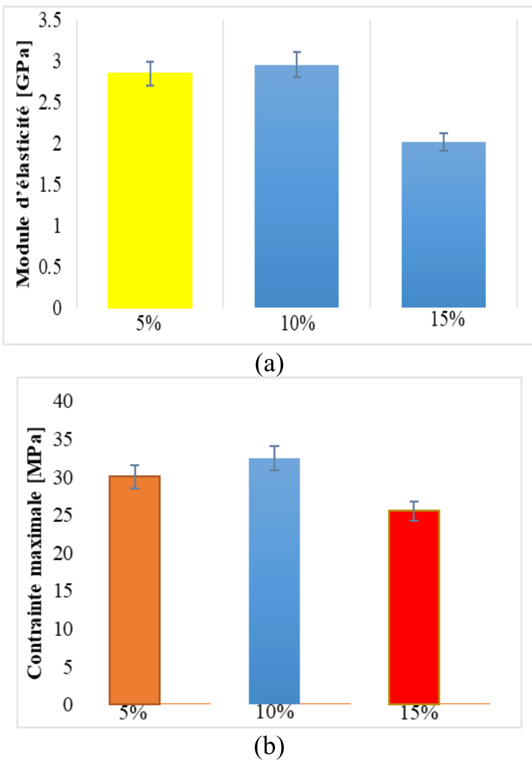

Figure 9. Tensile test results for different powder levels (a) Modulus of elasticity, (b) Maximum stress

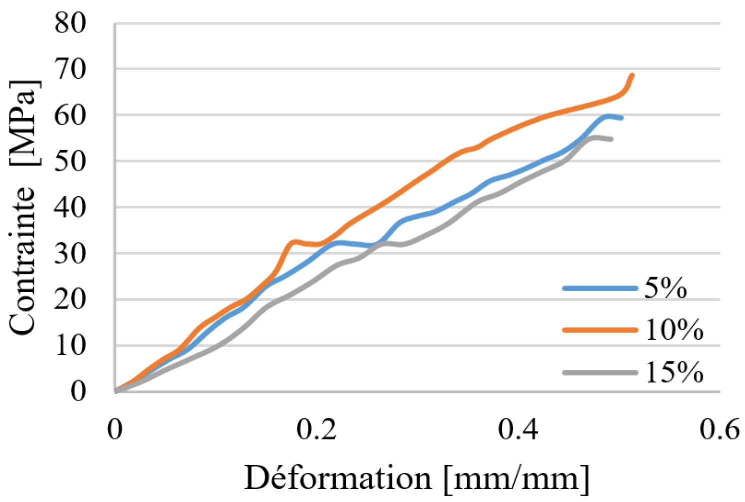

Figure 10. Load assessment based on displacement

Three-point bending tests were carried out on composites filled with date kernel powder at different rates. Figures 9(a) and 9(b) show the test results and their analysis respectively. As can be seen from the stress-strain curve (Figure 10), the optimum concentration of 10% gives the material superior mechanical properties to the other formulations tested.

Table 3 summarizes the results of the three-point bending tests conducted on specimens with different levels of date nut powder. It shows the maximum load corresponding to the maximum displacement and indicates that the specimens have a consistent Young's modulus value.

5. CONCLUSION

This study looked at the mechanical characterization of a bio sourced material from date palm date nut powder. To evaluate its performance, tests were carried out in accordance with the standards NF ISO 527 for traction and NF ISO 178 for three-point bending. Which are similar to French standards NF T57-101 and NF T57-104 relate respectively to tensile tests on reinforced plastics and composites based on thermosetting resins. Their alignment with international standards (ASTM and ISO) is partial, with notable differences that may influence the relevance of the results. These tests demonstrated the material's ability to withstand variable loads, demonstrating compliance with mechanical requirements.

The results obtained from the 10% powder content of date palm nut show a significant improvement in the strength of the material, confirmed by comparison with date palm test pieces from other regions. These conclusions underline its potential as a successful and sustainable alternative in the field of composite materials.

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