Original article

Physico-chemical and functional characteristics of date fruits from different *Phoenix* species (Arecaceae)

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Physico-chemical and functional characteristics of date fruits from different *Phoenix* species (Arecaceae).

Abstract – Introduction. The genus *Phoenix* has 13 species. Dates from *P. dactylifera* and *P. theophrasti* are the only ones that have been characterised so far. The aim of our study was to evaluate the physico-chemical and functional characteristics of date fruits in the Khalal and Rutab stages of *P. loureiroi*, *P. canariensis*, *P. reclinata* and *P. roebelenii*, and compare them with *P. dactylifera*. **Materials and methods**. Two samples of 15 date fruits in the Khalal stage and another 15 date fruits in the Rutab stage were chosen from each species for analyses and quality parameters. **Results and discussion**. Significant differences in the measured parameters were observed among the different species. Dates of *P. dactylifera* were larger than those of the other species and had the lowest [seed weight/fruit weight] proportion. In the Khalal stage, dates from *P. canariensis* and *P. dactylifera* were yellow, *P. loureiroi* and *P. reclinata* were dark yellow to orange, and those of *P. roebelenii* were brown purple. Dates of *P. dactylifera* (Rutab stage) showed higher sugar and lower organic acid contents than those of the other dates. Dates of *P. reclinata*, *P. roebelenii* and *P. canariensis* presented values of antioxidant activity and total phenols in the Khalal stage that were very high compared with those of *P. dactylifera*. These species are used as ornamental palms but their fruits are consumed locally as food. These dates presented high nutritional quality and can be used as novel foods for different purposes, such as snacks or food fortification, especially due to their high value in functional properties.

Spain / *Phoenix* / fruits / antioxidants / phenolic content / organic acids / sugars

Caractéristiques physico-chimiques et fonctionnelles des dattes de différentes espèces de *Phoenix* (Arecaceae).

Résumé – Introduction. Le genre *Phoenix* comprend 13 espèces. Les dattes de *P. dactylifera* et *P. theophrasti* sont les seules qui ont été caractérisées jusqu'à présent. Le but de notre étude a été d'évaluer les propriétés physico-chimiques et fonctionnelles des dattes de *P. loureiroi*, *P. canariensis*, *P. reclinata*, et *P. roebelenii* aux stades de maturité Khalal et Rutab, et de les comparer à celles des fruits de *P. dactylifera*. **Matériel et méthodes**. Deux échantillons de 15 dattes au stade Khalal et de 15 dattes au stade Rutab ont été constitués pour chaque espèce afin d'en effectuer les analyses et de déterminer leurs caractéristiques de qualité. **Résultats et discussion**. Les paramètres mesurés ont montré des différences significatives entre les différentes espèces. Les dattes de *P. dactylifera* ont été plus grandes que celles des autres espèces et ont présenté le plus faible rapport [poids des semences / poids fruits]. Au stade Khalal, les dattes de *P. canariensis* et *P. dactylifera* sont jaunes, celles de *P. loureiroi* et *P. reclinata* sont jaunes à orange foncé, et celles de *P. roebelenii* sont brun pourpre. Les dattes de *P. dactylifera* (au stade Rutab) ont montré des teneurs en sucre supérieures et des teneurs en acides organiques inférieures à celles des autres dattes étudiées. Les dattes de *P. reclinata*, *P. roebelenii* et *P. canariensis* ont présenté des valeurs d'activité antioxydante et de phénols totaux au stade Khalal très élevées par rapport à celles de *P. dactylifera*. Ces espèces sont utilisées comme palmiers ornementaux, mais leurs fruits sont consommés localement. Leurs dattes présentent donc une grande qualité nutritionnelle et peuvent être utilisées comme nouveaux aliments à différentes fins, tels que pour des collations ou l'enrichissement d'aliments, en particulier du fait de leurs importantes propriétés fonctionnelles.

Espagne / *Phoenix* / fruit / antioxydant / teneur en phénols / acide organique / sucres

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1. Introduction

The genus *Phoenix* (Arecaceae), with thirteen species [1], extends throughout Europe, Asia and Africa. Most are used as ornamental palms. The dates from eighty percent of the *Phoenix* species are edible and are consumed regularly in numerous countries in Africa, Asia and Europe. However, up to now, only the fruits of *Phoenix dactylifera* L. have been studied in detail. The physico-chemical and functional properties of fruits from *P. dactylifera* and *P. theophrasti* Greuter cultivars and their changes during growth and ripening have been studied [2–7]. Other *Phoenix* species furnish edible dates that are consumed locally as food and, often, as medicine [8–10]. *Phoenix acaulis* Roxb. dates are consumed in the Sikkim Himalayas instead of betel nuts [11]. *Phoenix atlantica* A. Chev. dates are sold as food in the markets of Praia and Mindelo (Cabo Verde Islands) (Jesus Meseguer, pers. commun.). Small, ripe dates of *P. canariensis* H. Wildpret in Chabaud are consumed locally in the Canary Islands (Spain) [12]. *Phoenix loureiroi* Kunth dates are consumed in Hong Kong [13] and Taiwan [9]. In Andra Pradesh (India), these are consumed for the treatment of diabetes [14]. *Phoenix paludosa* Roxb., *P. pusilla* Gaertn. and *P. sylvestris* (L.) Roxb. dates are consumed in Orissa, Kerala and Sulemaani Khajuur (India), respectively, for medicinal purposes [8]. The fruit of *P. reclinata* Jacq., although small and with only a thin layer of flesh, is edible; it provides high nutrition, and is consumed in Southern Africa [15]. Consumption of *P. sylvestris* dates has also been recorded in Pakistan [16].

However, there are no reports of analytical studies on date fruits from these or other *Phoenix* species. The aim of our work was to study different physico-chemical and functional parameters of date fruits in the Khalal, also called the colour or yellow stage [17], and the Rutab, also called the soft ripe stage [17], of four species of the genus *Phoenix*: *P. loureiroi* (mountain date palm), *P. canariensis* (Canary Islands date palm), *P. reclinata* (Senegal date palm) and *P. roebelenii* O´Brien (Pygmy date palm). All of these species are consumed locally [18, 19] but their physico-chemical properties have not yet been characterised. For comparison, fruits of the *P. dactylifera* L. (date palm) local cultivar were also analysed.

2. Materials and methods

2.1. Plant materials

Date fruits were collected from various sources in Spain: *Phoenix canariensis* from Espinardo (Murcia), *P. loureiroi* and *P. roebelenii* from Olocau (Valencia), and *P. dactylifera* var. "Elx 1" from Elche (Alicante). Date fruits of *P. reclinata* were received from the National Clonal Germplasm Repository for Citrus & Dates, Riverside (California, USA). Once in the laboratory, date fruits were classified according to their various stages of maturity. Two samples of 15 date fruits in the Khalal stage and another 15 fruits in the Rutab stage were chosen for analyses.

2.2. Morphological characterisation

Average weight, length and diameter were measured in 15 fruits from each maturation stage and species. The seed percentage is calculated as the seed weight/fruit weight in the Rutab stage. External colour was determined using a Minolta reflection colorimeter, model CR200 (Camera Co., Osaka, Japan) with 45º illumination, which expresses colour in CIELab L*, a* and b* coordinates. Three measurements were made in different zones of the equatorial area of each fruit. Results were mean ± standard error of the measurements taken for 15 fruits of each subsample in each maturation stage and species. Then, the chrome index was calculated as $[(a)^2 + (b)^2]^{1/2}$.

2.3. Sugars, organic acids, Trolox equivalent antioxidant capacity (TEAC) and total phenols

Two grams of date fruit from each sample were homogenised with 6 mL of 50 mM Na-phosphate buffer pH 7.5 using a Polytron homogeniser (IKA Labotechnik, Staufen, Germany) and centrifuged at 15000 *g* for

20 min at 4 °C. A 10-µL aliquot of the supernatant was used to quantify organic acids and sugars using a HPLC system (Hewlett-Packard, series 1100, Waldbrom, Germany) as previously reported [5]. Sugars and organic acids were quantified in triplicate for every stage and sample. Results were expressed as grams per 100 g of fresh weight (fw). The Maturity Index (MI) was expressed as the relationship between the Soluble Solid Content (SSC) and acidity. Soluble Solid Content was measured in triplicate for each subsample of each maturation stage and species (P20 RL2 refractometer, Minato-Ku, Tokyo, Japan) and calculated as °Brix at 20 °C. Acidity was determined in triplicate by potentiometric titration with 0.1 N NaOH to pH 8.1 (Herisau, Appanzell Rodas, Switzerland). The SSC and acidity results are not shown.

The same supernatant used for quantification of sugars and organic acids was used for TEAC and total phenol quantification. The TEAC was determined (in triplicate) using the enzymatic system composed of chromophore 2,2´-azino-bis-(3-ethylbenzothiazoline-6-sulphonic acid) diammonium salt (ABTS), horseradish peroxidase enzyme (HRP), and its oxidant substrate (hydrogen peroxide), in which $ABTS^{\cdot+}$ radicals are generated [20]. The assay temperature was 25 °C, and the reaction was monitored at λmax 414 nm until a stable absorbance was obtained using a UNICAM Helios α spectrophotometer (Cambridge, UK). After this, a suitable amount of date fruit extract was added, and the observed decrease in absorbance was determined. A calibration curve was performed with Trolox [(R)-(+)-6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid] as the standard antioxidant, and the results were expressed as milligrams of Trolox equivalents per 100 g of fresh weight. Total phenol contents were quantified using Folin-Ciocalteu reagent [21] as previously reported [5]. The results were expressed as mg of gallic acid equivalents (mg GAE) per 100 g of fresh weight.

2.4. Statistical analysis

The data were analysed by variance analysis (ANOVA) and means were compared by Tukey's multiple range test at $p < 0.05$. Sources of variation were maturation stages and species of the genus *Phoenix*. The data were analysed with the statistical package Statgraphics Plus 3.0. Least significant differences (LSDs at $p = 0.05$) were calculated for mean separations.

3. Results and discussion

3.1. Morphological characterisation

The results showed a clear difference in weights and sizes between the fruits of *P. dactylifera* and the other species (*table I*). The former were followed by *P. canariensis*, *P. loureiroi* and *P. reclinata*, and the smallest dates were those from *P. roebelenii,* in both the Khalal and Rutab stages. The weights, lengths and diameters of dates from *P. dactylifera* measured in our study were similar to those reported in the literature, with weights from (4 to 28) g, lengths from (26.5 to 50.0) mm, and diameters from (15.2 to 33.1) mm depending on the cultivar [5, 6, 22, 23]. Dates of *P. roebelenii* grown in Brazil had a length of 12.5 mm × 7.0 mm, higher than those found in our work [24]. Besides the seed % in all these species being much higher than *P. dactylifera*, with the maximum in dates of *P. roebelenii*, and followed by those of *P. loureiroi* and *P. canariensis*, *P. reclinata* dates had a much lower ratio, although their overall dimensions were very small. Dates with the minimum seed % were those of *P. dactylifera* and were within the ranges of other *P. dactylifera* cultivars, varying from 6.3% to 30.2%, depending on the cultivar [6, 22, 23].

The chrome index indicates colour intensity, so it is the ideal parameter to distinguish between dates in the Khalal and Rutab stages of maturity. In the Khalal preliminary stage of ripening, the lightest dates were the yellow ones of *P. canariensis* and *P. dactylifera*, with a maximum chrome index and high brightness, and with very high L* and b* values. Dates of *P. loureiroi* presented a dark yellow colour with lower luminosity and duller yellow. Dates of *P. reclinata* were orange with less luminosity. Dates of *P. roebelenii* had a very dark brown purple colour,

Table I.
Morphological characteristics of date fruits from different *Phoenix* species in the Khalal and Rutab stages (Spain).

Phoenix species	Stage studied	Weight (g)	Length (mm)	Diameter (mm)	Seed %	Colour	L*	a*	b*	Chrome index
P. dactylifera	Khalal	10.14 ± 0.72	44.14 ± 0.95	20.69 ± 0.52	–	Yellow	57.09 ± 0.65	13.77 ± 0.23	44.90 ± 0.59	47.01
	Rutab	12.14 ± 0.35	44.24 ± 1.08	20.68 ± 0.24	17.95 ± 0.25	Dark brown	29.99 ± 0.28	3.47 ± 0.26	4.27 ± 0.38	5.52
P. loureiroi	Khalal	0.54 ± 0.02	12.60 ± 0.13	8.31 ± 0.08	–	Dark yellow	45.87 ± 2.61	12.89 ± 1.90	36.00 ± 3.11	38.21
	Rutab	0.55 ± 0.01	13.04 ± 0.12	8.73 ± 0.10	63.63 ± 0.09	Black	19.79 ± 2.65	0.70 ± 0.21	0.72 ± 0.28	1.00
P. canariensis	Khalal	1.66 ± 0.03	16.69 ± 0.11	11.59 ± 0.07	–	Yellow	65.15 ± 1.59	22.50 ± 2.95	47.80 ± 1.98	52.85
	Rutab	1.77 ± 0.02	18.06 ± 0.13	12.36 ± 0.06	53.67 ± 0.11	Light brown	44.46 ± 2.80	14.60 ± 3.59	13.30 ± 4.21	19.73
P. reclinata	Khalal	0.40 ± 0.02	13.26 ± 0.17	6.86 ± 0.10	–	Orange	43.82 ± 1.02	25.99 ± 1.16	35.80 ± 2.39	44.27
	Rutab	0.43 ± 0.01	13.20 ± 0.11	7.17 ± 0.07	27.90 ± 0.07	Brown	30.80 ± 1.28	9.17 ± 0.84	12.30 ± 1.59	15.32
P. roebelenii	Khalal	0.24 ± 0.01	10.90 ± 0.13	5.28 ± 0.07	–	Brown purple	23.19 ± 3.27	9.61 ± 1.70	3.89 ± 1.17	10.37
	Rutab	0.26 ± 0.01	11.30 ± 0.10	5.71 ± 0.05	65.38 ± 0.01	Black	19.40 ± 1.86	1.70 ± 0.72	0.35 ± 0.33	1.74

Each analysis of weight, length, diameter and seed % was performed with two subsamples of 15 fruits and each L*, a* and b* colour analysis was done in triplicate for each fruit. The results are expressed as mean value ± standard error.

extremely different from those of the other species, with very little brightness. Dates of all these species, when fully ripe, in the Rutab stage, presented a brown colour with different intensities. Therefore, *P. canariensis* presented light brown dates with a maximum chrome index. *Phoenix reclinata* presented brown dates with a chrome index c = 15. Dates of *P. dactylifera* were dark brown. Finally, dates that had darker colours, almost black, were those of *P. roebelenii* and *P. loureiroi*, with minimum chrome indices. In all species, the colour parameters decreased from the Khalal to the Rutab stage. This is known in *P. dactylifera* dates with absolute values that vary according to the cultivar [2, 5, 22, 23]. Date colours are due mainly to carotenoids. Lutein, β-carotene and neoxathin are the predominant carotenoids in *P. dactylifera* fruits in the Rutab and Tamar (final ripening) stages, although carotenoid values varied among different cultivars, maturation stages and environmental conditions [25, 26]. *Phoenix reclinata* fruits contain different carotenoids; however, total anthocyanin pigments are higher in *P. reclinata* dates [27].

3.2. Sugars, organic acids and maturity index

In our study, the pattern of sugar contents in the different species studied was different (*table II*). *Phoenix dactylifera* dates in the Khalal stage had the same concentration of the three sugars, while fructose and glucose contents were greater than those of sucrose in the Rutab stage. However, in the other species studied, glucose and fructose contents were significantly higher than those of sucrose in both stages of maturity. In all species, glucose, fructose and total sugar contents increased from the Khalal to the Rutab stage. Sucrose contents decreased in *P. dactylifera* dates as they matured, whereas glucose and fructose contents increased due to an increase in invertase enzyme activity [5]. Individual sugars and total sugar contents were significantly higher in dates of *P. dactylifera* than in those of the other species studied, except for total sugars in the Rutab stage of *P. loureiroi*, which had a similar concentration to *P. dactylifera*. *Phoenix reclinata* and *P. canariensis* had intermediate concentrations of total sugar, and dates of *P. roebelenii* had the lowest sugar contents. In all the species studied, the glucose/fructose ratio was close to one, as reported earlier [5]. The sugar values found in our study are similar to earlier reports [4–6, 23]. The rapid accumulation of glucose and fructose from the Khalal to the Rutab stage is a clear indicator that the date is an excellent source of dietary carbohydrates.

Maturity index values increased in all species with maturation and, therefore, this

Table II.
Sugars, maturity index and organic acids of date fruits from different *Phoenix* species in the Khalal and Rutab stages (Spain).

Phoenix species	Stage studied	Glucose	Fructose	Sucrose	Total sugars	Maturity index	Malic acid	Citric acid	Succinic acid	Ascorbic acid
		(g·100 g fresh weight)					(g·100 g fresh weight)			
P. dactylifera	Khalal	10.42 ± 0.50	11.76 ± 0.59	11.80 ± 0.79	33.56 ± 0.59	130.40	0.20 ± 0.00	0.20 ± 0.03	0.47 ± 0.01	0.01 ± 0.001
	Rutab	22.83 ± 0.90	24.46 ± 1.19	0.53 ± 0.03	47.80 ± 0.89	176.77	0.71 ± 0.10	0.21 ± 0.01	0.30 ± 0.04	Not determined
P. loureiroi	Khalal	7.82 ± 0.90	8.48 ± 0.57	0.08 ± 0.02	16.38 ± 0.62	102.50	0.41 ± 0.01	0.40 ± 0.14	0.38 ± 0.03	0.02 ± 0.004
	Rutab	21.89 ± 1.20	24.19 ± 0.21	0.26 ± 0.07	46.34 ± 0.62	152.72	0.63 ± 0.11	0.35 ± 0.04	0.95 ± 0.01	0.03 ± 0.006
P.canariensis	Khalal	4.07 ± 0.20	5.27 ± 0.21	0.06 ± 0.04	9.4 ± 0.18	44.19	0.64 ± 0.00	0.82 ± 0.23	0.61 ± 0.02	0.05 ± 0.009
	Rutab	13.56 ± 0.00	15.84 ± 0.01	0.13 ± 0.00	29.53 ± 0.01	136.67	1.11 ± 0.07	0.72 ± 0.00	1.79 ± 0.69	0.05 ± 0.001
P. reclinata	Khalal	4.68 ± 1.20	5.37 ± 1.33	0.07 ± 0.07	10.12 ± 1.19	42.14	0.63 ± 0.14	0.60 ± 0.17	0.58 ± 0.19	0.04 ± 0.001
	Rutab	17.74 ± 1.70	19.72 ± 1.65	0.46 ± 0.28	37.92 ± 1.72	90.59	1.21 ± 0.10	1.76 ± 1.04	0.88 ± 0.17	Not determined
P. roebelenii	Khalal	3.64 ± 0.30	4.57 ± 0.48	0.32 ± 0.28	8.53 ± 0.32	45.89	0.71 ± 0.13	0.22 ± 0.07	0.49 ± 0.13	0.03 ± 0.017
	Rutab	7.97 ± 0.20	8.77 ± 0.04	0.28 ± 0.12	17.02 ± 0.14	118.57	0.57 ± 0.02	0.61 ± 0.10	1.13 ± 0.37	0.03 ± 0.007

Each analysis was done in triplicate and the results are expressed as mean value ± standard error.

parameter was maximum in Rutab-stage dates. *Phoenix dactylifera* dates presented maximum maturity index values; *P. loureiroi* presented a lower maturity index value but was still fairly high. *Phoenix canariensis*, *P. roebelenii* and *P. reclinata* dates had very low maturity index values in the Khalal stage, which significantly increased in the Rutab stage.

The concentration of organic acids in dates from all species studied was very low, and either malic, succinic or citric acid predominated depending on the species and stage of maturity. In the Khalal stage, malic acid was the predominant acid in all species studied, except in *P. dactylifera* samples, where it was succinic acid, and in *P. canariensis* samples, where citric acid was predominant. In Rutab-stage dates, malic acid was the highest acid in *P. dactylifera*, and citric acid in *P. reclinata*, while the highest concentration in *P. loureiroi*, *P. canariensis* and *P. roebelenii* was succinic acid. Citric acid was also found in a similar concentration to malic and succinic acids, while ascorbic acid was the lowest in all species studied in the Khalal stage; it was not detected in either *P. dactylifera* or *P. reclinata* in the Rutab stage. Similar organic acid contents have been reported for Spanish dates [5]; however, dates from Oman showed higher contents [28]. The amounts of ascorbic acid in *P. dactylifera* [(0.02 to 0.05) g·100 g^{-1}] are similar to an earlier report [26]. All species studied have acid contents higher than *P. dactylifera* in the Khalal and Rutab stages. In our study, almost all acids increase with increasing maturity, from the Khalal to the Rutab stage (*table II*), as was reported in dates from Spain [5].

3.3. Trolox equivalent antioxidant capacity and total phenols

All species showed higher Trolox equivalent antioxidant capacity (TEAC) values in the Khalal than in the Rutab stage except for *P. loureiroi*, which presented practically the same value in both (*table III*). This is in agreement with the literature, that also reports maximum TEAC values in the Khalal stage [5, 29]. *Phoenix reclinata* fruits showed the highest TEAC value, with (2430.97 ± 231.1) mg Trolox Eq·100 g^{-1} fresh weight in the Khalal stage, followed by *P. roebelenii*. *Phoenix canariensis* dates also had very high TEAC values in the Khalal stage. *Phoenix dactylifera* dates showed significantly lower TEAC values, and *P. loureiroi* presented the lowest values in both stages. *Phoenix canariensis,* followed by *P. roebelenii*, presented the

Table III.
Trolox equivalent antioxidant capacity (TEAC) values and total phenols of date fruits from different *Phoenix* species in the Khalal and Rutab stages (Spain).

Phoenix species	Stage studied	TEAC (mg Trolox Eq·100 g fresh weight)	Total phenols (mg gallic acid Eq·100 g fresh weight)
P. dactylifera	Khalal	322.01 ± 41.97	68.37 ± 4.56
	Rutab	38.37 ± 2.34	38.31 ± 1.83
P. loureiroi	Khalal	43.61 ± 0.96	37.79 ± 2.50
	Rutab	46.81 ± 1.72	52.56 ± 0.46
P. canariensis	Khalal	1077.25 ± 43.57	179.87 ± 3.41
	Rutab	360.21 ± 12.63	85.31 ± 7.64
P. reclinata	Khalal	2430.97 ± 231.11	256.75 ± 39.85
	Rutab	49.37 ± 3.62	81.78 ± 6.56
P. roebelenii	Khalal	1524.50 ± 45.69	174.18 ± 9.51
	Rutab	158.43 ± 10.80	63.16 ± 1.81

Each analysis was done in triplicate and the results are expressed as mean value ± standard error.

maximum TEAC values in the Rutab stage, whereas all other species had values below 100 mg Trolox Eq ·100 g^{-1} fresh weight. The maximum TEAC values were within the same range as those found for *P. dactylifera* dates from Spain [5]. However, other authors have found higher TEAC values in *P. dactylifera* date fruits from Oman and Iran [3, 26, 28, 30]. The differences may be due to environmental factors and intraspecific variability [29]. Different analytical procedures and chemical standards can also produce differences. TEAC values of *P. reclinata* and *P. roebelenii* dates in the Khalal stage were higher than those from 62 fruit types analysed by Fu *et al.* [31], which included olive, pomegranate, watermelon, guava, citrus, plum and peach, and the total antioxidant activity of *P. canariensis* is surpassed only by olive's values. Thus, in comparison with these fruits, dates are a good source of antioxidants, and this parameter is significantly higher in *P. reclinata, P. roebelenii* and *P. canariensis*, so the species have interesting functional properties.

In the Khalal stage, *Phoenix reclinata* presented the maximum total phenol value (TPV) (*table III*). *Phoenix canariensis* and *P. roebelenii* also had high total phenol values, but they were lower than those of *P. reclinata*. Dates of *P. dactylifera* showed much lower values, and *P. loureiroi* even more so. Dates of all species had higher total phenol values in the Khalal stage than in the Rutab stage, except for *P. loureiroi* dates. *Phoenix canariensis* and *P. reclinata* Rutab dates presented no significant total phenol value differences, and these were followed by *P. roebelenii, P. loureiroi* and *P. dactylifera* dates. Other authors have also reported a similar pattern, with a maximum in the Khalal stage [5, 29]. The total phenol value of *P. dactylifera* reported in the literature fluctuates widely, with very low values, as in Biglari *et al.* [(2.89 to 6.64) mg GAE·100 g^{-1} dry weight] [3], or those of Mansouri *et al.* [(2.84 to 8.36) mg GAE·100 g^{-1} fresh weight] [32]. These values are much lower than those found in our report. However, other authors found very high total phenol values in *P. dactylifera* dates, such as Mohamed and Al-Okbi (1461 mg GAE·100 g^{-1} dry weight) in dates of the Zaghol cultivar [33] and Sark *et al.* in Egyptian dates in the Khalal stage [23]. Intermediate values, in the same range as those found in our work, were shown by Amorós *et al.* for dates in the Khalal stage [(150 to 400) mg GAE·100 g^{-1} fresh weight] [5]; Allaith [(122.1 to 337.7) mg GAE·100 g^{-1} fresh weight] [29]; and Al-Farsi *et al.* [(172 to 246) mg GAE·100 g^{-1} fresh weight] [30]. The high divergence in all these

works may be due to factors such as the cultivars studied, agricultural practices, maturation stage, and environmental conditions during fruit development, *e.g.*, extreme temperatures and high sunlight exposure increase biosynthesis of phenolics as an adaptive response of the plant [28]. Fu *et al.* analysed 62 fruit samples in the same laboratory with the same method and chemical standards [31]. The phenolic contents of *P. reclinata*, *P. canariensis* and *P. roebelenii* dates in the Khalal stage were very high compared with fruits such as apple, avocado, banana, melon, cherry, citrus, grape and mango, among others [31]. The phenolic content was highly correlated with the TEAC value in all date fruits of all species, with r^2 = 0.945 for all samples in both the Khalal and Rutab stages, which rises to r^2 = 0.953 for samples in the Khalal stage only (data not shown). Thus, antioxidant activity might be mainly due to phenolic compounds according to previous reports, specifically in a water-soluble fraction [3, 5, 33] and others in which it was attributed to phenolic compounds and α-tocopherol [32, 33]. From these results, it may be concluded that the dates of the genus *Phoenix* are a good source of natural antioxidants with significant potential for use in functional foods.

4. Conclusion

The highest maturity index corresponded to dates of *P. dactylifera* in the Rutab stage, followed by those of *P. loureiroi* and *P. canariensis*. Not counting the dates of *P. dactylifera*, the sugar concentration was highest in *P. loureiroi*, which also had the lowest organic acid contents. Ascorbic acid was also detected in dates in the Rutab stage in *P. loureiroi*, but not in *P. dactylifera* dates. From a functional point of view, dates of *P. reclinata*, *P. roebelenii* and *P. canariensis* showed TEAC values in the Khalal stage that were very high compared with *P. dactylifera* and *P. loureiroi* dates. In the Khalal stage, dates of these species also showed very high values of total phenols, which correlated positively with TEAC values, and have good potential for use as functional foods.

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Características físico-químicas y funcionales de los dátiles de diferentes especies de *Phoenix* (Arecaceae).

Resumen – Introducción. El género *Phoenix* está constituido por 13 especies. Los dátiles de *P. dactylifera* y *P. theophrasti* son los únicos que han sido caracterizados. El objetivo de este trabajo ha sido estudiar, por primera vez, varios parámetros físico químicos y funcionales de dátiles en los estados Khalal y Rutab de *P. loureiroi, P. canariensis, P. reclinata*, *P. roebelenii*, y compararlos con *P. dactylifera*. **Materiales y métodos**. Dos muestras de 15 dátiles en estado Khalal y otros 15 dátiles en estado Rutab eran elegidos de cada especie para realizar los análisis y parámetros de calidad. **Resultados y discusión**. Se observaron diferencias significativas en los parámetros medidos entre las diferentes especies estudiadas. Los dátiles de *P. dactylifera* eran más grandes que las de las otras especies estudiadas, con una menor proporción de la relación peso de la semilla/peso del fruto. En el estado Khalal los dátiles de *P. canariensis* y *P. dactylifera* eran amarillos, los de *P. loureiroi* y *P. reclinata* eran amarillo oscuro a naranja y los de *P. roebelenii* eran púrpura oscuro. Los dátiles de *P. dactylifera* (estado Rutab) mostraron un mayor contenido de azúcar y menor contenido de ácidos orgánicos. Los dátiles de *P. reclinata*, *P. roebelenii* y *P. canariensis* presentaron valores de actividad antioxidante y fenoles totales en estado Khalal que fueron altos comparados con los de *P. dactylifera*. Estas especies son usadas como palmeras ornamentales pero sus frutos son localmente consumidos como alimento. Estos dátiles presentaron una alta calidad nutricional y pueden ser usados como nuevos alimentos para diferentes propuestas, tales como aperitivos o usados como fortificación de alimentos, especialmente por su alto valor en propiedades funcionales.

España / *Phoenix* / frutas / antioxidantes / contenido fenólico / ácidos orgánicos / azúcares