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Date palm seeds waste in Algeria: Mechanical characterization of epoxy/date palm seed composites

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Abstract: In this paper a literature review and an experimental study were presented in order to investigate the use date palm seeds waste in the elaboration of composite materials. The literature review showed that Algeria is the fourth world's largest date producer country. From 2008 to 2018, a growth rate of 50% is recorded in the date production in Algeria. An approach is proposed to estimate the annual quantity of date palm seeds waste obtained in Algeria from soft and dry dates, intended for industrial processing. In the experimental part, the mechanical properties of the composite were investigated using an epoxy matrix and five weight fractions of date palm seeds (0 to 40%). A comparison study is presented between tensile and three points bending results and those available from the literature on a similar composite. Beyond the usual discussions in the literature, the increase in the reinforcement weight fraction in the composite allowed observing and discussing two different behaviours: (i) Low weight fraction (10 and 20% of reinforcement), showed a decrease of the flexural modulus and maximum flexural stress. This is due to the small size of the particles in the composite ultimately leading to a weak particle to particle contact. (ii) When the reinforcement weight fraction increases (30 and 40%), more loads are transferred from the matrix to the reinforcement, known for its high rigidity. In this case, flexural modulus begging to increase and higher values, than that of the matrix, can be obtained for 40% of reinforcement.

1 Introduction

The use of natural wastes in the elaboration of composite materials is strongly recommended as alternative materials especially for their remarkable advantages such as renewable nature, good biodegradability and most of all low cost. The last decades have noticed a significant increase in the use of natural fibres for the manufacturing of new type of environmentally-friendly composites such as leaves from flax, jute, hemp, pineapple, sisal and palm date (Almi, et al., 2015a; Elkhouly, et al., 2020; Masri, et al., 2019, Yagoub et al. 2024). According to Mohammed et al. (2015) the worldwide industry sector of natural waste reinforced polymer composites reached USD 2.1 billion in 2010. The global market size for Natural Fibre Composites is estimated at USD 4.46 billion in 2016 (Vazquez-Nunez et al. 2021). This market size is estimated at US$7.1 Billion in

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2023 and is projected to reach US$14.0 Billion by 2030, growing at a CAGR of 10.1% from 2023 to 2030 (ResearchAndMarkets.com 2024)

Nowadays, the residues of Date palm tree (Phoenix dactylifera L.) have earned the reputation of being one of the interesting natural sources due to their renewability aspect and abundant availability (Agoudjil, et al., 2011). Indeed, date palm tree offers several kinds of wastes, such as Petiole, Rachis, Leaflets, Fibrillium, Bunch, Pedicels, Spathe, Thorns and date palm seeds (Almi, et al., 2015b; Touloum et al., 2016; Masri, et al., 2018; Nassar, et al., 2021; Malti et al., 2023). Beside of being an interesting natural source of waste, the date palm trees have also a worldwide production, utilization and industrialization of date fruits and its continuously increasing which indicates their importance. Furthermore, the date fruit has an interesting part which is the date palm seeds with 6 to 12% of the total weight of the fruit, depending on variety and quality grade (Ghazanfari, et al., 2005).

In this study, a literature review on the date palm plantation is presented in order to estimate date palm seeds waste in Algeria. Two aspects are presented: (i) the growth in plantation areas of date palm, and (ii) the date production in the principal producing countries. This literature review will allow positioning the annual potential of date palm seeds waste in Algeria compared to other date-producing countries. An approach to estimate the annual quantity of date palm seeds waste in Algeria is proposed. In the experimental part, five weight ratios between matrix and date palm seeds waste reinforcement are considered to prepare test specimens. The effects of weight ratios, between matrix and reinforcement, on the mechanical proprieties are investigated to evaluate the use of date palm seeds waste in the elaboration of composite materials.

2 Literature review

2.1 Date palm production

Date palm is the main fruit crop in arid and semiarid regions, particularly in North Africa and in the Arabian Gulf area. The palm tree is well adapted to the hot and dry environments. Beyond the desert climates, date palm can also be grown in many other countries for ornamental planting. The world population of date palm is distributed over an area of about 1 million hectares (ha), of which around 70% are in the north Africa and in the Arabian Gulf countries (see Table 1) (FAO, website visited on Dec. 2020).

Table 1 Growth in plantation areas of date palm from 2008 to 2018 in the Arab region and other countries (FAO, website visited in 2020).

Country	2008	2010	2012	2014	2016	2018
Iran	196938	214440	202242	182537	183177	171647
Algeria	162033	161091	163985	165378	167279	168855
Iraq	110000	123000	137458	149965	152642	147900
KSA	157074	155118	156848	107281	111615	116125
Pakistan	90700	90124	89600	91145	97713	100611
Morocco	37300	68176	57035	57744	58122	59127
Tunisia	39300	48253	49468	48700	61240	57329
Egypt	36828	41945	38503	44037	49765	49184
UAE	185330	197400	38233	58446	37963	38117
Libya	28000	30732	30818	31328	32035	32500
Oman	31353	31353	30615	36255	24120	25125
Yemen	14465	14955	14762	14381	13901	13736
Mauritania	8000	8611	8642	7840	8970	9058
USA	2307	3116	3561	4047	4978	5301
Kuwait	1549	1765	2411	2664	2937	3353
Bahrain	1500	1652	2630	2905	3500	3177
Jordan	1637	1708	1840	2222	2712	3146
Qatar	1440	2469	2477	2290	2407	2417
Syria	349	371	366	368	370	370
Sudan	36414	36600	37212	37225	369	366
Total area	**1142517**	**1232879**	**1068706**	**1046758**	**1015815**	**1007444**

Table 2 Date production in the principal producing countries in million quintals from 2008 to 2018 (FAO, website visited on Dec. 2020).

Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Egypt	13.26	12.70	13.53	13.74	14.00	13.28	14.65	16.85	15.49	15.42	15.62
KSA	9.86	9.92	9.92	10.08	10.31	10.95	6.57	10.39	11.53	12.24	13.03
Iran	9.62	9.84	10.07	10.30	10.70	10.14	10.33	10.33	11.85	12.02	12.04
Algeria	5.53	6.01	6.45	7.25	7.89	8.48	9.34	9.90	10.30	10.59	10.95
Iraq	4.76	5.07	5.68	6.19	6.55	6.76	6.62	6.02	6.15	6.19	6.15
Pakistan	5.66	5.31	5.24	5.57	5.25	5.27	5.37	4.68	4.39	4.41	4.72
Oman	2.67	2.59	2.76	2.68	2.81	3.08	3.17	3.45	3.55	3.61	3.69
UAE	7.58	7.59	8.25	2.39	2.22	2.38	3.29	4.03	4.11	3.45	3.45
Tunisia	1.45	1.62	1.74	1.90	1.92	1.95	1.99	2.23	2.41	2.60	2.41
Libya	1.50	1.54	1.66	1.64	1.66	1.67	1.70	1.76	1.73	1.75	1.76
Morocco	0.73	0.85	1.01	1.03	1.02	1.12	1.02	1.00	1.25	1.30	1.12
Kuwait	0.29	0.30	0.33	1.05	1.11	1.04	1.15	0.95	0.93	0.87	0.97
Yemen	0.55	0.57	0.58	0.56	0.55	0.54	0.52	0.50	0.48	0.48	0.48
USA	0.19	0.22	0.26	0.30	0.28	0.28	0.30	0.35	0.34	0.39	0.37
Qatar	0.22	0.21	0.21	0.21	0.22	0.31	0.27	0.28	0.29	0.28	0.29
Mauritania	0.19	0.20	0.21	0.21	0.21	0.22	0.19	0.21	0.22	0.22	0.22
Jordan	0.07	0.10	0.11	0.11	0.10	0.12	0.10	0.20	0.13	0.25	0.20
Bahrain	0.13	0.13	0.13	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11
Sudan	4.34	4.38	4.39	4.39	4.39	4.39	4.41	0.03	0.04	0.04	0.04
Syria	0.03	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03
Total Production	**68.63**	**69.19**	**72.57**	**69.76**	**71.35**	**72.14**	**71.13**	**73.3**	**75.33**	**76.25**	**77.65**

The planting areas of date palm has reduced at an average rate of 13% from 2008-2018 in the World. Table 1 shows also that Algeria recorded an increase of 4% of planting areas during the same period.

The world's largest producer over the same period (2008-2018) was Egypt with an average of 15.62 million quintals of dates, followed by KSA with a production of about 13.03 million quintals, Iran (12.04 million quintals), Algeria (10.95 million quintals) and Iraq (6.15 million quintals) (see table 2). The reduction in the area under production is coupled with an expansion in the total production of dates in the world (Table 2). The production has grown at an average rate around 12% from 2008-2018 in the Word and 50% in Algeria.

2.2 Location of the Algerian oases

Generally, freshly picked dates, having matured under normal conditions, are classified according to their consistency in three categories (Harrak and Boujnah, 2012): (i) Soft dates, with very watery pulp when fresh, which requires treatment, aimed at reducing their water content for good conservation, such as Rhars or Ghars (Algeria), Boufeggous (Morocco) and Barhi (Iraq) varieties. (ii) Semi-soft dates, whose water content in the pulp is lower than that of the previous category, and which remain of soft consistency like the varieties of Deglet-Nour (Algeria), Mejhoul (Morocco)and Zahidi (Iraq). (iii) Dry dates, whose pulp is naturally dry like Degla-Beïda or Mech-Degla (Algeria), Ademou (Morocco)and Kentichi (Tunisia). The Algerian palm groves present a genetic diversity with soft, semi-soft and dry dates. Figure 1 shows the principal location of the Algerian oases cultivated in the Saharan regions of the country: Ziban (Biskra), Le Souf (El-Oued), Oued-Righ (M 'Ghaïr, Touggourt…), Ouargla, M'Zab (Ghardaïa), Touat (Adrar), Gourrara (Timimoun), Tidikelt (In-Salah), Saoura (Bechar), Hoggar-Tassili (Tamanrasset, Djanet). There are also small palm groves in the south of the region of Tebessa, Khenchella, Batna, Djelfa, Laghouat, M'Sila, Naâma, El-Bayedh (Abdessemed and Djemiat, 2017).

2.3 Date palm seed resources in Algeria

Date production statistics in Algeria show that production is mainly concentrated in the south-eastern part of the country, which is responsible of 76 % of national production. The province of Biskra ranks first among the Algerian provinces in number of palm trees and in date production with nearly 31% of national date production;

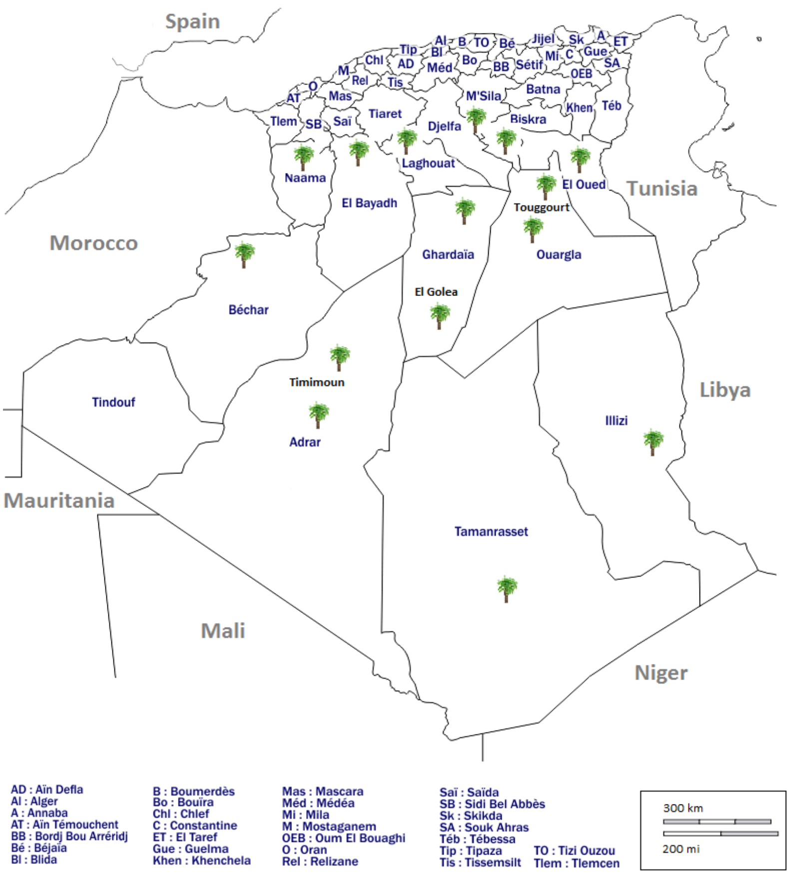

Figure 1 Principal location of the Algerian oases (Abdessemed and Djemiat, 2017).

followed by El Oued with 27% and Ouargla with 18% (Bouguedoura, et al., 2015). Biskra province is also known with the famous dates of Deglet-Nour, especially from Tolga, with an annual production of 2.8 million quintals (62% of the total province production). The rest of the date production is 1 Million Quintals of dry dates (Mech-Degla) with 24% and soft dates (Ghars) up to 500,000 Quintals with 14% of the total province production (Harrak, 2007). The choice of the large planting of Deglet-Nour variety was one of the recommendations of a congress held in Biskra (Algeria), in 1931, on the major climatic and economic aspects of the production of dates. Among the congress recommendations were to promote the cultivar of Deglet Nour variety in the Biskra region (Date palm week, 1931).

The consumption of dates and the process of transformation of dates (Pate Elghars, date flour, juice, dark honey ...) and the use of dates in traditional Cakes and other preparations generates a significant amount of date palm seeds. At present, date palm seeds are used mainly for animal feeds for cattle, sheep and camel. Thus, utilization of such waste is very important to date cultivation and to increase income for the date palm sector (Al-Farisi and Lee, 2014). In fact, this natural resource is not sufficiently exploited as much as many other natural sources such as jute, flax, ramie, hemp and flake fibers, whose use as reinforcement is carried out in several industrial applications (Almi, et al., 2015a).

The exploitation of date palm seeds waste is linked to the development of the industrial sector particularly in date-producing countries. The date palm sector in Algeria includes seven public industrial facilities of date processing and packaging located at (i) the province of Biskra with two units in Biskra and Tolga, (ii) the province of El-Oued with three units in M'ghair, Djamaa and El-Oued, and (iii) the province of Ouargla with two units in Tougourt and Ouargla. The management of these facilities was initially the responsibility of the Office of Fruits and Vegetables (OFLA) and the National Office of Dates (OND) established in 1971. Since 2000, the industrial sector has undergone profound changes under the National Agricultural Development Plan (PNDA). Actually, many private industrial facilities on the date palm sector were installed in many regions of Algeria (Bouguedoura, et al., 2015).

The approach to estimate the annual quantity of date palm seeds waste in Algeria is based on the following assumptions:

- The date seeds of the soft and dry date varieties are a potential that can be recovered after the industrial process of transformation.
- The quantity of Soft and dry dates can be estimated around 4.4 million quintals in 2018. This assumption is based on the statistics of the annual production of Soft and dry dates in the region of Biskra (around 40% of the total date production); and on the fact that the other oasis in Algeria produce more than 50% of these two varieties.
- The transformation capacity of the industrial sector in Algeria is estimated around 40% of the total annual production of Soft and dry dates (i.e. 1.76 million quintals).
- The seed/date weight ratio is considered 1/5. This assumption is based on the fact that the proportion of the date palm seeds, in relation to the whole date, constitutes a characteristic of appreciation of its commercial qualities; this proportion is expressed by the weight ratio (seeds/date), which varies depending on the date cultivars, but also depending on ecological factors and growing conditions (Munier, 1973). In general, the average weight of the seeds represents 20% of the total weight of the date (Dowson and Aten, 1962; Munier, 1973). The annual waste quantity of date palm seeds can be estimated around 352 000 Quintals. This quantity represents 3.2% of the total Algerian annual production of date palm.

2.4 Use of date palm seeds as reinforcement

Generally, date palm seeds are used as a soil organic, feed for livestock or can be used for the production of activated carbon (El-Naas, et al., 2010; Girgis and El-Hendawy, 2002; Yousif, et al., 1996). A review of recent literature has shown that there is some research works on the use of date palm seeds for the elaboration of composite materials (Elkhouly, et al., 2019; Masri, 2018; Nagaraj, et al., 2020). Ghazanfariet al. (2008, 2005) were the first authors who considered the use of date palm seeds in the manufacturing of composite materials. These authors used the date palm seeds and pistachio shells together with high-density polyethylene for the production of bio-composite plates (Ghazanfari, et al., 2005). It has been concluded that date palm seeds have shown a good use opportunity as reinforcement in a bio-composite production with a good appearance. In 2010, Alsewailem et al. (2010) proposed the formulation and the characterization of polymer/date palm seed composites. The study focused on the effect of date seed types and polymers on the mechanical and thermal properties of the obtained composites. In 2015, Marzouk et al. (2015) used Tunisian date palm seeds as reinforcements for thermoplastic matrix. The author studied the effect of date palm seeds' weight on the process ability, mechanical, absorption water capacity and thermal stability. In 2016, Abu-Jdayil and Mourad (2016) used date palm seeds with polyester resin for the composition of a thermal insulation composite material. These authors think that this composition will have a future use in the industrial field.

3 Materials and methods

3.1 Materials

The date palm seeds used in this study were extracted from the fruit (date) of the date palm trees (Phoenix Dactylifera) of the region of Biskra (Figure 2). The date palm seeds chosen as reinforcement were cleaned with water to remove dust and impurities and then naturally dried during three days. In order to reduce a maximum of water content, the date palm seeds are dried in an oven at 105 °C during 24 ours. After drying, date palm seeds will be grinded and sieved to obtain reinforcement with particle sizes of 0.2-0.4 mm.

The matrix used in the preparation of the composite material is Sikadur thermoset epoxy matrix (Algeria). The matrix has an excellent adhesion on various materials such as wood, fibres, polyethylene foam, cement, brick, metals, etc. It can be used on wet surfaces and is inflammable. The poly-epoxy matrix was obtained through a polymerization reaction of an epoxy pre-polymer (two thirds of volume)

Figure 2 (a) Date palm seeds and (b) Particles of date palm seeds powder (0.2-0.4mm).

with an amine curing agent (one third of volume). For each preparation, the matrix hardening is carried out at room temperature for 72 hours.

3.2 Test specimens and Methods

In this study, tensile tests are performed in order to characterize the used epoxy matrix. Flexural tests are performed on the matrix and composite (based on date palm seeds waste as reinforcement) specimens using three-point bending test.

To prepare the tensile test specimens (Figure 3a), the resin was moulded as a plate of dimensions 240×140×4mm with no applied pressure. After curing the plate (72 hours), the plate was cut with a Computer Numerically Controlled to obtain a dumbbell shape test specimen with dimensions according to ISO 527-1 (ISO 527-1, 2012). The tensile properties of the matrix, namely maximum stress, Young's modulus and Poisson's ratio were determined using an Instron 5969 universal testing machine (US). A crosshead speed of 2 mm/min maintaining a gauge length of 50 mm was considered. For the determination of Poisson's ratio, an advanced video extensometer device is placed on the testing machine and calibrated to record measurements of the transverse and axial strains of specimens. The mechanical properties of tensile test were calculated according to the standard ISO 527-1 (ISO 527-1, 2012). In each case, three samples were used and the average values are reported.

To prepare the specimens for three-point bending test (Figure 3b), a metal mould, with a dimension of 200x10x15 mm, was manufactured and used to obtain the test specimens according to ISO 14125 (ISO 14125, 1998). Two kinds of test specimens were prepared: (i) one consists of only resin specimen (B1) as a reference, and (ii) the composite specimens using the resin and five weight fractions of the particles of date palm seeds within a range from 10% to 40% (B2-B5), as shown in table 3. It should be noted that all specimens were moulded with no applied pressure. All obtained specimens are dried for 72 hours. In each case, two samples were used and the average values are reported. The three-point bending properties were determined using a universal testing machine Instron 5969 model. The speed testing is 2 mm/min and the test details are defined according to ISO 14125 standard (ISO 14125, 1998) by using the following dimensions: lb=200 mm, La=160 mm, h=10 mm, and width b=15 mm (Figure 4). The flexural modulus Ef was calculated according to the standard ISO 178 (ISO 178, 2010) by the following equation:

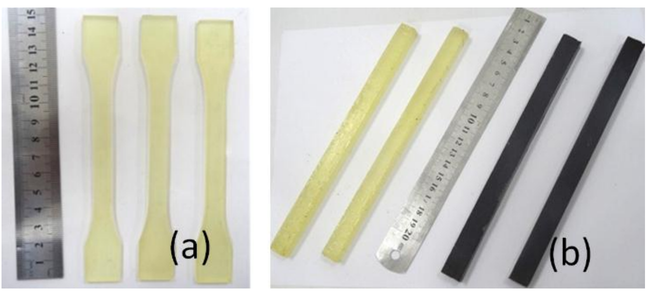

Figure 3 Standard test specimens: (a) Tensile test specimens (b) Flexural test specimens.

Table 3 Different studied samples.

Product	Samples	Matrix (wt %)	Reinforcement (wt %)
Tensile test specimen	T1	100	0
Bending test specimen	B1	100	0
	B2	90	10
	B3	80	20
	B4	70	30
	B5	60	40

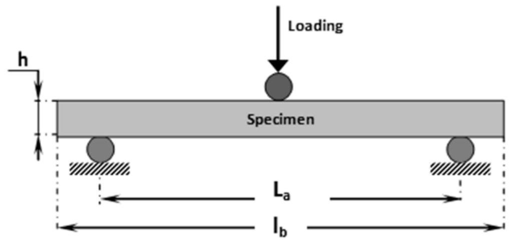

Figure 4 Three-point bending test.

$$E_f = (L_a^3.F)/(4.b.h^3.y) \quad (1)$$

4 Results and discussions

4.1 Tensile tests

The results relating to stress/strain tensile test performed on epoxy samples (T1) until failure are plotted in figure 5. This figure shows similar ascending curves with two successive linear parts linked by a yield region. Failure region is also presented by the same break behaviour for all samples with a fragile fracture at maximum stress around 8 MPa. The tensile Young's modulus, with an average value of 323 MPa, was measured as the slope of the stress strain curve in the linear region between 0.05% and 0.25%.

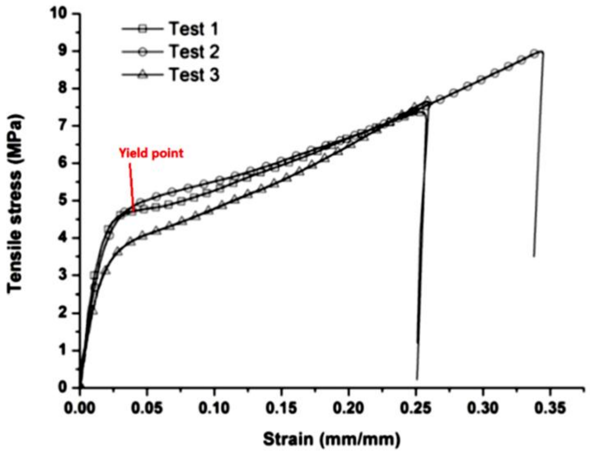

Figure 5 Stress/strain tensile curve of the matrix.

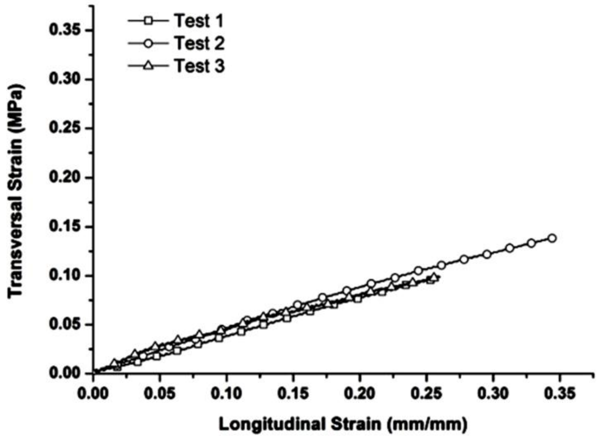

Figure 6 The transversal strain versus the longitudinal strain of the matrix obtained by tensile test.

Table 4 Mechanical properties of the matrix.

	Young modulus, E (MPa)				Maximum stress (MPa)			
	1st test	2nd test	3rd test	Mean value	1st test	2nd test	3rd test	Mean value
Present study	393	321	254	323	7.37	9.00	7.65	8.01
Ghazanfari et al. (Ghazanfari, et al., 2008)	/	/	/	339	/	/	/	15.80

Table 4 shows a comparison between the Young's modulus and the maximum stress of the studied resin specimens (T1) and the matrix used by Ghazanfari et al. (2008) to prepare a similar composite based on date palm seeds. These authors have used the high-density polyethylene as a matrix. The Young's modulus of the used matrix presents a similarity rate of 95% with the matrix used by Ghazanfari et al. (2008). The Maximum stress of the matrix used by Ghazanfari et al. is better twice to the matrix used in the present study.

Figure 6 presents the evolution of the tensile transversal strain as a function of the longitudinal strain on the studied resin specimens (T1). This figure shows a linear relationship between the longitudinal and transversal strains until the break point. Therefore, a Poisson's ratio of 0.4 is computed according to the ISO 527 standard (ISO 527-1, 2012) with a good accuracy (with 5% error using a least square method).

4.2 Bending tests

This part concerns the effect of reinforcement weight fraction on the mechanical behaviour in the epoxy/date palm seed composites. Figure 7 shows the stress-strain curves of all the studied samples. These curves show the mechanical behaviour of the pure matrix and date palm seeds-reinforced epoxy composites. The composites with 0, 10 and 20% of date palm seeds exhibit a high flexural deformation without breaking. In these same samples (B1, B2 and B3) a presence of small cracks is observed on the lower part of the test specimens (on the tensile part as shown in the figure 8).

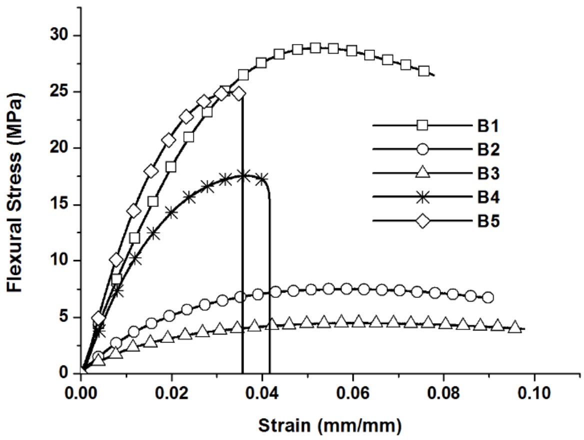

Figure 7 Flexural stress-strain curves of the studied epoxy/date palm seed composites.

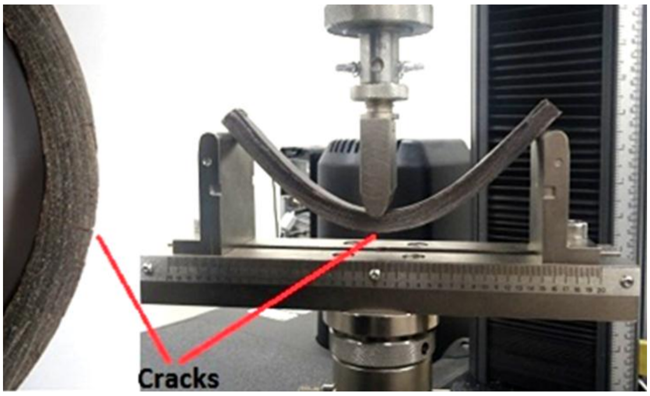

Figure 8 Three-point bending tests illustrating epoxy/date palm seed composites with a high flexural deformation

For a better illustration of all bending test results, flexural modulus (E_f) and maximum flexural stress (σ_{Max}) are presented in table 5 and figures 9a,b and compared with similar composites proposed by Ghazanfari et al. (2008). Table 5 shows that Ef and σ_{Max} of the matrix, used in the elaboration of the epoxy/date palm seed composites, are respectively 1.97 and 1.16 greater than the obtained results of by Ghazanfari (2008). Figures 9a,b show that the obtained E_f and σ_{Max} of the composite are generally higher than those given by Ghazanfari et al. (2008). With 40% reinforcement (B5), E_f and σ_{Max} increase respectively 3.5 and 1.5 more than those given by Ghazanfari et al. (2008). Contrary to the results obtained on the studied material, the E_f and σ_{Max} of the matrix used by Ghazanfari et al. (2008) are greater than the flexural modulus of the composite.

Figures 9a,b shows also that the increase in the reinforcement weight fraction generates a decrease followed by an increase of the flexural modulus and maximum flexural stress (E_f and σ_{Max}) of the composite. Indeed, the addition of 10 and 20% of reinforcement (B2 and B3) decreases E_f and σ_{Max} of the composite with comparison to the reference sample B1 (100% Matrix). The increase of E_f and σ_{Max} are again noticed from the addition of 30% of reinforcement (B4 and B5). Similar behaviour has been reported by other researchers (Hamma, et al., 2013; Onyechi, et al., 2015; Raju, et al., 2012). This behaviour is

Table 5 Mechanical properties of epoxy/date palm seed composites with a with similar composites proposed by Ghazanfari et al. (Ghazanfari, et al., 2008).

	Samples	**B1**	**B2**	**B3**	**B4**	**B5**
	Reinforcement/matrix (wt%)	**0/100**	**10/90**	**20/80**	**30/70**	**40/60**
E_f (MPa)	Present study	961	454	330	842	1380
	Ghazanfari et al. (Ghazanfari, et al., 2008)	487	402	404	398	396
	E_f (Present study) / E_f (Ghazanfari et al. [9])	1.97	1.13	0.82	2.12	3.48
σ_{Max} (MPa)	Present study	28.94	7.54	4.08	17.05	23.57
	Ghazanfari et al. (Ghazanfari, et al., 2008)	25.031	23.855	21.118	16.910	16.060
	σ_{Max} (Present study) / σ_{Max} (Ghazanfari et al. [9])	1.16	0.32	0.19	1.01	1.47

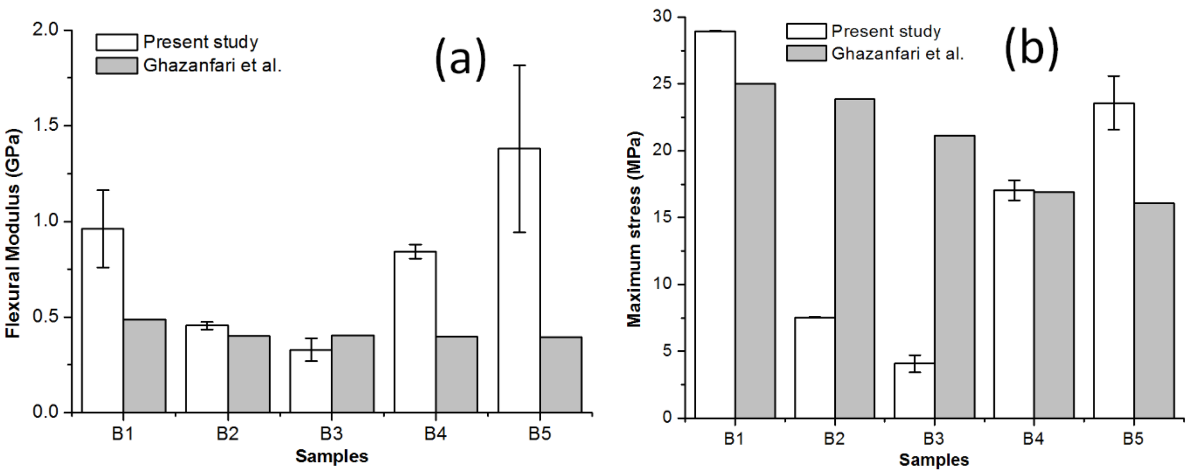

Figure 9 Bending test results of epoxy/date palm seed composites and a similar composite (Ghazanfari, et al., 2008): (a) Flexural Modulus and (b) Maximum flexural stress.

explained in the literature by the fact that since there is no sufficient adhesion between the reinforcement and matrix, slipping between the reinforcement and matrix is occurred, which therefore decreases the composite stiffness. When the reinforcement content increases more loads are transferred from the matrix to the reinforcement in the composite (Bisht and Gope, 2015). In the case of low weight fraction of reinforcement, Akgul and Tozluoglu (2008) explain the decrease of the flexural modulus by the small size of the particles in the composite, ultimately leading to a weak particle to particle contact. In the case of epoxy/date palm seed composites, the explanation reported above by Bisht and Gope (2015) and Akgul and Tozluoglu (2008), is valid and explains the decrease (from B1 to B3) and the increase (B4, B5) of the flexural modulus and maximum flexural stress (E_f and σ_{Max}). When the reinforcement content increases (B4, B5), more loads are transferred from the matrix to the reinforcement, known for its high rigidity. In these cases, E_f and σ_{Max} can obtain higher values than that of the matrix.

5 Conclusion

In this work, a literature review is conducted to estimate the annual potential of date palm seeds waste in Algeria. It has been shown that Algeria is among the four first countries in planting date palms and date production, with several varieties, namely: soft, semi-soft and dry dates. From 2008-2018, a growth rate of 50% is recorded in the date production in Algeria with nearly 11 million quintals in 2018, against a Word average growth rate around 12%. A detailed approach to estimate the annual potential waste in Algeria is proposed basing on four assumptions. The annual waste quantity of date palm seeds, intended for industrial processing, is estimated around 352 000 Quintals per year. This quantity represents 3.2% of the total Algerian annual production of date palm.

In the experimental part, date palm seeds waste is used as reinforcement with an epoxy matrix using five weight fractions of the particles within a range from 0% to 40%. The study investigates the effect of the amount of the date palm seeds particles, on the mechanical properties of the composite using tensile and three points bending tests. A comparison study is presented between the obtained results and those available in the literature on a similar composite, proposed by Ghazanfari et al. (2008) with a matrix of high density polyethylene. The results showed that the mixing of the date palm seeds with the epoxy is carried out and led to a homogeneous composite material. Beyond the usual discussions in the literature, the increase in the reinforcement weight fraction of the studied composite allowed observing and discussing two different behaviours: (i) In the case of low weight fraction (10 and 20% of reinforcement), the decrease of the flexural modulus and maximum flexural stress by the small size of the particles in the composite; ultimately leading to a weak particle to particle contact. (ii) When the reinforcement content increases (30 and 40% of reinforcement), more loads are transferred from the matrix to the reinforcement, known for its high rigidity. In this case, flexural modulus begging to increase and higher values can be obtained for 40% of reinforcement, 44% compared to the flexural modulus of the matrix. Finally, the proposed composite material can be used as a building material in civil engineering and mechanical purposes.

Nomenclature

L	Initial distance between grips, mm
L_0	Gauge length, mm
l_1	Length of narrow parallel-sided portion, mm
L_2	Distance between broad parallel-sided portions, mm
l_3	Overall length, mm
b_1	Width of narrow portion, mm
b_2	Width at ends, mm
h	Preferred thickness, mm
E_f	Flexural modulus, MPa
E	Modulus of elasticity, MPa
l_b	Length of specimen, mm
L_a	Support span length, mm
h	Thickness of the test piece, mm
b	Width of specimen, mm
F	Applied load, N
y	Deflection, mm
Greek Letters	
σ_{fM}	Maximum flexural stress, MPa
σ_{tM}	Maximum tensile stress, MPa
υ	Poisson ratio

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