



Nutritional Value, Phytochemical Composition, and Antioxidant Activities of *Phoenix dactylifera L.*: Comparison Between Fleshes and Seeds of Tunisian and Algerian Varieties

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Abstract

Purpose Date palm (*Phoenix dactylifera L.*) cultivation has developed worldwide. Increased cultivation has a direct and profound impact on the development of low-quality dates and their waste.

Methods This study compares the Kentichi and Mech-Degla flesh powder (KFP and MFP) and their seeds (KSP and MSP) in order to assess physicochemical and nutritional components and antioxidant activity.

Results For fruit flesh, physicochemical compositions, phytochemical compositions, and antioxidant capacity are as follows: pH (6.3–5.6), ash (1.0–1.9%), total sugars (67.9–64.8%), proteins (3.8–2.8%), total phenolic (232.0–167.7 mg GAE/100 g DW), condensed tannins (10.3–15.8 mg CE/100 g DW), (DPPH IC₅₀ = 3.6–5.2 mg/mL, ABTS IC₅₀ = 0.6–3.2 mg/mL, FRAP = 16.9–10.6 μmol AAE/mL DW and, TAA = 22.0–19.1 μmol Fe(II)/mL DW) in KFP and MFP, respectively. Corresponding values in seeds were as follows: pH (5.6–6.1), ash (2.6–2.8%), total sugars (10.6–5.6%), proteins (5.4–4.0%), total phenolic (8012.7–4095.0 mg GAE/100 g DW), condensed tannins (3246.4–665.6 mg CE/100 g DW), (DPPH IC₅₀ = 0.04–0.2 mg/mL, ABTS IC₅₀ = 0.02–0.08 mg/mL, FRAP = 85.9–35.1 μmol AAE/mL DW and, TAA = 125.3–50.5 μmol Fe(II)/mL DW) in KSP and MSP, respectively. Principal Component Analysis indicated that Kentichi cultivar has specific characteristics compared Mech-Degla cultivar. The sugar profile of KFP and KSP after analysis by HPLC shows KFP contains 58.8% sucrose, 23.3% glucose, and 18.0% fructose, while KSP had fructose 0.3%, glucose 0.2%, sucrose 3.8%.

Conclusion The examined dates' flesh and seed were extremely valuable nutritionally and had high antioxidant activity, valorizing them as potential building ingredients for functional foods.

Keywords Date flesh · Date seed · Nutritional composition · Polyphenolic content · Antioxidant activity · Principal component analysis

1 Introduction

One of the oldest and most well-known fruit trees in the world is the date palm (*Phoenix dactylifera L.*), a monocotyledonous woody perennial of the *Arecaceae* family [1], that is especially prevalent in the arid and semiarid regions [2]. Iraq, Egypt, Saudi Arabia, Tunisia, Algeria, the United Arab Emirates, Oman, Libya, Pakistan, and Sudan are the world's leading date palm producers [3]. In recent years, Tunisian

dates exports are at the top of the world ranking, Algeria is the world's third-largest producer of date palm fruits and the seventh-largest exporter [4]. It plays an essential part from economic, social, and ecological standpoints [5].

Date palm fruits are well-known for their numerous health benefits due to their high phenolic component and antioxidant potential [6]. Agronomically, the Tamar stage in date palm fruit growth lasts around 200 days from pollination to full maturity [5]. According to pomology, date palm fruit is composed of a fleshy pericarp around a seed [7]. The fleshy pericarp is consumed in a variety of processed forms, such as dough and jam, due to its high nutritional value [5]. Moreover, seeds are considered a waste product generated by date palm industries [8] and are mostly employed in

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animal food [9]. Seeds can also be transformed into foods like decaffeinated coffee and cosmetics [10].

Several researchers on the composition of date palm varieties (flesh and seed) have been published; according to Ibrahim et al. [11] dates contain nutrients such as protein, fiber, fat, minerals, and vitamins. In addition, the most important components of date fruits are carbohydrates, which include soluble sugars (glucose, fructose, and sucrose) as well as dietary fiber (cellulose, hemicelluloses, pectin, and fructans) [12]. Dates are high in phenolic antioxidants, although their value varies according to the variety of dates, agronomic, and environmental conditions [13]. On the other hand, Date seeds contain a larger proportion of protein (essential amino acids) and fat than date pulp [14], and it's also rich in dietary fibers [15]. Among secondary metabolites, polyphenols comprise one of the largest groups [10].

The date palm is one of the most essential fruits for human health due to dates (flesh and seed) antioxidants may protect the body from various degenerative conditions by lowering oxidative stress caused by phenolic components that inhibit oxidative damage of nucleic acids, proteins, and lipids and activating both enzymatic and non-enzymatic antioxidant mechanisms [16].

Compositional research on Tunisian and Algerian date palm varieties are few, particularly those devoted to describing both flesh and seeds to promote them as potential components for functional food formulation, highlighting the work's novelty. The objectives of this study were to investigate the nutritional composition of the two parts of the date fruit (flesh and seeds) (sugar content, lipids, proteins, phytochemical compositions, and antioxidant activity), assess the interrelationships between parameters using Principal Component Analysis, and determine the free sugars composition of the Tunisian variety.

2 Material and Methods

2.1 Plant Material

Two varieties of date palm fruits were used in this work, a Tunisian variety (Kentichi) and an Algerian variety (Mech-Degla) in Tamar stage (fully mature). Flesh and seeds of dates were cleaned, dried at 50 °C for 15 min, and ground using a mortar for the seeds and using a coffee grinder for the flesh into a fine powder (500 µm of diameter). Kentichi flesh and seed powders (KFP and KSP) and Mech-Degla flesh and seed powders (MFP and MSP) were kept in airtight bottles in the refrigerator at 4 °C until they were needed [17].

2.2 Analytical Methods

The water, dry matter, ash, organic matter, pH, titrable acidity, and fat contents of KFP, KSP, MFP, and MSP) were analyzed according to the standard analytical method [18]. The sulfuric acid and phenol method was used to determine the total sugar content [19]. Using the DNS method to determine the content of reducing sugars [20], with glucose as a standard for total and reducing sugars. The sucrose content was calculated using the formula established by Chafi et al. [21] using the following Eq. 1:

$$\text{Sucrose (\%)} = (\text{total sugars (\%)} - \text{reducing sugars (\%)}) \quad (1)$$

The protein assay is performed using the method of Lowry [22], using bovine serum albumin as a standard. All experiments were performed in triplicate.

2.3 Free Sugars Analysis

The contents of fructose, glucose, sucrose, maltose, and lactose were determined using the HPLC technique. A 0.45 µm filter was used to filter KFP and KSP. The analytical standards and samples were injected individually in equal quantities (5 µL). HPLC analysis was performed out using liquid chromatography and a diode-array detector (DAD). Shimadzu SHIMPACK VP-ODS 4.6 150 mm, 5 µm RP column was used for separation. A combination of methanol and distilled water (10:90 v/v) was utilized as the mobile phase for the chromatographic analysis. A 5 µL volume was injected at a rate of 1.2 mL/min for 20 min, throughout the experiment the temperature of the column was kept constant at 30 °C [23].

2.4 Phytochemical Composition

Secondary metabolites demonstrated alkaloids, saponins, and terpenoids using the method of Bidie et al. [24].

The presence of alkaloids was determined by combining 2 mL of each aqueous extract with a few drops of iodized potassium iodide, which produced a brown-black precipitate and indicated a positive reaction. To test for saponins, 1 mL of each aqueous extract was mixed with 3 mL of distilled water in a test tube. For 2 min, the tube is stirred. Saponins are present when the persistent foam height exceeds 1 cm. 2.5 mL of each aqueous extract was mixed with 1 mL of chloroform to test for terpenoids. After homogenization, 1.5 mL of sulfuric acid was added. A positive reaction is indicated by the formation of a reddish-brown color.

2.5 Fat-Soluble Pigment Content

The determination of the content of fat-soluble pigments is based on the method of Barros et al. [25]. For 1 min, a fine dried powder (150 mg) was rapidly agitated with 10 mL of acetone-hexane combination (4:6) and filtered through Whatman No. 4 filter paper. At 453, 505, 645, and 663 nm, the absorbance of the filtrate was measured.

It is calculated as follows Eqs: 2, 3, 4, and 5.

$$\beta - \text{carotene} \left(\frac{\text{mg}}{100} \text{mL} \right) = 0.216 \times A_{663} - 1.220 \times A_{645} - 0.304 \times A_{505} + 0.452 \times A_{453} \quad (2)$$

$$\text{Lycopene} \left(\frac{\text{mg}}{100} \text{mL} \right) = -0.0458 \times A_{663} + 0.204 \times A_{645} - 0.304 \times A_{505} + 0.452 \times A_{453} \quad (3)$$

$$\text{Chlorophyll a} \left(\frac{\text{mg}}{100} \text{mL} \right) = 0.999 \times A_{663} - 0.0989 \times A_{645} \quad (4)$$

$$\text{Chlorophyll b} \left(\frac{\text{mg}}{100} \text{mL} \right) = -0.328 \times A_{663} + 1.77 \times A_{645} \quad (5)$$

2.6 Extracts Preparation

The active molecule amount was determined using a modified Bigrali et al. [26] methodology. A part of the samples (100 g) were steeped in 300 mL of methanol for 24 h with the aid of a magnetic stirrer before being filtered through filter paper. The supernatant was concentrated employing a rotary evaporator at 40 °C and kept in dark glass bottles at 4 °C until it was utilized.

2.7 Total Phenolic Content

The total phenolic content (TP) was determined using the colorimetric technique and the Folin-Ciocalteu reagent [27]. 100 μL of each extract is combined with 500 μL of diluted Folin reagent and 1 mL of distilled water. 1.5 mL of Na_2CO_3 (20%) is added and properly mixed after one minute of incubation. After 2 h in the dark, absorbance at 760 nm was measured. The findings are presented in milligrams of gallic acid equivalents per 100 g of dry weight.

2.8 Total Flavonoid Content

The total flavonoid content (TF) was assessed using the colorimetric method with aluminum chloride as the reagent and quercetin as the standard, as described by Biglari et al. [26]. Each extract was combined with 1.5 mL of a 2% (AlCl_3 ,

$6\text{H}_2\text{O}$) solution. The absorbance was measured at 367 nm after 10 min incubation at room temperature. The findings are expressed in milligrams of quercetin equivalents (QE) per 100 g of dry weight.

2.9 Flavonol Content

Flavonol content (F) is carried out by the colorimetric method Jimoh et al. [28]. Using rutin as a standard. 500 mL of extracts were mixed with an equal volume of aluminum chloride (2%) and sodium acetate solutions (5%). After incubation for 2.5 h at room temperature, the absorbance was measured at 440 nm. The results are expressed in milligrams of rutin equivalents (RE) per 100 g of dry weight.

2.10 Condensed Tannins Content

The technique of Laouini et al. [29] is used to evaluate the condensed tannins content (CT), with catechin as a standard. A volume of 0.5 mL extract was mixed with 3 mL of vanillin and methanol (4%), and 1.5 mL of hydrochloric acid was added and thoroughly mixed. The resulting mixture was allowed to stand at 20 °C for 15 min. Each absorbance was measured at 500 nm. The findings are expressed in milligrams of catechin equivalents (CE) per 100 g of dry weight.

2.11 Hydrolyzable Tannins Content

Hydrolyzable tannins content (HT) is determined by the method of Willis and Allen [30], using tannic acid as a standard. 0.5 mL of extracts is added to a volume of 2.5 mL of the 2.5% potassium iodate solution. After incubation for 4 min at room temperature in the dark, the absorbance was measured at 550 nm. The results are expressed in milligrams of tannic acid equivalents (TAE) per 100 g of dry weight.

2.12 Antioxidant Activity

Antioxidant activity was determined by the phosphomolybdate method (TAA), reducing power (FRAP), and scavenging different radicals (DPPH and ABTS).

2.13 Antioxidant Activity by the Phosphomolybdate Method

The total antioxidant activity (TAA) of a sample in the phosphomolybdenum method was determined by the reduction of molybdenum Mo (VI) to molybdenum Mo (V) in the presence of antioxidant compounds, resulting in the formation of a green phosphate/complex Mo (V) at acidic pH [31], with ascorbic acid as a standard. 0.3 mL of extracts was combined with 3 mL of reagent solution

(0.6 M sulfuric acid, 28 mM sodium phosphate, and 4 mM ammonium molybdate). This combination is incubated in a 95 °C water bath for 90 min before being cooled at room temperature for 6 min. At 695 nm, absorbance was observed. Results are expressed as micromole of ascorbic acid equivalents per milliliter.

2.14 Antioxidant Activity by the FRAP Method (Ferric Reducing Antioxidant Power)

The FRAP method described by Oyaizu [32] was used to reduce power. The objective of this technique is to assess the ability of ferric iron (Fe^{3+}) in the ferrous iron complex (Fe^{2+}) to be reduced. As a standard, iron sulfate (FeSO_4) is used. 1 mL of the extracts was mixed with 2.5 mL of a 1% potassium ferrocyanide [$\text{K}_3\text{Fe}(\text{CN})_6$] solution and 2.5 mL of phosphate buffer (0.2 M; pH 6.6). Then the mixture is incubated at 50 °C for 20 min. To stop the reaction 2.5 mL of 10% trichloroacetic acid are added. After centrifugation at 6504 rpm/10 min, 2.5 mL of supernatant are added to 2.5 mL of distilled water and 0.5 mL of 0.1% iron chloride (FeCl_3). At 700 nm, the absorbance of the reaction media is measured. The results are expressed as micromoles of ferrous iron (Fe II) equivalents per milliliter.

2.15 DPPH Radical Scavenging Activity

The ability of (KFP, KSP, MFP, and MSP) to scavenge 2,2-diphenyl-2-picrylhydrazyl free radicals (DPPH) was determined by the Jan et al. [33] method. The results are expressed as a percentage of inhibition; radical scavenging activity (%) was calculated using the following Eq. 6:

$$\text{DPPH scavenging activity}(\%) = \left(\frac{A_{\text{control}} - A_{\text{sample}}}{A_{\text{control}}} \right) \times 100 \quad (6)$$

where $\text{Abs}_{\text{control}}$ is the absorbance of DPPH· in methanol instead of samples. The antioxidant capacity of the various extracts was determined from the IC_{50} , which corresponds to a concentration necessary to reduce 50% of the DPPH· radical, it was calculated graphically from the percentage of inhibition relative to the concentration of the extracts.

2.16 ABTS Radical Scavenging Activity

The ability of (KFP, KSP, MFP, and MSP) to scavenge free radicals (2,2'-Zinobis- (3 ethylbenzothiazoline)-6-sulfonic acid ammonium salt) radical ABTS. The preparation of the ABTS⁺ radical is carried out according to the method described by Jan et al. [33]. The results are expressed as a percentage of inhibition; radical scavenging activity (%) was calculated using the following Eq. 7:

$$\text{ABTS scavenging activity}(\%) = \left(\frac{A_{\text{control}} - A_{\text{sample}}}{A_{\text{control}}} \right) \times 100 \quad (7)$$

where $\text{Abs}_{\text{control}}$ is the absorbance of ABTS· in ethanol instead of samples. The antioxidant capacity of the various extracts was determined from the IC_{50} , which corresponds to a concentration necessary to reduce 50% of the ABTS· radical, it was calculated graphically from the percentage of inhibition relative to the concentration of the extracts.

2.17 Statistical Analysis

Principal component analysis (PCA) was performed in IBM SPSS version 22 software on a data set (Physico-chemical compositions, DPPH·, ABTS·⁺, FRAP, and TAA) obtained for samples. PCA is a very powerful chemometric approach that allows for sample grouping. The original variables are decreased, and the new ones acquired after various mathematical transformations provide us with a better understanding of groupings and correlations between investigated samples.

3 Results and Discussion

3.1 Physico-Chemical Composition and Nutrient Analysis

The pH of KFP and MFP was 6.3 and 5.6, respectively, while KSP and MSP showed values of 5.6 and 6.1, respectively (Table 1). These results show a significant difference between the flesh and between the seeds ($P \leq 0.05$). These results are consistent with the findings of other researchers; Khali et al. [34] found values pH between 5.8 and 6.1. On the other hand, our study's pH values are lower than those previously discovered by Pasha et al. [35], for commercially available dates mucilage (6.7). The pH variance could be attributed to climate change. According to Barnaud et al. [36], despite differences in various factors potentially impacting berry pH, the climate is the primary determinant. KFP and MFP were analyzed for titrable acidity, which was found to be 1.9 and 3.4%, respectively, with a significant difference between the two varieties ($P \leq 0.05$). While KSP and MSP had values of 0.2 and 0.1%, respectively (Table 1), the analysis found no significant difference between these two varieties ($P \geq 0.05$). These acidity values were comparable to those reported by Di Cagno et al. [37], who obtained a value of 0.3% for date variety grown in Egypt.

In fact, the water content in MFP and KFP is 12.3 and 13.3% compared to 8.9 and 9.0% in MSP and KSP,

Table 1 Physico-chemical composition of date powders Kentichi and Mech-Degla flesh and seed

Parameters	Flesh		Seed	
	KFP	MFP	KSP	MSP
pH	6.3 ± 0.07 ^a	5.6 ± 0.04 ^b	5.6 ± 0.19 ^b	6.1 ± 0.01 ^a
Titrate acidity (%)	1.9 ± 0.15 ^b	3.4 ± 0.31 ^a	0.2 ± 0.03 ^a	0.1 ± 0.02 ^a
Water content (%)	13.3 ± 0.44 ^a	12.3 ± 0.44 ^a	9.0 ± 1.26 ^a	8.9 ± 0.26 ^a
Dry matter (%)	86.7 ± 0.44 ^a	87.7 ± 0.44 ^a	91.0 ± 1.26 ^a	91.2 ± 0.26 ^a
Ash (%)	1.0 ± 0.37 ^b	1.9 ± 0.10 ^a	2.6 ± 0.62 ^a	2.8 ± 0.49 ^a
OM (%)	99.0 ± 0.37 ^a	98.1 ± 0.10 ^b	97.4 ± 0.62 ^a	97.3 ± 0.49 ^a
C*	30.4 ± 0.004 ^a	28.5 ± 0.004 ^b	30.1 ± 0.004 ^a	26.5 ± 0.04 ^b
Fat (%)	0.2 ± 0.02 ^b	0.6 ± 0.04 ^a	8.6 ± 0.42 ^a	8.5 ± 0.45 ^a
Protein (g/100 g DW)	3.8 ± 0.02 ^a	2.8 ± 0.008 ^b	5.4 ± 0.02 ^a	4.0 ± 0.04 ^b
Total sugars (g/100 g DW)	67.9 ± 0.38 ^a	64.8 ± 0.61 ^b	10.6 ± 0.03 ^a	5.6 ± 0.01 ^b
Reducing sugars (g/100 g DW)	8.9 ± 0.03 ^b	14.0 ± 0.03 ^a	5.8 ± 0.06 ^a	3.1 ± 0.01 ^b
Sucrose (g/100 g DW)	51.8 ± 0.33 ^b	53.6 ± 0.61 ^a	4.6 ± 0.09 ^a	2.5 ± 0.006 ^b
Terpénoides	+	+	+	+
Alcaloïdes	+	+	+	+
Saponines	–	–	–	–
TP (mg GAE/100 g DW)	232.0 ± 6.44 ^a	167.7 ± 1.58 ^b	8012.7 ± 28.06 ^a	4095.0 ± 29.70 ^b
TF (mg QE/100 g DW)	122.5 ± 2.08 ^a	114.5 ± 0.69 ^b	373.8 ± 10.86 ^a	78.8 ± 0.81 ^b
F (mg RE/100 g DW)	7.8 ± 0.008 ^a	6.2 ± 0.1 ^b	371.8 ± 17.22 ^a	25.0 ± 0.60 ^b
CT (mg CE/100 g DW)	10.3 ± 1.28 ^b	15.8 ± 0.64 ^a	3246.4 ± 13.61 ^a	665.6 ± 7.55 ^b
HT (mg ATE/100 g DW)	0.01 ± 0.0015 ^a	0.01 ± 0.0012 ^a	14.7 ± 1.35 ^a	4.1 ± 0.06 ^b
β-Carotenes (mg/100 g DW)	0.4 ± 0.02 ^a	0.3 ± 0.03 ^a	0.3 ± 0.005 ^a	0.04 ± 0.01 ^b
Lycopenes (mg/100 g DW)	0.1 ± 0.003 ^a	0.06 ± 0.0009 ^b	0.1 ± 0.004 ^a	0.2 ± 0.01 ^a
Chlorophylls a (mg/100 g DW)	0.7 ± 0.011 ^a	0.8 ± 0.011 ^a	0.4 ± 0.006 ^a	0.02 ± 0.0004 ^b
Chlorophylls b (mg/100 g DW)	0.6 ± 0.03 ^a	0.5 ± 0.04 ^a	0.4 ± 0.01 ^a	0.01 ± 0.002 ^b

The values given are the means of three repetitions ± standard deviation. Means with different letters (a,b) in a row are significantly different at $P \leq 0.05$ according to the SNK test

DW Dry weight, MO Organic matter, AGE Gallic acid equivalents, QE Quercetin equivalents, RE Rutin equivalents, CE Catechin equivalents, ATE Tannic acid equivalents, + Positive, – Negative

respectively (Table 1). The flesh results are nearly higher than those of Yefsah-Idres et al. [17] (12.1%), while the seed results are similar to Herchi et al. [38], who worked on the same Kentichi variety, they discovered 9.2%. It is also worth noting that date fruit moisture has been known to decline dramatically throughout ripening, reaching a low value at the Tamar stage [39]. However, this study showed that the dry matter of KFP and MFP is about 86.7 and 87.7%, whereas KSP and MSP are approximately 91.0 and 91.2%, respectively (Table 1). The analysis shows no significant difference between the two varieties ($P \geq 0.05$). These results were similar of Noui et al. [40], who reported values between 88.0 and 88.4% for Algerian varieties.

The organic matter and ash levels were respectively 99.0 and 1.0% in KFP and 98.1 and 1.9% in MFP (Table 1), the results indicate a significant difference between the two dates ($P \leq 0.05$). On the other hand, the organic matter and ash levels were respectively 97.4 and 2.6% in KSP and 97.3 and 2.8% in MSP (Table 1), the results indicate no significant difference between the two seeds ($P \geq 0.05$). The

findings of ash are situated in the range of those reported by Benmeziiane Derradji [41] who obtained values ranging between 1.5 to 6.2% for date cultivars grown in UAE, Saudi Arabia, and Tunisia.

The C* values of KFP and MFP was 30.4 and 28.5, respectively, while KSP and MSP demonstrated values of 30.1 and 26.5, respectively (Table 1). These results show that KFP and KSP have a more intense and significantly darker color than MFP and MSP. Abdul-Hamid et al. [42] measured the color of nine varieties of Saudi dates and obtained values that differed from our results. Dates fruit color is a great quality indication; it is related to secondary metabolite formation and accumulation, such as phenolic and terpenoid components [43].

Moreover, the total protein and fat levels were respectively 3.8 g/100 g DW and 0.2% in KFP and 2.8 g/100 g DW and 0.6% in MFP (Table 1). Analysis indicated a significant difference between these two varieties. For seed, the results of the fat show no significant difference between the two varieties ($P \geq 0.05$). In fact, the fat in KSP and MSP is 8.6

and 8.5%, respectively (Table 1). On the other hand, the total protein was 5.4 and 4.0 g/100 g DW in KSP and MSP, respectively. The results indicate a significant difference ($P \leq 0.05$). Ibourki et al. [5] state that the protein content of flesh ranges between 1.6 and 3.5%, whereas the protein content of seeds varies between 3.2 and 5.0% for cultivars grown in Morocco. Our results regarding fat of flesh were comparable to those reported by Oladzad et al. [44] (0.1–3.3%). When compared to commercial cultivars, our findings are higher than those of Ahmed et al. [45], who found protein levels ranging from 1.9 to 3.0 g/100 g FW.

Messadi et al. [46] showed that Kentichi date powder extract contains the majority of the essential amino acids. As a result, Kumar et al. [47] revealed that the optimum digestion of proteins from different plant origins can deliver adequate amino acids to suit human health requirements.

However, the level of total sugars in MFP and KFP is 64.8 and 67.9 g/100 g DW, of which 14.0 and 8.9 g/100 g DW are reducing sugars, the major fraction of sugars is composed mainly of sucrose with a content of 53.6 and 51.8 g/100 g DW, respectively. While MSP and KSP contain 5.6 and 10.6 g/100 g DW of total sugars, reducing sugars are 3.1 and 5.8 g/100 g DW, of which 2.5 and 4.6 g/100 g DW are sucrose, respectively (Table 1). The total sugars, reducing sugars, and sucrose contents show a significant difference ($P \leq 0.05$) between the two dates studied. In fact, the immediate carbohydrate composition of the fleshes date powders was in the same ranges as those obtained by Djaoudene et al. [48]. But, the seeds' carbohydrate content is higher than that found by Metoui et al. [49], who examined the total sugar of 12 Tunisian cultivars and found values between 1.2 and 3.8%. Our results are higher than those published by Ahmed et al. [45], who indicated that commercial cultivars had total sugar contents between 44.3 and 64.1 g/100 g FW.

Sugars provide a variety of purposes in the food industry, including conservation, fermentation, color, flavor, consistency, solubility, hygroscopicity, crystallinity, and viscosity [50].

These differences in the physicochemical compositions can be explained by various factors such as the origin of the plants (species, cultivar), the growing conditions, the maturity, the season, the geographical origin, the fertilization, the type of soil, storage conditions, drying, rate of sun exposure, and harvest period [51].

3.2 Phytochemical Composition

Table 1 shows the phytochemical composition of KFP, MFP, KSP, and MSP. The search for saponins has been negative. On the other hand, terpenoids and alkaloids are present in considerable quantities. This is consistent with other works that have reported that dates are rich in phytochemicals [52].

In addition, the present study has shown that the phenolic levels are 167.7 and 232.0 mg EAG/100 g DW, respectively for MFP and KFP. While MSP and KSP have polyphenol content of 4095.0 and 8012.7 mg EAG/100 g DW, respectively. For seed, our results are far higher than those found by Maqsood et al. [53] and Mani et al. [54], who reported values between 269.7 and 4430 mg AGE/100 g.

The total phenolic content could be a good indicator of antioxidant activity. Their redox characteristics are primarily responsible for their action; they may scavenge reactive oxygen species, neutralize free radicals, and degrade peroxides [55].

However, the flavonoid levels observed for MFP and KFP are 114.5 and 122.5 mg EQ/100 g DW, respectively, and 78.8 and 373.8 mg EQ/100 g DW for MSP and KSP, respectively. These results are higher than those found by other researchers [56, 57]. These compounds have a wide range of chemical and biological activity, including radical scavenging abilities [26].

On the other hand, the flavonol contents of MFP and KFP are 6.2 and 7.8 mg ER/100 g DW. Likewise, the flavonol contents of MSP and KSP are 25.0 and 371.8 mg ER/100 g DW, respectively. These values fall within the range noted by Benmeddour et al. [58], which are between 6.7 and 36.6 mg RE/100 g.

In fact, the results showed that MFP and KFP have condensed tannin contents of 15.8 and 10.3 mg EC/100 g DW, respectively, whereas MSP and KSP have 665.6 and 3246.4 mg EC/100 g DW, respectively. MFP and KFP contain the same amount of hydrolyzable tannins (0.01 mg EAT/100 g DW), the analysis found no significant difference between these two varieties ($P \geq 0.05$), whereas MSP and KSP contain 4.1 and 14.7 mg EAT/100 g DW, respectively. Condensed tannins' results are within the range discovered by Alahyane et al. [59], who worked on 17 Moroccan date varieties, and determined values between 5.3 and 152.2 mg CE/100 g DW.

The fat-soluble pigments of KFP and MFP are 0.4 and 0.3 mg/100 g DW for β -Carotenes, of which 0.1 and 0.06 mg/100 g DW are lycopene, 0.7 and 0.8 mg/100 g DW are chlorophylls a and 0.6 and 0.5 mg/100 g DW are chlorophylls b, whereas KSP and MSP contain 0.3 and 0.04 mg/100 g DW β -Carotenes, lycopene is 0.1 and 0.2 mg/100 g DW, of which 0.4 and 0.02 mg/100 g DW are chlorophylls a and 0.4 and 0.01 mg/100 g DW are chlorophylls b. The β -Carotene results are low when compared to the results estimated by Boudries et al. [60], which are between 2.5 and 6.4 μ g/100 g. However, the lycopene results are comparable to those reported by Habib et al. [61] found lower values of lycopene (0.1 mg/100 g date seed) from a well-known commercial date in the UAE. Additionally, Herchi et al. [38] showed that the chlorophyll

value is 0.1 mg /100 g oil; our findings of chlorophyll a and b are high.

The phenolic components have a protective impact on human health [62]. Phenolic compounds are governed by several factors; including date variety, geographic origin, fruit storage time, extraction conditions such as solvent used, plant material/solvent ratio, and extraction time [63].

3.3 Antioxidant Activity

The antioxidant activity of KFP, MFP, KSP, and MSP as determined by the TAA and FRAP methods is shown in Table 2. The two types of dates' flesh and seed differ significantly ($P \leq 0.05$). The results show that the TAA method has a concentration of 22.0 and 19.1 $\mu\text{mol AAE/mL DW}$, respectively in KFP and MFP. However, KSP and MSP both have extremely high activity, registering 125.3 and 50.5 $\mu\text{mol AAE/mL DW}$, respectively. The results of Ali Haimoud et al. [64] for the flesh are higher than ours, but they are lower than the seed results (42.8–90.3 $\mu\text{mol AAE/mL}$ of extract).

The FRAP test has an activity which is 16.9 and 10.6 $\mu\text{mol Fe(II)E/mL DW}$, respectively in KFP and MFP. In addition, the FRAP of KSP and MSP is 85.9 and 35.1 $\mu\text{mol Fe(II)E/mL DW}$, respectively (Table 2). There was a significant difference ($P \leq 0.05$) between the two varieties of dates studied. The flesh findings are higher than those provided by Alam et al. [13], which range from 2.0 to 12.5 $\mu\text{mol TE/mL}$ sample. However, the seed results are higher than those obtained by Jabeen et al. [14], who discovered FRAP antioxidant activity in the order of 41.3 $\mu\text{mol Fe(II)/g DW}$ with 250 $\mu\text{g/mL}$ of date seed extract.

Table 2 depicts the anti-free radical activity (DPPH) and (ABTS) of KFP, MFP, KSP, and MSP in comparison with BHT as a positive control.

The antioxidant activity (DPPH) in KFP has an IC_{50} value of 3.6 mg/mL, whereas the concentration in MFP is 5.2 mg/mL. There was a significant difference ($P \leq 0.05$) between the two varieties of dates studied. None of the dates' flesh exceeded the positive control's (BHT) 0.2 mg/mL exhibiting value. The IC_{50} of KSP and MSP is 0.04 and 0.2 mg/mL, respectively. There was a significant difference ($P \leq 0.05$) between the two seeds. MSP and BHT have comparable IC_{50} values. However, the IC_{50} of KSP was 5 times lower than the control, showing that it has an extremely high DPPH radical scavenging ability. The DPPH test's IC_{50} results are significantly high than those provided by Djaoud et al. [65] found a concentration of DPPH of 24.3 mg/mL after extracting pectin from an Algerian common variety.

The ABTS test results showed a significant difference between the two types of dates flesh and seed ($P \leq 0.05$). The results show that KFP and MFP had IC_{50} concentrations of 0.6 and 3.2 mg/mL, respectively. Nonetheless, the KFP and MFP have been less efficient than the control BHT (0.07 mg/mL). On the other hand, the IC_{50} of KSP and MSP is 0.02 and 0.08 mg/mL, respectively. The date seeds had high antioxidant activity, as evidenced by their low IC_{50} when compared to BHT. For the ABTS, KSP was more active than BHT. The ABTS test results are more active than those obtained by Ourradi et al. [66].

All antioxidant assays came to the same conclusion: date seeds, particularly KSP, have the highest antioxidant activity. According to Guo et al. [67] the date possesses the second-highest antioxidant activity among 28 fruits usually consumed in China. Since the antioxidant activities are directly proportional to the count of polyphenols contained in the extract, the present study finds a significant quantity of

Table 2 Antioxidant activities from date powders Kentichi and Mech-Degla flesh and seed

Variety	TAA ($\mu\text{mol AAE/mL DW}$)	FRAP ($\mu\text{mol Fe(II)E/mL DW}$)	DPPH· (IC_{50} mg/mL)	ABTS· ⁺ (IC_{50} mg/mL)
Fleashes				
KFP	22.0 ± 0.16 ^a	16.9 ± 0.29 ^a	3.6 ± 0.08 ^b	0.6 ± 0.09 ^b
MFP	19.1 ± 0.43 ^b	10.6 ± 0.22 ^b	5.2 ± 0.05 ^a	3.2 ± 0.07 ^a
Seeds				
KSP	125.3 ± 0.07 ^a	85.9 ± 0.18 ^a	0.04 ± 0.67 ^b	0.02 ± 0.66 ^b
MSP	50.5 ± 0.09 ^b	35.1 ± 0.04 ^b	0.2 ± 0.6 ^a	0.08 ± 0.66 ^a
BHT (positive control)	–	–	0.2 ± 0.003	0.07 ± 0.001

The values given are the means of three repetitions ± standard deviation. Means with different letters (a-b) in a row are significantly different at $P \leq 0.05$ according to the SNK test

TAA Total antioxidant activity, FRAP Ferric reducing antioxidant power, DPPH· 2,2-diphenyl-2-picrylhydrazyl radical, ABTS·⁺ 2,2'-zino-bis-(3-ethylbenzothiazoline)-6-sulfonic), IC_{50} Concentration necessary to reduce 50% of the DPPH· radical, AAE Ascorbic acid equivalents, Fe(II)E Sulphate of iron equivalents, BHT Butylated Hydroxytoluene, DW Dry weight

polyphenols in the dates flesh and seed extracts, and the difference in their quantities can be directly attributed to the observed activity [3].

3.4 Principal Component Analysis (PCA)

PCA has been demonstrated to be a successful discriminative technique [68] based on the researched fruit's physical and chemical properties, utilized as a multivariate statistical approach to discriminate among date palm varieties on the one hand and between fruit fleshes and seeds on the other (dependent variables). The first two principal components (PCs) explained 82.58% of the total data variability (63.50 and 19.08% for PC1 and PC2, respectively).

Points shown on the surface determined by axes 1 and 2 (Fig. 1a) are correlated to fruit varieties (flesh) plotted

against physicochemical and phytochemical composition, and antioxidant activity, which appear to be separated along with the first component (PC1). Figure 1b shows the distribution of fleshes versus the analyses performed on the surface determined by PC1 and PC2. From these results, KFP was distributed according to PC1. On the positive side of this component, KFP was correlated with the greatest phytochemical composition, FRAP, TAA, OM, water, protein, and total sugar. It seems that the ABTS, DPPH, and fat were associated, with the positive side of the second component (PC2). MFP was distributed according to PC1, on the negative side of this component with higher values of sucrose, reducing sugars, CT, acidity, ash, dry matter, and chlorophyll a (Fig. 1a). Points on the surface determined by axis 1 and 2 (Fig. 1c) are associated with fruit seeds. Figure 1d represents the distribution of

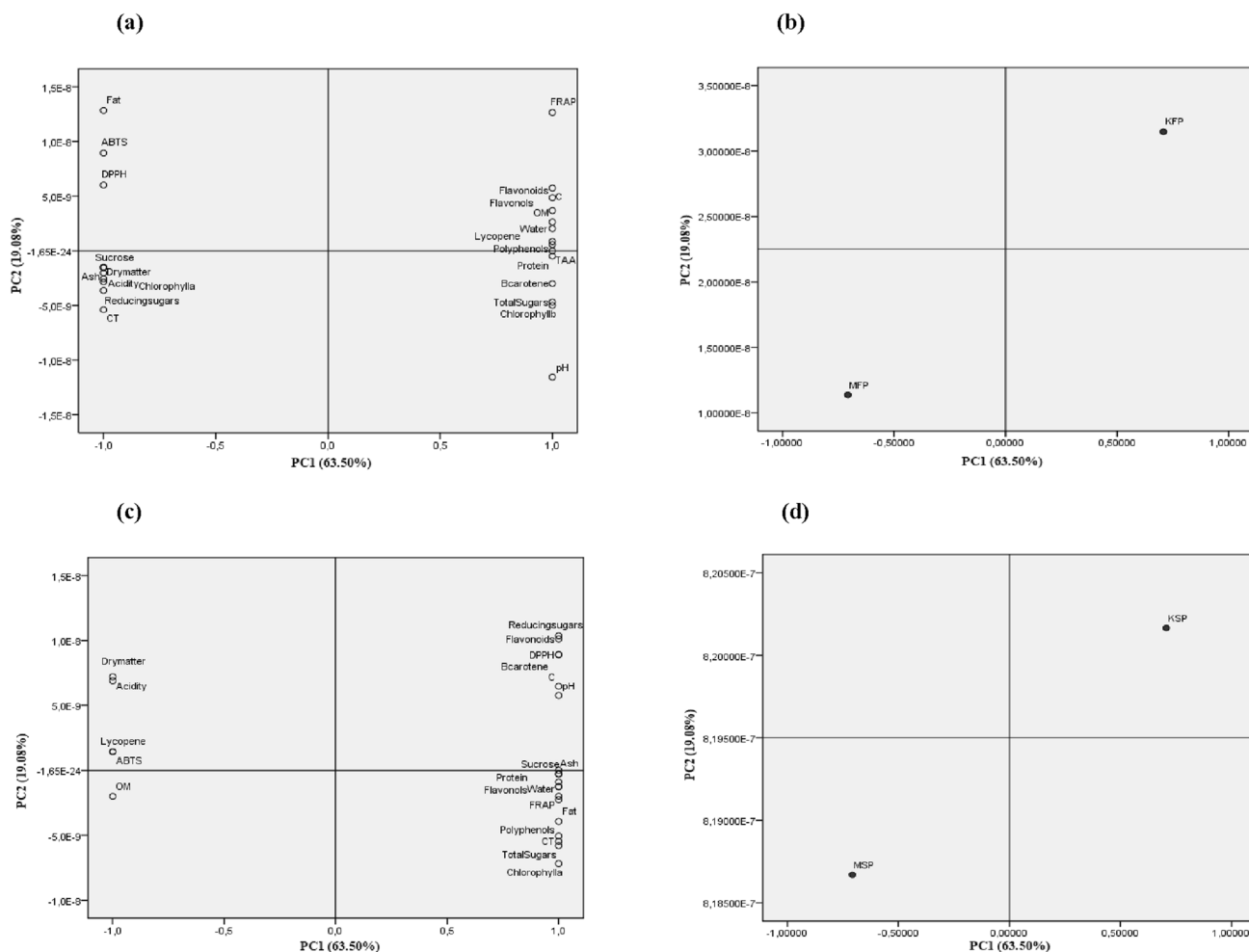


Fig. 1 Principal component analysis (PCA) projections on PC1 and PC2. Plotted points are mean values of each studied parameter including physicochemical characteristics of fruit and antioxidant activity (a, c), and the distribution of fleshes and seeds (b, d)

Table 3 Sugar profiles for date powder Kentichi flesh and seed

Free sugars (%)	KFP	KSP
Fructose	18.0	0.3
Glucose	23.3	0.2
Sucrose	58.8	3.8
Maltose	–	–
Lactose	–	–

– Not detected

seeds in relation to the analyses done on the surface determined by PC1 and PC2.

KSP was distributed in accordance with PC1. On the positive side, KFP showed the highest correlations with both physicochemical and phytochemical composition as well as antioxidant activity. MSP was distributed according to PC1, on the negative side of this component (Fig. 1c). The variety Kentichi (flesh and seed) is plotted following the first component PC1. This indicated that they have higher nutritional profiles than the Mech-Degla variety.

In the literature, as a method for discriminating between varieties and environments based on fruit attributes, PCA is commonly utilized [69]. Based on nutritional, chemical, and seed oil fatty acid profile combined with PCA, Ibouarki et al. [5] successfully separated the seed and flesh of 8 date palm dates cultivated in Morocco.

3.5 Free Sugars Composition

Table 3 illustrates the sugar profile of KFP and KSP after analysis by HPLC. As the data show, one of the most essential components of KFP is sucrose, which is found in greater levels than glucose and fructose. KFP contains 58.8% sucrose, 23.3% glucose, and 18.0% fructose; however, maltose and lactose are no longer present. Furthermore, the date seeds had low sugar levels, while KSP had fructose 0.3%, glucose 0.2%, sucrose 3.8%, and maltose and lactose were absent.

Djaoud et al. [70] obtained in the sugar content of date juices (50.8% sucrose, 20.7% glucose, and 28.6% fructose) from the flesh Algerian common date variety (Degla-Beida), which is commonly underutilized. The seed values are higher than those reported by Kamal et al. [71], who studied the free sugars in 18 date seed varieties from the UAE; the sugar profile is (0.03–0.5% sucrose, 0.09–0.8% glucose, and 0.08–0.8% fructose).

Reducing sugars are mostly composed of glucose and fructose, both of which contribute to the sweet taste and are rapidly absorbed by the human body to produce energy quickly [72]. Nonetheless, sugar contents may change between cultivars even at the same maturation stage due to

known environmental influences impacting nutritional components [73].

4 Conclusion

Overall, our results shed light on the nutritional content and composition of two date cultivars (Mech-Degla and Kentichi) grown in Algeria and Tunisia. Flesh date fruit is a high-nutritional-value source of total sugar, sucrose, and antioxidants. On the other hand, Date seed is commonly utilized as a substance in human health, cosmetics, and pharmaceuticals due to its high content of protein, fat, polyphenolic, and antioxidant activity extreme. Our findings show that the two date cultivars (flesh or seed) produce a necessary nutrient and valuable richness diet with significant potential health advantages. The principal component analysis showed the correlations between different varieties based on physicochemical characteristics and antioxidant activity. The PCA plot revealed that the Kentichi cultivar has significant characteristics that allow it to be distinguished from the Mech-Degla cultivar. Furthermore, the sugar profile of KFP and KSP following HPLC analysis demonstrates that the flesh is richer in sugar, particularly sucrose, than the seed. Due to their nutritional value and high antioxidant activity, date seed and flesh are matrices that could be used as fundamental ingredients in the formulation of functional foods.

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Declarations

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References

1. Safeena MIS, Dissanayake Y, Zakeel MCM, Warnakula L, Cooray R, Dayarathna DARK (2021) An improved method for efficient recovery of high quality DNA from date palm (*Phoenix dactylifera* L.; Arecaceae). *MethodsX* 8:101384
2. Hammadi H, Walid E, Kameleddine N (2021) Date palm seed oil (*Phoenix dactylifera* L.) green extraction: physicochemical

- properties, antioxidant activities, and phenolic and fatty acid profiles. *J Food Qual.* <https://doi.org/10.1155/2021/2394220>
3. Zihad SMNK, Uddin SJ, Sifat N, Lovely F, Rouf R, Shilpi JA, Göransson U (2021) Antioxidant properties and phenolic profiling by UPLC-QTOF-MS of Ajwah, Safawy and Sukkari cultivars of date palm. *Biochem Biophys Rep* 25:100909
 4. Noui N, Douffi M, Ghomrani N (2022) Exports excluding hydrocarbons from dates sector as a diversification strategy, « case of the company SED OASIS of Biskra ». *Revue Sci Econ Gestion Sci Commerciales* 2:333–347
 5. Ibourki M, Azouguigh F, Jadouali SM, Sakar EH, Bijla L, Majourhat K, Gharby S, Lakniffi A (2021) Physical fruit traits, nutritional composition, and seed oil fatty acids profiling in the main date palm (*Phoenix dactylifera* L.) varieties grown in morocco. *J Food Qual* 51:38043
 6. Benouamane O, Vergara-Barberan M, Benaziza A, García-Alvarez-Coque MC, Simo-Alfonso E, Bernard China B, Lerma-García MJ (2022) Characterization of different cultivars of Algerian date palm (*Phoenix dactylifera* L.) leaves and pollen by comprehensive two-dimensional liquid chromatography of phenolic compounds extracted with different solvents. *Microchem J* 182:107874
 7. Tafti AG, Solaimani Dahdivan N, Yasini Ardakani SA (2017) Physicochemical properties and applications of date seed and its oil. *Int Food Res J* 24:1399–1406
 8. Mostafa H, Airouyawa JO, Maqsood S (2022) A novel strategy for producing nano-particles from date seeds and enhancing their phenolic content and antioxidant properties using ultrasound-assisted extraction: a multivariate based optimization study. *Ultrason Sonochem* 87:106017
 9. Ourradi H, Ennahli S, Martos MV, Hernandez F, Dilorenzo C, Hssaini L, Elantari A, Hanine H (2021) Proximate composition of polyphenolic, phytochemical, antioxidant activity content and lipid profiles of date palm seeds oils (*Phoenix dactylifera* L.). *J Agric Food Res* 6:100217
 10. Allaqaband S, Dar AH, Patel U, Kumar N, Nayik GA, Khan SA, Ansari MJ, Alabdallah NM, Kumar P, Pandey VK, Kovács B, Shaikh AM (2022) Utilization of fruit seed-based bioactive compounds for formulating the nutraceuticals and functional food: a review. *Front Nutr* 9:902554
 11. Ibrahim SA, Ayad AA, Williams LL, Ayivi DR, Krastanov GR, A, Aljaloud SO, (2020) Date fruit: A review of the chemical and nutritional compounds, functional effects and food application in nutrition bars for athletes. *J Food Sci Technol* 56(4):1503–1513
 12. Kamal-Eldin A, George N, Sobti B, AlRashidi N, Ghnimi S, Ali AA, Andersson AAM, Andersson R, Antony A, Hamed F (2020) Dietary fiber components, microstructure, and texture of date fruits (*Phoenix dactylifera*, L.). *Sci Rep* 10(1):21767
 13. Alam MZ, Alhebsi MSR, Ghnimi S, Kamal-Eldin A (2021) Inability of total antioxidant activity assays to accurately assess the phenolic compounds of date palm fruit (*Phoenix dactylifera* L.). *Nutr Food Sci* 22:32–40
 14. Jabeen A, Parween N, Sayrav K, Prasad B (2020) Date (*Phoenix dactylifera*) seed and syringic acid exhibits antioxidative effect and lifespan extending properties in *Caenorhabditis elegans*. *Arab J Chem.* <https://doi.org/10.1016/j.arabjc.2020.10.028>
 15. Al-Farsi MA, Lee CY (2017) Nutritional and functional properties of dates: a review. *Crit Rev Food Sci Nutr* 48:877–887
 16. El-Beltagi HS, Aly AA, El-Desouky W (2019) Effect of Gamma irradiation on some biochemical properties, antioxidant and antimicrobial activities of Sakouti and Bondoky dry dates fruits genotypes. *J Radiat Res Appl Sci* 12(1):437–446
 17. Yefsah-Idres A, Benrima A, Hammouchi K, Bennazoug Y (2019) Essai de valorisation de la datte Mechi-Degla par sa substitution au sucre blanc dans la formulation d'un biscuit. *Revue Agrobiol* 9(2):1543–1559
 18. Association of Official Analytical Chemicals (AOAC) (1990) Official methods of analysis (15th edition) Washington.
 19. Dubois M, Gilles KA, Hamilton JK, Rebers PA, Smith F (1956) Colorimetric method for determination of sugars and related substances. *J Anal Chem.* <https://doi.org/10.1021/ac60111a017>
 20. Miller GL (1959) Use of dinitrosalicylic acid reagent for determination of reducing sugar. *J Anal Chem.* <https://doi.org/10.1021/ac60147a030>
 21. Chafi A, Benabbes R, Bouakka M, Hakkou NA, Kouddane Berrichi A (2015) Pomological study of dates of some date palm varieties cultivated in Figuig oasis. *J Mater Environ Sci* 6(5):1266–1275
 22. Lowry OH (1951) Protein measurement with the folin phenol reagent. *J Biol Chem.* [https://doi.org/10.1016/S0021-9258\(19\)52451-6](https://doi.org/10.1016/S0021-9258(19)52451-6)
 23. Alghamdi AA, Awadelkarem AM, Sharif Hossain ABM, Ibrahim NA, Fawzi M, Ashraf SA (2018) Nutritional assessment of different date fruits (*Phoenix dactylifera* L.) varieties cultivated in Hail province Saudi Arabia. *Biosci Biotech Res Comm* 11(2):263–269
 24. Bidie ADF, Nguessan BB, Yapo AF, Nguessan JD, Djama AJ (2011) Activités antioxydantes de dix plantes médicinales de la pharmacopée ivoirienne. *Sci Nat* 8(1):1–11
 25. Barros L, Cabrita L, Boas MV, Carvalho AM, Ferreira ICFR (2011) Chemical biochemical and electrochemical assays to evaluate phytochemicals and antioxidant activity of wild plants. *Food Chem* 127:1600–1608
 26. Biglari F, Abbas FM, Alkarkhi FMA, Easa A (2008) Antioxidant activity and phenolic content of various date palm (*Phoenix dactylifera*) fruits from Iran. *J Food Chem.* <https://doi.org/10.1016/j.foodchem.2007.10.033>
 27. Waterhouse AL (2002) Determination of total phenolics. *Curr Protoc Food Anal Chem.* <https://doi.org/10.1002/0471142913.fai0101s06>
 28. Jimoh FO, Adedapo AA, Afolayan AJ (2010) Comparison of the nutritional value and biological activities of the acetone, methanol and water extracts of the leaves of *Solanum nigrum* and *Leonotis leonorus*. *Food Chem Toxicol* 48(3):964–971
 29. Laouini SE, Kelef A, Ouahrani MR (2018) Free radicals scavenging activity and phytochemical composition of astermisia (*Herba-Alba*) extract growth in Algeria. *J Fundam Appl Sci.* <https://doi.org/10.4314/jfas.v10i1.20>
 30. Willis RB, Allen PR (1998) Improved method for measuring hydrolyzable tannins using potassium iodate. *Analyst* 123(3):435–439
 31. Laloo D, Sahu AN (2011) Antioxidant activities of three Indian commercially available Nagakesar: an in vitro study. *J Chem Pharm Res* 3(1):277–283
 32. Oyaizu M (1986) Antioxidative activities of products of browning reaction prepared from glucosamine Japanese. *J Nutr Diet.* <https://doi.org/10.5264/eiyogakuzashi.44.307>
 33. Jan S, Khan MR, Rashid U, Bokhari J (2013) Assessment of antioxidant potential, total phenolics and flavonoids of different solvent fractions of *Monothea buxifolia* fruit. *J Public Health Res Perspect.* <https://doi.org/10.1016/j.phrp.2013.09.003>
 34. Khali M, Boussen Z, Boutekrabi L (2015) Effet de l'incorporation de dattes sur les caractéristiques technologiques et fonctionnelles de la farine de blé tendre. *Nat Technol B Sci Agron Biol* 12:16–26
 35. Pasha AZ, Anwer Bukhari S, Ali El Enshasy H, Hala El Adawi H, Al Obaid S (2022) Compositional analysis and physicochemical evaluation of date palm (*Phoenix dactylifera* L.) mucilage for medicinal purposes. *Saudi J Biol Sci* 29:774–780
 36. Bouhlali ET, Ramchoun M, Alem C, Ghafoor K, Ennassir J, Zegzouti YF (2015) Functional composition and antioxidant activities of eight Moroccan date fruit varieties (*Phoenix dactylifera* L.). *J Saudi Soc Agric Sci* 16(3):257–264

37. Di Cagno R, Filannino P, Cavoski I, Lanera A, Mamdouh BM, Gobetti M (2017) Bioprocessing technology to exploit organic palm date (*Phoenix dactylifera L.* cultivar Siwi) fruit as a functional dietary supplement. *J Funct Foods* 31:9–19
38. Herchi W, Kallel H, Boukhchina S (2014) Physicochemical properties and antioxidant activity of Tunisian date palm (*Phoenix dactylifera L.*) oil as affected by different extraction methods. *Food Sci Technol* 34(3):464–470
39. Ahmed J, Al-Jasass FM, Siddiq M (2014) Date fruit composition and nutrition. *Dates: postharvest science, processing technology and health benefits*. Wiley Blackwell, Chichester, p 328
40. Noui Y, Alloui Lombarkia O, Bekrar A, Chibane Amellal H, Lekbir A (2015) Quality characteristics and sensory evaluation of apricot jams made with date palm products (syrup). *J Food Sci Technol* 7(2):53–62
41. Benmezziane-Derradji F (2019) Nutritional value, phytochemical composition, and biological activities of Middle Eastern and North African date fruit: an overview. *Euro-Mediterr J Environ Integr* 4(1):2
42. Abdul-Hamid NA, Mustaffer NH, Maulidiani M, Mediani A, Ismail IS, Tham CL, Shadid K, Abas F (2018) Quality evaluation of the physical properties, phytochemicals, biological activities and proximate analysis of nine Saudi date palm fruit varieties. *J Saudi Soc Agric Sci*. <https://doi.org/10.1016/j.jssas.2018.08.004>
43. Aziz Elhoumaizi M, Jdaini K, Alla F, Parmar A (2023) Variations in physicochemical and microbiological characteristics of ‘Mejhoul’ dates (*Phoenix dactylifera L.*) from Morocco and new countries of its expansion. *J Saudi Soc Agric Sci*. <https://doi.org/10.1016/j.jssas.2023.02.003>
44. Oladzad S, Fallah N, Mahboubi A, Afsham N, Taherzadeh MJ (2021) Date fruit processing waste and approaches to its valorization: a review. *Bioresour Technol* 340:125625
45. Ahmed J, Al-Jasass FM, Siddiq M (2013) Date fruit composition and nutrition. *Dates* 2:261–283
46. Messadi N, Mechmeche M, Setti K, Tizemmour Z, Moktar H, Kachouri F (2023) Optimization of extraction parameters and characterization of Tunisian date extract: a scientific approach toward their utilization. *Sugar Tech* 25:460–472
47. Kumar M, Tomar M, Potkule J, Reetu S, Punia J, Dhakane Lad S, Singh S, Dhupal PC, Pradhan B, Bhushan T, Anitha O, Alajil A, Amarowicz A, Alhariri Kennedy JF (2021) Functional characterization of plant-based protein to determine its quality for food applications. *J Food Hydrocoll* 123:106986
48. Djaoudene O, Bachir Bey M, Louaileche H (2019) Physicochemical characteristics and nutritional compositions of some date (*Phoenix dactylifera L.*) Fruit cultivars. *Acta Univ Cibiniensis Ser E Food Technol* 2:129–137
49. Metoui M, Essid A, Bouzoumita A, Ferchichi A (2019) Chemical composition, antioxidant and antibacterial activity of tunisian date palm seed. *Pol J Environ Stud* 28:1–8
50. Zaitoun M, Ghanem M, Harphoush S (2018) Sugars: types and their functional properties in food and human health. *Int J Public Health Res* 6(4):93–99
51. Al-Farsi M, Alasalvar C, Al-Abid M, Al-Shoaily K, Al-Amry M, Al-Rawahy F (2007) Compositional and functional characteristics of dates, syrups, and their by products. *J Food Chem* 104:943–947
52. Gourchala F, Ouazouaz M, Mihoub F, Henchiri C (2015) Compositional analysis and sensory profile of five date varieties grown in south Algeria. *J Chem Pharm Res* 7(2):511–518
53. Maqsood S, Adiamo O, Ahmad M, Mudgil P (2019) Bioactive compounds from date fruit and seed as potential nutraceutical and functional food ingredients. *Food Chem* 2:125522
54. Mani V, Arfeen M, Mohammed HA, Elsis HA, Sajid S, Almogbel Y, Aldubayan M, Dhanasekaran M, Alhowail A (2019) Sukkari dates seed improves type-2 diabetes mellitus-induced memory impairment by reducing blood glucose levels and enhancing brain cholinergic transmission: In vivo and molecular modeling studies. *Saudi Pharm J* 30:750–763
55. Bouhlali E, Dine T, Alem C, Ennassir J, Benlyas M, Mbark AN, Zegzouti YF (2017) Phytochemical compositions and antioxidant capacity of three date (*Phoenix dactylifera L.*) seeds varieties grown in the South East Morocco. *J Saudi Soc Agric Sci* 16(4):350–357
56. Kchaou W, Abbès F, Attia H, Besbes S (2014) In vitro antioxidant activities of three selected dates from Tunisia (*Phoenix dactylifera L.*). *J Chem* 2:67681
57. Hachani S, Hamia C, Boukhalkhal S, Silva AMS, Djeridane A, Youssi M (2018) Morphological, physico-chemical characteristics and effects of extraction solvents on UHPLC-DAD-ESI-MSn profiling of phenolic contents and antioxidant activities of five date cultivars (*Phoenix dactylifera L.*) growing in Algeria. *Nutr Food Sci J*. <https://doi.org/10.1016/j.nfs.2018.10.001>
58. Benmeddour B, Mehinagic E, Le Meurlayb D, Louaileche H (2013) Phenolic composition and antioxidant capacities of ten Algerian date (*Phoenix dactylifera L.*) cultivars: a comparative study. *J Funct Foods* 5:346–354
59. Alahyane A, Harrak H, Ayour J, Elateri I, Ait-Oubahou A, Benichou M (2019) Bioactive compounds and antioxidant activity of seventeen Moroccan date varieties and clones (*Phoenix dactylifera L.*). *S Afr J Bot* 121:402–409
60. Boudries H, Kefalas P, Hornero-Mendez D (2007) Carotenoid composition of Algerian date varieties (*Phoenix dactylifera*) at different edible maturation stages. *Food Chem* 101:1372–1377
61. Habib HM, Kamal H, Ibrahim WH, Dhaheri ASA (2013) Carotenoids, fat soluble vitamins and fatty acid profiles of 18 varieties of date seed oil. *Ind Crops Prod* 42:567–572
62. Cianciosi D, Forbes-Hernández TY, Afrin S, Gasparrini M, Borebodo-Rodríguez P, Manna PP, Zhang J, Lamas LB, Flórez SM, Toyos PA, Quiles JL, Giampieri F, Battino M (2018) Phenolic compounds in honey and their associated health benefits: a review. *Molecules* 23:2322
63. Masmoudi-Allouche F, Touati S, Mnafigui K, Gharsallah N, El Feki A, Allouche N (2016) Phytochemical profile, antioxidant, antibacterial, antidiabetic and anti-obesity activities of fruits and pits from date palm (*Phoenix dactylifera L.*) grown in south of Tunisia. *J Pharmacogn Phytochem* 5(3):15–22
64. Ali Haimoud S, Allem R, Merouane A (2015) Antioxidant and anti-inflammatory properties of widely consumed date palm (*Phoenix dactylifera L.*) fruit varieties in algerian oases. *J Food Biochem* 2:1745–4514
65. Djaoud K, Muñoz-Almagro N, Benítez V, ÁngelesMartín-Cabrejas M, Madani K, Boulekbache-Makhlouf L, Villamiel M (2022) New valorization approach of Algerian dates (*Phoenix dactylifera L.*) by ultrasound pectin extraction: physicochemical, techno-functional, antioxidant and antidiabetic properties. *Int J Biol Macromol* 212:337–347
66. Ourradi H, Ennahli S, Martos MV, Hernadez F, Dilorenzo C, Hssaini L, Elantari A, Hanine H (2021) Proximate composition of polyphenolic, phytochemical, antioxidant activity content and lipid profiles of date palm seeds oils (*Phoenix dactylifera L.*). *Int J Agric Food Res* 6:100217
67. Guo C, Yang J, Wei J, Li Y, Xu J, Jiang Y (2003) Antioxidant activities of peel, pulp and seed fractions of common fruits as determined by FRAP assay. *Nutr Res* 23(12):1719–1726
68. Zeroual A, Sakar EH, Eloutassi N, Mahjoubi F, Chaouch M, Chaqroune A (2021) Wild chamomile [*cladanthus mixtus (L.) chevall.*] collected from central-northern morocco: Phytochemical profiling, antioxidant, and antimicrobial activities. *Bio-interface Res Appl Chem* 2:9358–9371
69. Sakar EH, El Yamani M, Rharrabti Y (2019) Fruit gravimetric traits in almond [*Prunus dulcis (Mill.) D.A. Webb*]: combined

- effects of genetic control and environmental drivers. *Erwerbsobstbau*. <https://doi.org/10.1007/s10341-019-00457-x>
70. Djaoud KL, Arkoub-Djermoune H, Remini S, Sait M, Tazarourte S, Hadjal A, Romero K, Madani Boulekbache-Makhlouf L (2020) Syrup from common date variety (*Phoenix dactylifera L.*): optimization of sugars extraction and their quantification by high performance liquid chromatography. *J Curr Nutr Food Sci* 2:3
71. Kamal H, Habib HM, Ali A, Show P, Koyande AP, Kheadr E, Ibrahim WH (2022) Food waste valorization potential: fiber, sugar, and color profiles of 18 date seed varieties (*Phoenix dactylifera L.*). *J Saudi Soc Agric Sci*. <https://doi.org/10.1016/j.jssas.2022.11.001>
72. Ghnimi S, Al-Shibli M, Al-Yammahi HR, Al-Dhaheri A, Al-Jaberi F, Jobe B, Kamal-Eldin A (2018) Reducing sugars, organic acids, size, color, and texture of 21 Emirati date fruit varieties (*Phoenix dactylifera L.*). *NFS* 12:1–10
73. Mrabet A, Jiménez-Araujo A, Guillén-Bejarano R, Rodríguez-Arcos R, Sindic M (2020) Date seeds: a promising source of oil with functional properties. *Foods* 9(6):1–14

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