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RESEARCH ARTICLE

DETERMINATION OF MECHANICAL PROPERTIES FOR DATE PALM MIDRIBS AND LEAFLETS

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ABSTRACT

This paper focuses on the determination of mechanical properties of three species of date palm midribs and leaflets. The three species are SIWI, FREHI, and GAGA date palms located at the Bahariah oases, Egypt. These results have then been compared with known wood species. The comparison shows that Frehi midribs have the highest values of bending strength, and Young's modulus in compression. Siwi midribs have the highest values for Young's modulus in bending, and transverse shear strength. GAGA midribs have the highest values of compression strength, and longitudinal shear strength. The Frehi leaflets have the highest value of tensile strength, while Siwi leaflets have the highest value of Young's modulus in tension.

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INTRODUCTION

A large number of date palms are grown in Egypt (more than 15 million (Ministry of Agriculture, Economic affairs sector, Central administration of agricultural economy, 2016.)) providing a large quantity of secondary products, e.g. palm midribs, spadix stems, coir, leaflets, and midrib bases (Figure 1). Figure 2 illustrates the cross section of palm midrib across its length. These products result from the annual process of pruning of the palm. Most of these products are open-field burnt, leading to environmental pollution. Meanwhile, these products could be used as a source of lignocellulosic materials instead of wood. The properties of palm midrib differ according to the location along its length. Across the midrib, three zones can be distinguished; the peripheral, transitional, and inner zone. In the first and second zones, the fiber sheath is thick, and the vascular bundles are numerous. The third zone is the broadest, where the bundles reach their highest diameter. The average width of the periphery and transitional zones across the midrib is 1.265 mm. Fiber tissue percent is higher in the periphery and transition zone (38%) than the inner or centeral zone (10%) (Elmously, 1995).

MATERIALS AND METHODS

Research subject

The material was selected from three species of date palms in the Baharia oases, Egypt, which are called Siwi, Frehi, and GaGa, and collected by artsan, working in date palm pruning (Figure 3). Samples including date palm midribs and leaflets have been tested in the polymer lab at faculty of Engineering, Ain Shams University.

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Selection of samples

Three date palms were selected for each type of date palms (Siwi, Frehi, GaGa), and five samples from each date palm have been tested. For date palm midribs, a selected portion of its length (2m) from the midrib base has been selected for each date palm type to take samples (2m, measured from the bigger section of the midrib).

Green Samples

The material have been kept in closed place while awaiting preparation for test, and before testing, it have been removed from the closed place and cut to cross section with dimensions (10X10mm).

Air-dried samples

When the moisture content is about 10±2% the samples have been cut to cross section of (10X10mm).

Determination of moisture content

Before mechanical characterization, the moisture content determination was performed according to (BS EN 322:1993) with the following procedure (Wood-based panels — Determination of moisture content).

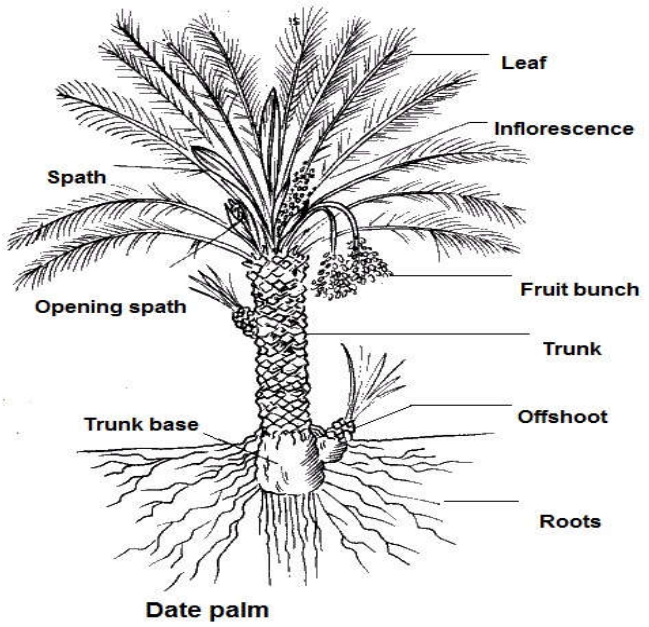

Figure 1. Palm structure [http://www.biotech-ecolo.net, Date palm (Phoenix dactylifera L.).[Cited 2013] Available from:]

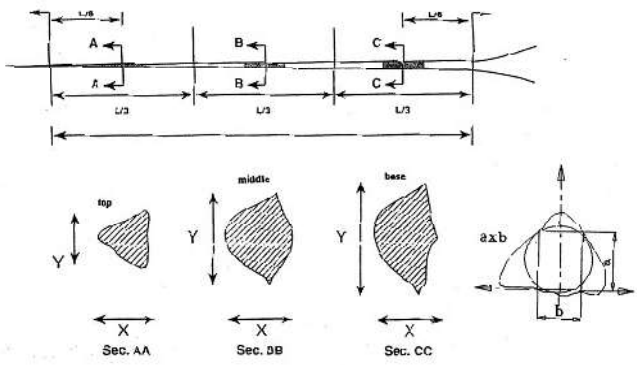

Figure 2. The cross section of palm midrib along its length [Elmously, 1995]

Figure 3. The collected samples of date palm midribs and leaflets

Weigh before drying

Weigh each test piece in the as-sampled state to an accuracy of (0,01g). This initial weighing shall be carried out immediately after sampling or where this is impossible, precautions have been taken to avoid changes in the moisture content of the test piece after sampling.

Drying

Place the test pieces in the drying oven at a temperature of (103 ± 2)°C until constant mass has been reached. Constant mass is considered to be reached when the results of two successive weighing operations, carried out at an interval of6h, do not differ by more than0, 1% of the mass of the test piece.

Weighing after drying

After the test pieces have been cooled to approximately room temperature in the desiccator (Figure 4), weigh each test piece to an accuracy of 0,01g, rapidly enough to avoid an increase in moisture content greater than 0.1%

Figure 4. Disiccator

RESULTS

Calculate the moisture content H of each test piece, as a percentage by mass to the nearest0,1%, in accordance with the following formula:

$$H = \frac{m_H - m_0}{m_0} \times 100$$

Where

m_H is the initial mass of the test piece, in grams.
m_O is the mass of the test piece after drying, in grams

Mechanical characterization

Static Bending

Three points bending test was performed by using bending standard specimens of size 10x10x152 mm supported at a span length of 142 mm and tested using an LRXPlus universal testing machine at a crosshead speed of 2.5 mm/min in compliance with ASTM D143-83.

Compression parallel to fibers Test

Compression parallel to fibers test was performed by using compression standard specimens of size 10x10x40 mm. The tests were performed using a LRXPlus universal testing machine at a crosshead speed of 0.08 mm/min in compliance with ASTM D143-83.

Shear test in longitudinal direction

The shear parallel to fibers test was performed by using shear standard specimens as shown in Figure 5.

The test was conducted using a LRXPlus universal testing machine and a suiTable shear test apparatus at a crosshead speed of 0.6 mm/min (Figure 6) in compliance with ASTM D143-83.

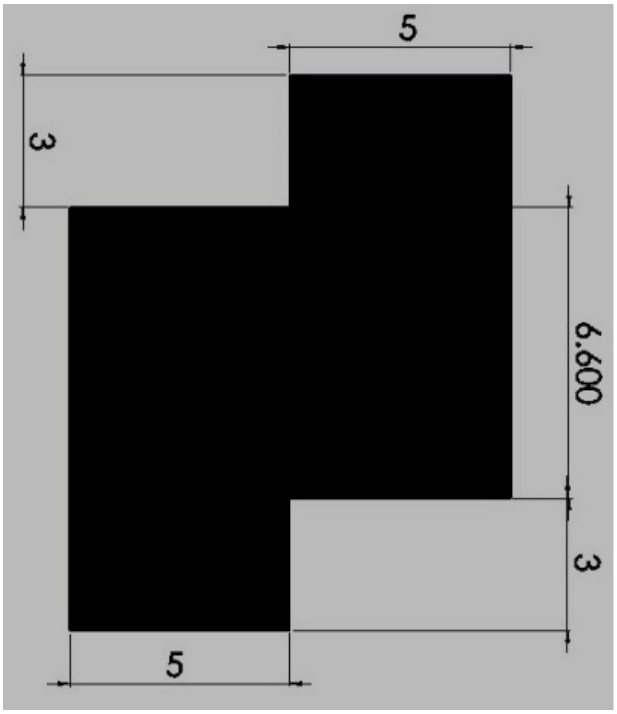

Figure 5. The shear test sample

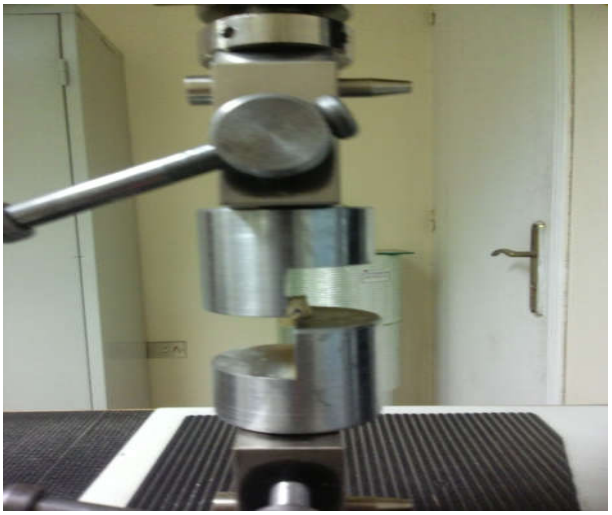

Figure 6. LRXPlus universal testing machine during shear test

Shear test in transverse direction

Shear perpendicular to fibers test was performed by using shear specimens from the midrib. The test was conducted using a LRXPlus universal testing machine and a suiTable shear test apparatus at a crosshead speed of 0.6 mm/min in compliance with ASTM D143-83.

Tensile test for date palm leaflets

The tensile test was performed with samples of leaflets with total length 200mm, and span length of (145mm), using a LRXPlus universal testing machine (Figure 7).

Figure 7. The tensile test sample for date palm leaflets while performing tensile test

The test was conducted at a crosshead speed of 1 mm/min using a 2.5 kN load cell, in compliance with ASTM D143-83.
5. Results and discussion

RESULTS AND DISCUSSION

Determination of moisture content

Table 1 illustrates the results of measurements of the moisture content of sample of date palm midrib specimens. The average moisture content of three species of date palm midribs is below 12% and thus is suiTable for mechanical testing.

Table 1. Results of measurement of the moisture content of palm midrib samples

No	Palm midrib species	Average moisture content (%)
1	SIWI midrib	6.648294 (0.225)
2	FREHI midrib	7.170348 (0.78)
3	GAGA midrib	6.075548 (0.58)

Static bending test for midribs

Figure 8 shows the bending strength of the three species of date palm midribs (Siwi, Frehi, GaGa). The results illustrate that frehi date palm midribs has the highest bending strength, amounting to 90.54 Mpa. Figure 9 shows the Young's modulus in bending of the three species of date palm midribs (Siwi, Frehi, GaGa).

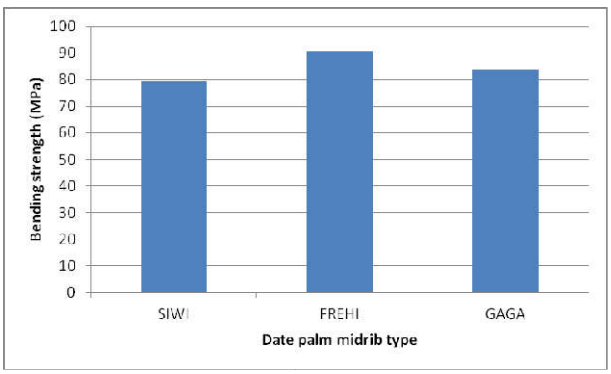

Figure 8. Comparison between the bending strength for three species of date palm midribs

The results illustrate that Siwi date palm midribs has the highest Young's modulus in bending, amounting to 7395 Mpa. Figure 10 illustrates the pattern of failure in the static bending test.

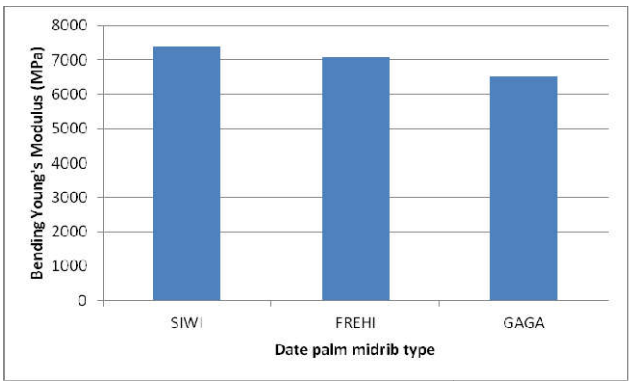

Figure 9. Comparison between the bending Young's modulus for three species of date palm midribs

Figure 10. The pattern of failure of static bending test for the three species of date palm midribs (splintering tension)

A comparison has been performed between the results of static bending properties average for the three date palm midribs. The results show that Frehi date palm midribs have the highest bending strength amounting to 90.54 Mpa, and Siwi date palm midribs have the highest Young's modulus in bending amounting to 7395 Mpa as shown in (Table 2).

Table 2. The average bending strength, Young's modulus in bending, and strain at maximum bending stress for the three species of date palm midribs

No	Date palm midrib species	$\sigma_{b\,(MPa)}$	$E_{b\,(MPa)}$	$^{r}{}_{at}\,\sigma_b$
1	SIWI midrib	79.48 (5.5)	7395 (839.3)	0.016 (0.002)
2	FREHI midrib	90.54 (13.46)	7088.6 (1299)	0.019 (0.0016)
3	GAGA midrib	83.75 (6.4)	6527.5 (643.2)	0.018 (0.001)

Compression test of midribs

Figure 11 shows the compression strength of the three species of date palm midribs (Siwi, Frehi, GaGa). The results illustrate that GaGa date palm midribs has the highest compressive strength, amounting to 42.94 Mpa. Figure 12 shows the Young's modulus in compression of the three species of date palm midribs (Siwi, Frehi, GaGa). The results illustrate that Frehi date palm midribs have the highest Young's modulus in compression, amounting to 807.6 Mpa. Figure13 illustrates the compression test specimen, as well as the pattern of failure of the specimens.

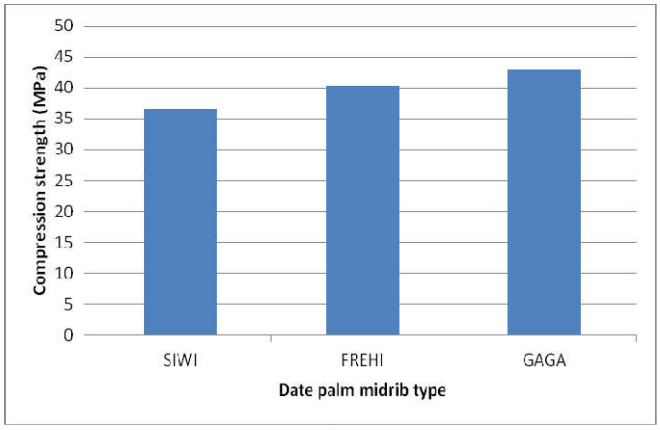

Figure 11. Comparison between the compression strength for three species of date palm midribs

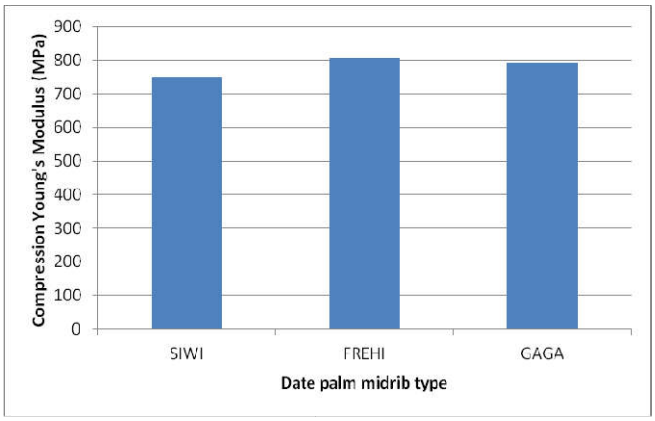

Figure 12. Comparison between the compression Young's modulus for three species of date palms

A comparison has been performed between the results of compression properties average for the three date palm midribs. The results show that GaGa date palm midribs have the highest compressive strength, amounting to 42.94 Mpa, and Frehi date palm midribs have the highest Young's modulus in compression, amounting to 807.6 Mpa as shown in (Table 3).

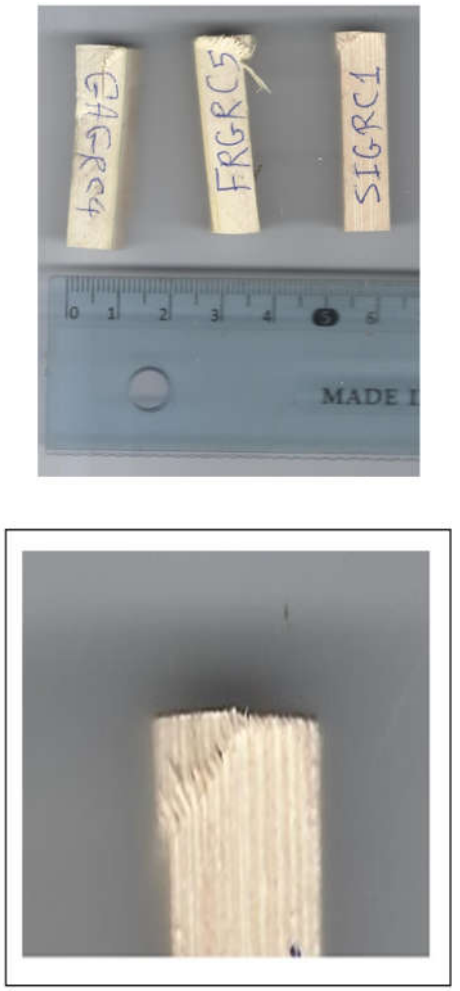

Figure 12. Comparison between the compression Young's modulus for three species of date palms

Table 3. Average compression properties for three species of date palm midribs

No	Date palm midrib species	бc (MPa)	Ec (MPa)
1	SIWI midrib	36.53 (1.74)	750.5 (37.4)
2	FREHI midrib	40.36 (5.23)	807.6 (76)
3	GAGA midrib	42.94 (5.6)	791.3 (17.8)

Shear Test of midribs

Figure 14 shows the longitudinal shear strength of the three species of date palm midribs (Siwi, Frehi, GaGa).

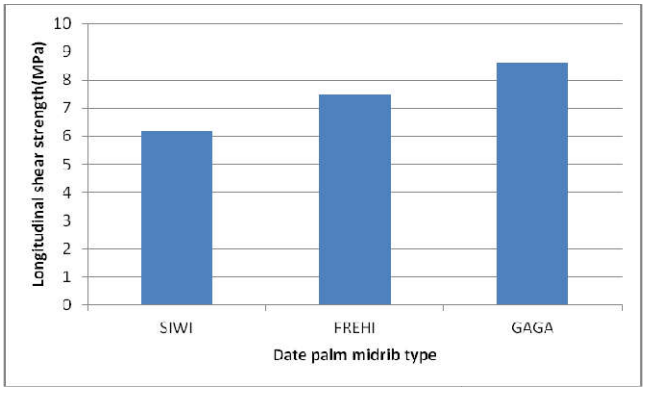

Figure 14. Comparison between the longitudinal shear strength for three species of date palms

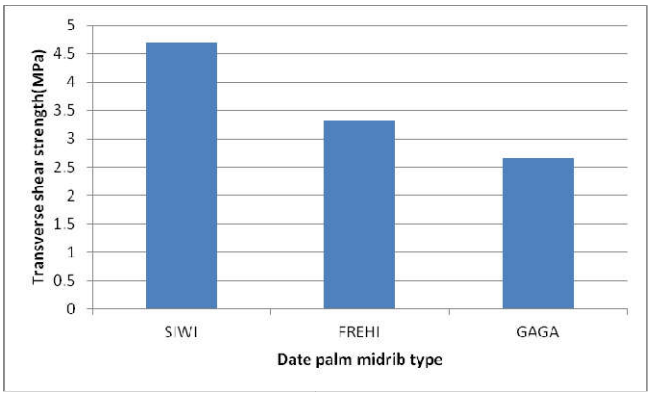

Figure 15. Comparison between the transverse shear strength for three species of date palms

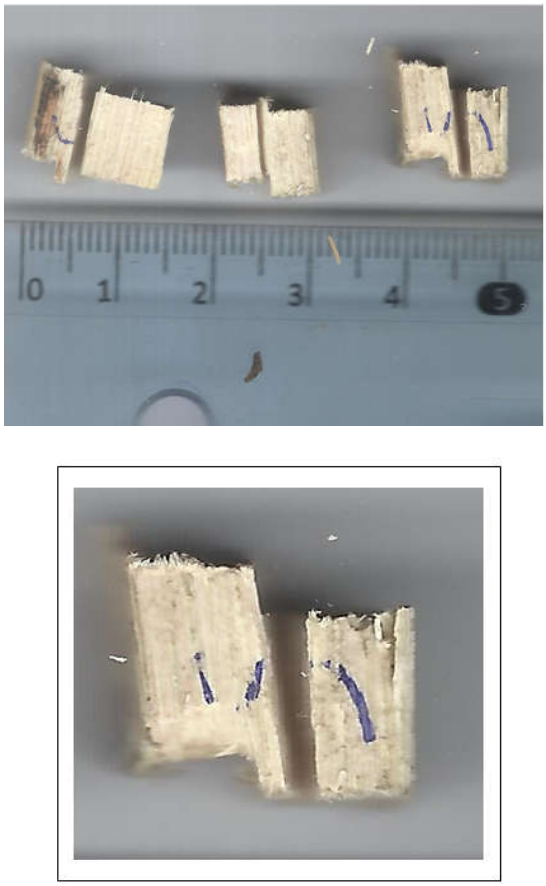

Figure 16. The pattern of failure of shear test for the three species of date palm midribs in longitudinal direction (splintering and shearing)

Table 4. Average shear strength for three species of date palm midribs in longitudinal and transverse directions

No	Date palm midrib species	τ_{SL} (MPa)	τ_{ST} (MPa)
1	SIWI midrib	6.18 (1.3)	4.7 (0.3)
2	FREHI midrib	7.2 (0.95)	3.32 (0.2)
3	GAGA midrib	8.62 (0.32)	2.65 (0.45)

The results illustrate that GaGa date palm midribs have the highest longitudinal shear strength, amounting to 8.62 Mpa. Figure 15 shows the transverse shear strength of the three species of date palm midribs (Siwi, Frehi, GaGa). The results illustrate that Siwi date palm midribs have the highest transverse shear strength, amounting to 4.7 Mpa. Figure 16,17 illustrate the pattern of failure of longitudinal and transverse shear respectively.

Table 5. Mean values of mechanical properties for the three date palm midribs species

property Date Palm midrib species	Bending strength (MPa)	Bending young's modulus (MPa)	Compressive strength (MPa)	Compression Young's modulus (MPa)	Shear strength (MPa)	
					L	T
SIWI midrib	79.48(5.5)	7395.12(839.3)	36.53(1.74)	750.5(37.4)	6.18 (1.3)	4.7 (0.3)
FREHI midrib	90.54(13.5)	7088.6(1299)	40.36(5.23)	807.6(76)	7.2 (0.95)	3.32 (0.2)
GAGA midrib	83.75(6.4)	6527.5(643.2)	42.94(5.6)	791.3(17.8)	8.62 (0.32)	2.65 (0.45)

Table 6. Mean values of bending properties for the two species of wood

Property / Wood type	Bending strength (MPa)	Bending young's modulus (MPa)
Beech	142.16 (5.84)	12326.86 (629.35)
Red European pine	85.22 (3.65)	8484.5 (317)

Table 7. Mean values of mechanical properties for the three date palm leaflets species

Property Date Palm leaflets species	Tensile strength (MPa)		Tensile young's modulus (MPa)	
	Green	Dry	Green	Dry
SIWI leaflets	33.64 (9.1)	31.62 (6.7)	1733 (609.3)	2268 (325)
FREHI leaflets	37 (7.6)	38.9 (6.14)	1758 (364)	2448 (193)
GAGA leaflets	13.8 (4.3)	18 (4.15)	1066 (151)	2131 (177)

A comparison has been performed between the results of shear properties average for the three date palm midribs. The results show that GaGa date palm midribs have the highest longitudinal shear strength S_L, amounting to 8.62 Mpa and Siwi date palm midribs have the highest transverse shear strength S_T, amounting to 4.7 Mpa as shown in (Table 4). Table 5 illustrates the mean values of mechanical properties for the three date palm midribs species. This Table includes the values of the bending strength, Young's modulus in bending, compressive strength, Young's modulus in compression, as well as longitudinal, and traverse shear strength. A comparison has been performed between the results of bending properties average for the two species of wood (Beech wood, and Red European pine wood). The results show that Beech wood has the highest bending strength, amounting to142.16 Mpa and young's modulus in bending, amounting to 1232686 Mpa as shown in (Table 6).

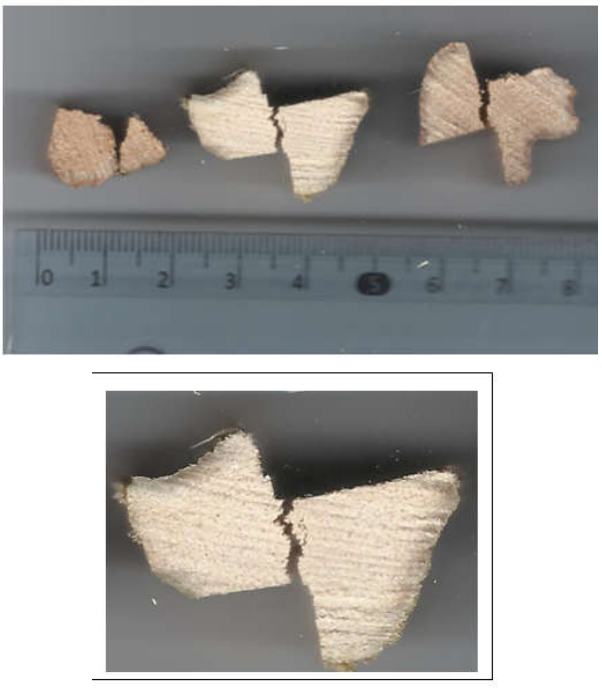

Figure 17. The pattern of failure of shear test for the three species of date palm midribs in transnverse direction (splintering and shearing)

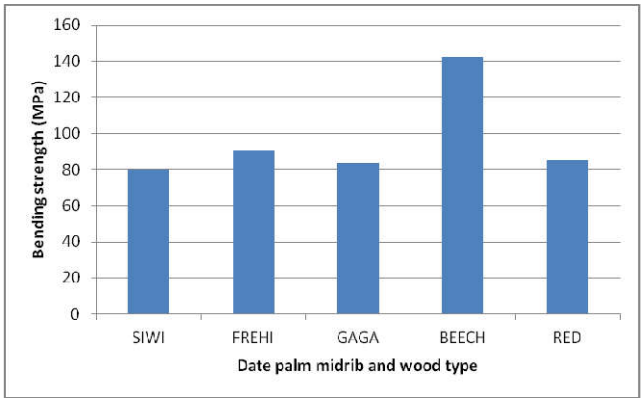

Figure 18. Comparison of the bending strength of the three date palm species and other wood species

Figure 18. illustrates a comparison between the bending strength of the three species of palm midribs and that of Beech and Red European pine wood species. It is clear from this figure that the Frehi palm midribs surpass the Red European pine (106.24%) whereas the Siwi and Gaga are near to that of the Red European pine(less than Red European pine by 6.73% and 1.72% respectively). Figure 19 illustrates a comparison between the Young's modulus in bending of the above measured palm midribs species and that of Beech and Red European pine.

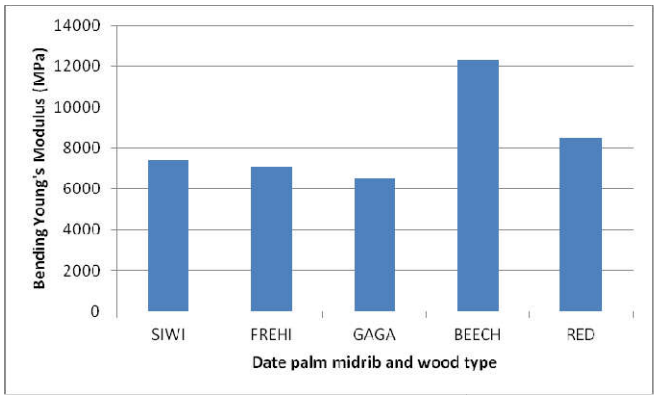

Figure 19. Comparison of the bending Young's modulus of the three date palm species and other wood species

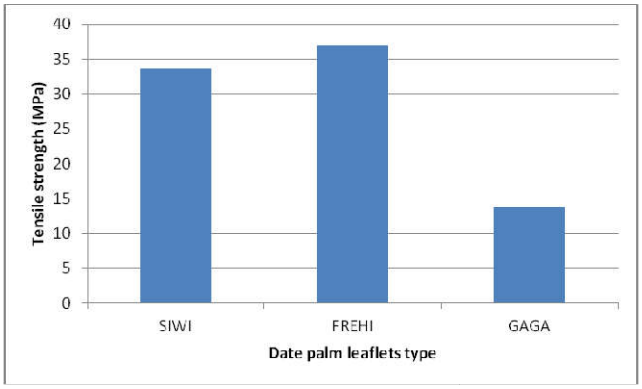

Figure 20. Comparison between tensile strength for the three species of date palm green leaflets

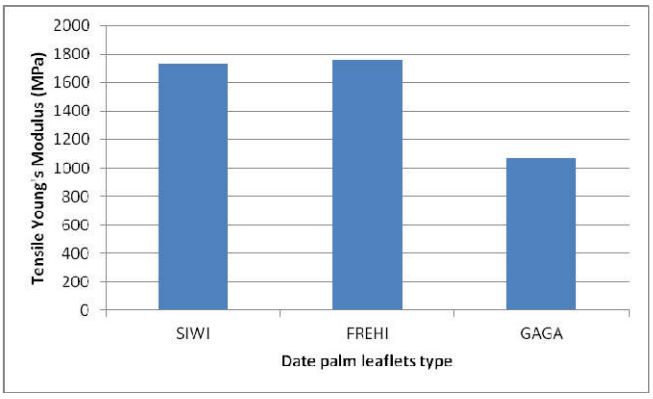

Figure 21. Comparison between tensile Young's modulus for the three species of date palm green leaflets

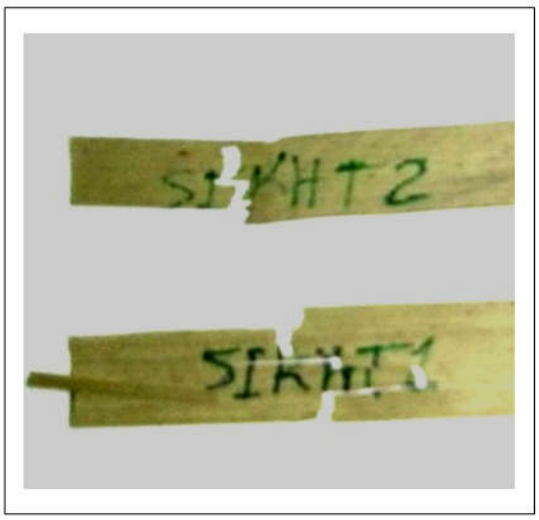

Figure 22. The pattern of failure for the date palm leaflets during the tension test

It is clear from the figure that the values of Young's modulus in bending for the Siwi, Frehi, and Gaga are near to that of the Red European pine (less than Red European pine by 12.84%, 16.45%, and 23.07% respectively).

Tensile test for date palm leaflets

Table 7 and Figure 20 show the tensile strength of the three species of date palm leaflets (Siwi, Frehi, GaGa). The results illustrate that Frehi date palm leaflets have the highest tensile strength, amounting to 37 Mpa and 38.9 Mpa for green and dry species respectively. Table 7 and Figure 21 show the Young's modulus in tension of the three species of date palm leaflets (Siwi, Frehi, GaGa). Results illustrate that Frehi date palm leaflets have the highest Young's modulus in tension, amounting to 1758 Mpa, and 2448 Mpa for green and dry specimen respectively. Figure 22 illustrates the pattern of failure of the palm leaflets during the tension test**.** A comparison has been performed between the results of tension properties average for the three date palm leaflets. The results show that Frehi date palm leaflets have the highest tensile strength, amounting to 37 Mpa and 38.9 Mpa for green and dry species respectively, and Young's modulus in tension, amounting to 1758 Mpa, and 2448 Mpa for green and dry specimen respectively as shown in (Table 7).

Conclusion

- The Frehi midribs have the highest values of bending strength, compression Young's modulus.
- The Siwi midribs have the highest values for bending Young's modulus, and transverse shear strength
- The GAGA midribs have the highest values of compression strength, and longitudinal shear strength
- The Frehi leaflets have the highest value of tensile strength, while Siwi leaflets have the highest value of tensile Young's modulus.
- All tested species of date palm midribs have bending strength values adjacent to those of Red European pine wood. Thus, the date palm midribs could be used as an alternative to wood because of their high availability potential.

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