Quantitative and Qualitative Characterization of 'Boufeggous' Dates (*Phoenix dactylifera* L.): A Comparative Analysis from Different Provinces in Southeast Morocco

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Summary

This study aimed to examine changes in the pomological characteristics of fruits, phenolic composition, and antioxidant activity of 'Boufeggous' dates (*Phoenix dactylifera* L.) from various provinces of southeast Morocco, including Errachidia, Zagora, Tata, and Figuig. A significant difference ($P < 0.05$) was observed between the different 'Boufeggous' cultivar samples by analyzing the pomological characteristics, phenolic compounds, and antioxidant activity. Principal Component Analysis (PCA) classified the samples into two distinct groups. The first group comprises samples of 'Boufeggous', notably those from Figuig and Zagora, characterized by their large size and remarkably thick flesh. In contrast, dates from Errachidia and Tata had smaller dimensions. The second group consists of 'Boufeggous' from Tata, which demonstrates an abundance of polyphenols and displays significantly higher antioxidant activity than dates from other provinces. Therefore, dates originating from Errachidia are richer in flavonoids and anthocyanins. These promising results pave the way for the increased valorization of Boufeggous dates by optimizing agricultural practices and exploring phenolic compounds for nutraceutical applications while adapting these cultivars to the specific conditions of the provinces studied.

Key words

Antioxidant Activity, 'Boufeggous' Variety, *Phoenix dactylifera* L., Phenolic Content, Southeast Morocco

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Introduction

The date palm is an important fruit crop in dry and semi-arid areas with approximately 150 million trees worldwide (Jain & Johnson, 2015). The fruits of date palm (*Phoenix dactylifera* L.) are widely consumed in many parts of the world, constituting a staple and essential food for the diet in Arab countries (Hasnaoui et al., 2012). In Morocco, the date palm occupies approximately 65,432 ha; date production has significantly increased over the last decade, reaching 137,393.77 tons in 2022 (FAOSTAT, 2024), with a dominance of Khalt varieties (36%), followed by Mejhoul (27%) and Boufeggous (19 %) (Jdaini et al., 2023). Dates pass through several stages of ripening, named Kimri (immature green), Khalal (fully colored mature), Rutab (soft brown) and Tamar (hard, raisin-like). In Moroccan oases, dates are consumed during the Tamar stage because of their good preservation, sweet taste, and low astringency. This fruit plays an important economic and social role in provinces where date palm cultivation occurs. It is estimated that 2.82 kg/year of dates are consumed per person. However, more than 68% of cases are occasional, especially during Ramadan (Harrak & Chetto, 2001; Harrak et al., 2005). It is appreciated for its high productivity, high nutritional value, environmental benefits, employment opportunities, and income enhancement in rural areas (Soomro et al., 2023).

The nutritional value of dates is linked to their abundant sugar content (glucose, fructose, sucrose, maltose, and galactose). The proportion of sugar in dry matter varies according to the variety (Zhang et al., 2015). It depends on numerous factors, including climatic conditions, soil composition, and fruit maturity (Myhara et al., 2000). The dates contain proteins, lipids, cellulose, minerals, vitamins, and enzymes. The high mineral content of dates contributes to a balanced diet, and high potassium levels are beneficial to human health. Depending on the moisture content varies from 10 to 40% depending on the date variety and production region (Essebbahi et al., 2023).

In addition, dates are a significant source of bioactive compounds (Guo et al., 2003; Vayalil, 2002). They are rich in several varieties of polyphenols, including phenolic compounds, especially cinnamic and coumaric acids, and their derivatives. Thus, they contain a very significant content of flavonoid glycosides (luteolin, methyl luteolin, quercetin, and methyl quercetin), flavones, flavanols (catechin, epicatechin), and anthocyanins. These compounds allow for various uses of dates, such as in pharmaceutical and therapeutic domains (Maqsood et al., 2020). The richness of fruits and vegetables in polyphenols and flavonoids, which are characterized by a high antioxidant capacity, enables the inhibition of the oxidation of various substances, such as proteins and cholesterol (Al-Turkietal., 2010).

Despite its many assets, the date palm sector in Morocco is declining due to various abiotic and biotic constraints. There is a need to increase cultivar diversity within Moroccan oases to better resist various biotic and abiotic factors rather than focusing on intensive palm planting with a single cultivar. Unfortunately, owing to a lack of awareness of its nutritional importance, the production of "Boufeggous" cultivars in Morocco is very limited. This study aims to promote and enhance the value of the 'Boufeggous' cultivar, which is more adaptable to Moroccan conditions and has significant nutritional and organoleptic values. To the best of our knowledge, few studies have been conducted on the variability of pomological characteristics, phenolic compounds, and antioxidant activity depending on the origin of the 'Boufeggous' cultivar. Hence, the present study focused on the evaluation of the morphological properties, phenolic compounds, and antioxidant activity of "Boufeggous" date samples from different provinces of Morocco, namely, Zagora, Errachidia, Tata, and Figuig. A comparative study of the morphological and nutritional value of the dates of this variety was conducted.

Materials and methods

Plant material

The random sample of dates studied was harvested at the height of the harvesting season (October 2023), with a quantity of one kilogram per province. These samples were brought back to the laboratory for morphological parameter determination and biochemical analyses.

Study area

Southeastern Morocco, including Errachidia, Figuig, Tata, and Zagora, is characterized by an arid-saharan climate with very low annual precipitation, high summer temperatures, and abundant sunshine (Table 1 and Fig. 1). Soils are often sandy to loamy, low in fertility, and sometimes saline, requiring careful management of irrigation and fertilizer applications. Water resources are depend on the traditional irrigation systems. Date palms, which are well adapted to these conditions, are the main crops supported by drought-resistant plants such as acacias and tamarisks.

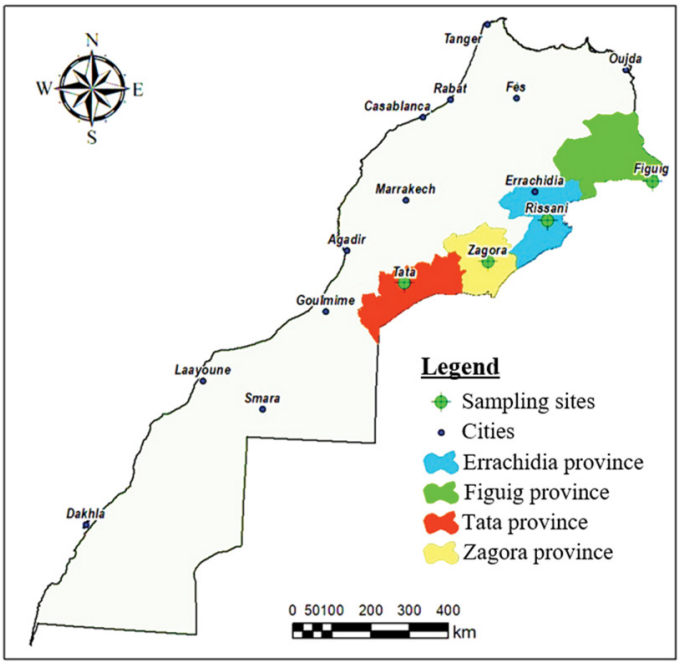

Figure 1. Geographical location of the four studied provinces in Morocco

Table 1. Geographical location, bioclimatic stage, annual rainfall and temperature in the studied provinces

Sampling area	Erachidia	Zagora	Tata	Figuig
Altitude (m)	759	724	688	900
Latitude	31.17'18.8556"N	30°19'"50' N	29°44',784 N.	32°06'32"N
Longitude	4°16'30.9174"W	5°50"17'W	7°58',176 W	1°13'42"W
Annual rainfall (mm)	15.6	16.3	11.49	34.1
Annual temperature (°C)	23.7	24.7	26.03	18.8
Bioclimatic stage	Saharan	Saharan	Saharan	Arid

Figuig province

Figuig province is characterized by an arid Mediterranean climate, very hot summers (Tmax 42 °C), and very cold winters (Tm = 3 °C), with an average annual rainfall of 122 mm (Anonymous, 2015). Figuig province lies at an altitude of 898m, with the following geographical coordinates: latitude 32°06'32" "N and longitude 1°13'42" " W. The area covers 1,427 km^2, with 175,000 date palms of approximately ten varieties. The annual date production is approximately 35,000 t·year^{-1} (Baba et al., 2022).

Tata province

The province of Tata is characterized by a continental Saharan climate, with temperatures varying between 49 °C in summer and 12 °C in winter, and deficient annual rainfall of approximately 74 mm. Date palm cultivation is the mainstay of agriculture in this province, with more than 150 cultivated varieties. 'Boufeggous', 'Bytoube', 'Bouskri', and 'Jihel' were the most common varieties in this province.

Zagora province

The province of Zagora is a part of the Draa Tafilalet region. Its geographical coordinates are: situated at an altitude of 724m; latitude 30°19"50" North; and longitude 5°50"17" West. The climate is Saharan, with very high temperatures in summer (48 °C), very low temperatures in winter (0 °C), and an average annual rainfall of 74 mm·year^{-1} at Zagora station (El-Araby and Faleh, 2017). The average annual production in this province is approximately 34,125 tons.

Errachidia province

The Errachidia province is part of the Draa Tafilalet region, bordered by Merzouga, Jolf-Alnif, Erfoud, and Tauz to the east, west, north, and south, respectively. The town of Errachidia lies on the Ghris and Oued Ziz rivers (31°17'18.8556' 'N–4°16'30.9174 W). The province is a biogeographical sub-desert with water constraints, an annual rainfall below 150 mm, salinization, soil erosion, siltation, poverty, and population migration. In this context, the main household activities of the local populations in the Drâa-Tafilalet region are essentially based on date palm cultivation (El Mansouri et al., 2011).

Measured parameters

Date pulp and seed weight

The weight was measured using a precision analytical balance (AXIS ± 0.0001). Quality ratios were calculated as percentages according to the following formulas:

Ratio: P/D(%) = [(Flesh weight) / (Date weight)] x 100

Ratio: N/D (%) = [(Seed weight) / (Date weight)] x 100

Dimension of dates

Date dimensions (length, width, and pulp thickness) were measured using a digital caliper (DELIXI DWKC-2012) in millimeters (mm).

Total phenolic compounds

Preparation of polyphenolic extracts

The polyphenolic extracts were prepared as described by Bouhlali et al. (2017). The date powder (30 g) was mixed with 150 ml of methanol-water (4:1, v/v), followed by incubation with orbital shaking at 35 °C for 12 h. The mixture was then filtered. The filtrate was concentrated under reduced pressure using a rotary evaporator at 40 °C until the solvent completely evaporated. The crude extracts were stored in a dark glass vial.

Total phenolic compounds

The total phenolic content of the dates was determined using the method specified by the International Organization for Standardization (ISO 14502-1, 2005). The technique used consisted of adding 100 µL of extract to 500 µL of Folin-Ciocalteu reagent (diluted 1/10 with water), followed by 400 µL of sodium carbonate solution (7.5% w/v). The mixture was then incubated at room temperature for 60 min. The absorbance was measured at 765 nm and calibration curves were generated using gallic acid. The phenolic content was expressed as mg gallic acid equivalent/100 g dry weight of date.

Flavonoid content

The total flavonoid content of dates was determined using the method described by Kim et al. (2003), which involves mixing 1 mL of date extract with 4 ml of distilled water. Then 0.3 mL of

sodium nitrite solution (5%) was added together with 0.3 mL of aluminum chloride solution (10%). After incubation for 5 min at room temperature, 2 ml of sodium hydroxide (1 M) was added to the mixture and adjusted to the final volume. A 10 mL dilution with distilled water was prepared. The mixture was vortexed carefully, and the absorbance was measured at 510 nm. The measurement results were calibrated against the standard curve of the prepared rutin solution and expressed as milligram equivalents of rutin (RE) 100 g^{-1} dry weight (DW).

Condensed tannin content

Condensed tannin content was determined in methanolic extracts of dates according to the technique used by Ribéreau-Gayon and Stonestreet (1965). The extract (1 ml of the extract was diluted 50 times in two different test tubes: 0.5 ml of distilled water and 1.5 ml of 12 N hydrochloric acid (HCl). One tube was placed in a water bath at 100 °C for 30 min and the other at room temperature, then 0.25 ml of 95% ethanol was added to stop the reaction. Absorbance was measured at 550 nm using a spectrophotometer (Rayleigh). The concentration of total condensed tannins was determined by the difference in the optical density before and after heating, according to the following relationship:

Condensed tannin content (g/l) = 19.33^{x} (DO hydrolysis - DO control)

Anthocyanin content

Anthocyanins in the date extracts were quantified using the method described by Ribéreau-Gayon and Stonestreet (1965). In brief, 0.5 ml of the extract was mixed with 0.5 mL of ethanol prepared using 0.1% hydrochloric acid (HCl), and 10 mL of 2% hydrochloric acid was added. In the first test tube, 2.5 mL of the mixture was added to 1 mL of distilled water, and the optical density was measured at 550 nm (OD_1). In a second test tube, 2.5 mL of the mixture was added to 0.5 mL of distilled water plus 0.5 mL of $NaHSO_3$, and then measured the optical density at 550 nm (OD_2).

The anthocyanin content of dates is determined based on the following relationship:

$$\text{Anthocyanin content (mg/l)} = (OD_1 - OD_2)$$

Evaluation of antioxidant activity (DPPH)

The DPPH was evaluated according to the method described by Blois (1958) with slight modifications. The reaction mixture contained 100 µL of different concentrations of date extracts and 1.9 ml of methanolic DPPH (0.3 mM). The mixture was incubated at room temperature for 20 min and the absorbance was measured at 517 nm. IC_{50} values (the concentration that ensures 50% inhibition) were calculated from a plot of capture activity versus sample concentration.

Test FRAP (Ferric Reducing Antioxidant Power)

The iron-reducing activity of the date fruit extracts was estimated using the method described by Benzie and Strain (1999). FRAP reagent was prepared by combining 50 mL of acetate buffer pH 3.6 (0.3 M), 5 mL of 10 mM tripyridyltriazine (TPTZ) solution in HCl (40 mM), and 5 mL of trichlorotriazine (FeCl3) iron solution (20 mM) (FeCl3). Freshly prepared FRAP reagent (2 mL) was then added to 10 µL of the extract. After 10 min at room temperature, absorbance was measured at 593 nm against a blank. Standard curves were constructed using the Trolox software. The results are expressed as Trolox equivalents in µmol·100 g^{-1} dry weight.

Statistical analysis

Outcomes were examined using one-way analysis of variance (ANOVA). Tukey's multiple comparison test was used to assess differences between the means of the treatments. A significance level of $P < 0.05$ was considered acceptable. The pomological, phenolic composite, and oxidant activity datasets were subjected to principal component analysis (PCA) to determine which variables affected the quality of 'Boufegous' dates and to confirm whether it was possible to distinguish samples based on their growing province.

Results and discussion

Morphological characterization of dates

The pomological characteristics showed significant variations in the date length ($P < 0.05$) (Fig. 2). The longest dates are those from Zagora (38.80 ± 3.39 mm), followed by those from Errachidia (30.75 ± 4.3668 mm) and followed by those from Errachidia 30.75 ± 4.37 mm, and finally those from Figuig with 30.67 ± 3.51 mm. Dates from Tata had a minimum length of 29.44 ± 2.38 mm. These values are similar to those reported by Taouda et al. (2014) and Chafi et al. (2015) for the same "Boufeggous" variety in the Figuig oasis (4.61 cm) and (approx. 3.83 cm), respectively.

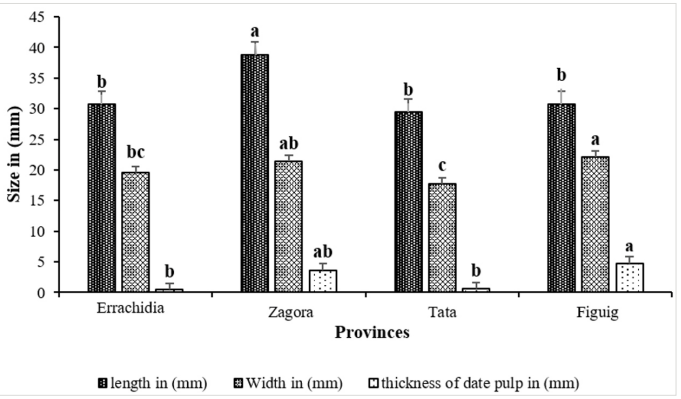

Figure 2. Graphical representation of measurements for dates of the Boufeggous variety in the provinces studied. Values followed by the same letters are not significantly different according to the Tukey test ($P < 0.05$)

On the other hand, the average date width varies between 22.07 ± 2.16 mm for Figuig dates and 17.74 ± 1.70 mm for Tata dates (Fig. 2). The range contains the average width (2.28 cm) of 'Boufeggous' dates, as highlighted by Chafi et al. (2015) for dates from the Figuig Oasis. However, Taouda et al. (2014) reported lower measurements than our results. Overall, the morphometric characterization of the dates varied depending on the nature of the variety and province. The Pakistani date varieties studied by Markhand et al. (2010) ranged from 1.5 to 4.5 cm in width and 2 to 6 cm in length. Iranian date varieties (Jahromi et al., 2007) are 3.3 to 4.2 cm long and 1.8 to 2.5 cm wide.

Our results on the weight of dates from different provinces showed that dates from Zagora have an average weight of 17.66 ± 2.08 g, while those from Errachidia have an average weight of 7.61 ± 1.32 g (Fig. 3). Dates from Zagora and Figuig appeared to contain more flesh than dates from other origins. In addition, Zagora dates had the highest pulp-to-date weight ratio (P/D) of 91.42%. We noted that dates from Tata and Errachidia were the least abundant in flesh (Fig. 4). The P/D ratio is an interesting measurement because it indicates the amount of flesh on the date, which is an important characteristic of date quality. The determination of flesh thickness ranged from 4.62 ± 0.4829 mm in Zagora to 0.58 ± 0.25 mm in Tata. Dates with thick pulp are sought-after for consumers. Our study showed that dates from Zagora and Tata are the most abundant in the market because they are well presented.

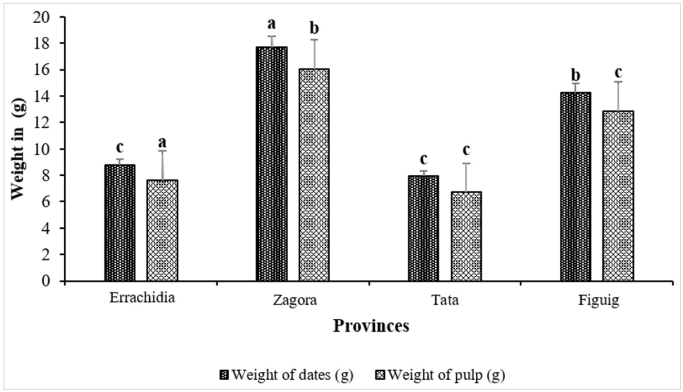

Figure 3. Variation in date weight, pulp weight, and stone weight of Boufegous dates from different provinces studied. Values followed by the same letters are not significantly different according to the Tukey test ($P < 0.05$)

The results obtained by Said et al. (2013) on the Boufeggous date variety showed that Algerian Oases have a P/D ratio of 91.23%. Similar P/D ratios were obtained in the present study for the Boufeggous variety grown in different provinces of Morocco (84.52% and 91.42%). Dates are considered of good quality if they weigh approximately 10 g with 10% seed and 90% flesh, compared with a foreign cultivar such as 'Deglet-Nour' (Harrak and Boujnah, 2012). Our results are comparable to those of Taouda et al. (2014) for 'Boufeggous' dates from the Figuig oasis, which are approximately 88%, but higher than those obtained by Chafi et al. (2015) for two Moroccan varieties, 'Aziza manzou' and 'Afroukhntijant, ' with flesh contents of 77.06% and 83.80%, respectively. The dates from all four origins had high weights and were of good quality.

These results suggest that differences in the characteristics of dates from the four origins may be influenced by differences in climatic conditions and cultural factors as well as pedoclimatic effects and different pollination methods (Bano et al., 2022). The morphometric evaluation assessed the size and weight of dates from the four provinces studied, exceeding the minimum weight threshold of 4 g according to UNECE Standard DDP-08 (2010).

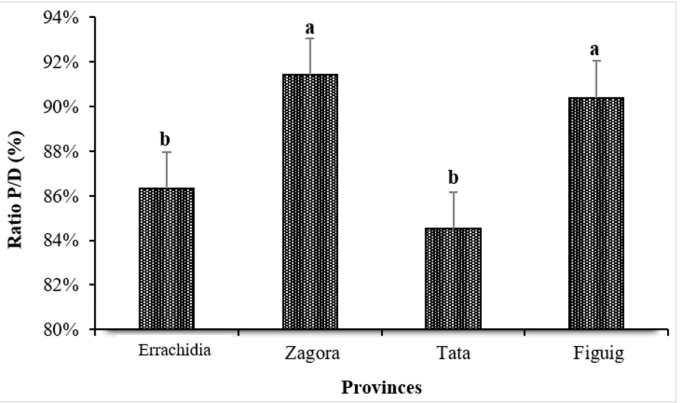

Figure 4. Distribution of pulp to date weight ratio (P/D). Values followed by the same letters are not significantly different according to the Tukey test ($P < 0.05$)

Polyphenol content

The polyphenol contents are presented in Table 2. Analysis of variance for polyphenol content revealed a highly significant effect of province ($P \leq 0.001$). The highest polyphenol content was recorded in the Boufeggous variety of Tata 387.45 mg GAE ·100 g^{-1} DW, followed by Boufeggous from Errachidia and Zagora. However, the 'Boufeggous' variety from Figuig had a low polyphenol content of 285.74 mg GAE ·100 g^{-1} DW. Our results are consistent with those reported by Kchaou et al. (2013), Benmeddour et al. (2013), and Bouhlali et al. (2015), who found that the total phenolic content varied between 19.4 and 353.92 mg GAE ·100 g^{-1} DW in six Tunisian varieties. 226 to 955 mg GAE ·100 g^{-1} DW in ten Algerian date varieties and 331.86 mg and 525 mg GAE ·100 g^{-1} DW in eight Moroccan date varieties were analyzed, respectively. These variations in total phenolic content may be due to several factors, including growing conditions, pedoclimatic conditions, ripeness, harvesting season, geographical origin, fertilizers used, soil type, and storage conditions. The amount of sunlight received is also important in this regard (Besbes et al., 2009). However, despite its high sensitivity, the Folin-Ciocalteu method can present interference problems, as the Folin-Ciocalteu reagent can react with amino acids (tyrosine and tryptophan) and reducing sugars (glucose and fructose). Notably, the results of phenolic compound assays do not provide exact values for polyphenol content (Boizot and Charpentier, 2006). In comparison with the phenolic composition of other fruit crops, we found that the date cultivars examined in this study had a higher phenolic content than raisins (194 mg CE·100 g^{-1} DW) and figs, but less than plums (551 mg CE·100 g^{-1} DW) (Vinson et al., 2005).

Flavonoid content

Results for flavonoid content showed that the Boufeggous variety from Zagora recorded a high flavonoid concentration of 162.47 ± 2.86 mg RE·100 g^{-1}, followed by Tata and Errachidia, while the Boufeggous figuig variety has the lowest flavonoid content, 102.05 ± 0.19 mg RE·100 g^{-1} DW (Table 2).

Table 2. Total polyphenol, flavonoid, condensed tannin, and anthocyanin content of Boufeggous varieties in different provinces

Provinces	Polyphenols mg GA/ 100 g DW	Flavonoids mg RE/ 100 g DW	Condensed tannins mg / 100 g DW	Anthocyanins mg / 100 g DW
Errachidia	333.72 ± 3.6^{b}	123.55 ± 3.39^{c}	70.93 ± 0.53^{c}	15.74 ± 0.14^{a}
Zagora	294.74 ± 4.63^{c}	162.47 ± 2.86^{a}	51.77 ± 1.26^{d}	8.67 ± 0.38^{c}
Tata	387.45 ± 3.26^{a}	143.44 ± 1.88^{b}	87.85 ± 0.40^{a}	8.52 ± 0.37^{c}
Figuig	285.74 ± 2.23^{d}	102.05 ± 0.19^{d}	86.45 ± 0.37^{b}	11.55 ± 0.52^{b}

Note: values are expressed as mean ± SD (n = 3). Values followed by the same letters are not significantly different according to the Tukey test with a $P < 0.05$

This difference was highly significant ($P \leq 0{,}001$). Overall, the total flavonoid content obtained in our study is higher than the results reported by Biglari et al. (2008) and (Hasnaoui et al., 2012), ranging from 1.62 to 81.79 mg EC·100 g^{-1} DW and 43.28 to 84.95 mg QE·100 g^{-1} DW, respectively, for cultivars of Iranian dates and Moroccan dates. Our results are consistent with those obtained by (Benmeddour et al., 2013), who found that the total flavonoid content ranged between 15.22 and 299.74 mg QE·100 g^{-1} DW, and by Kchaou et al. (2013), who reported that flavonoids ranged between 58.92 and 213.76 mg QE·100 g^{-1} DW. The results showed that all varieties had a high flavonoid content compared to other fruits such as raisins (30.9 mg·L^{-1}), apricots (31.9 mg QE·100 g^{-1} of water), prunes (46.6 mg QE·100 g^{-1} of water), and figs (79.9 mg QE·100 g^{-1} of water) (Ouchemoukh et al., 2012).

Total condensed tannins

The analysis of condensed tannins revealed a high content of these molecules in extracts of 'Boufeggous' variety from different provinces in Morocco. This reached 87.85 ± 0.40 mg·100 g^{-1} DW for the Tata province, 86.45 ± 0.37 mg·100 g^{-1} DW for the Figuig province, and 70.93 ± 0.53 mg·100 g^{-1} DW for the Errachidia province. However, the Zagora province recorded a lower content with 51.77 ± 1.26 mg·100 g^{-1} DW (Table 2). These results are similar to those obtained by other authors; (Benmeddour et al., 2013) (82.81–525.06 mg EC·100 g^{-1} MS) and (Amira et al., 2012) (111.11-234.70 mg EC·100 g^{-1} MF) reported significantly higher results than our study.

Anthocyanin Content

The results presented in Table 2 allowed us to highlight the variation in anthocyanin content among Boufeggous varieties from the four provinces studied. The highest anthocyanin content was obtained in the date variety from the Errachidia province (15.74 ± 0.14 mg·100 g^{-1} DW), followed by those from Figuig and Zagora with values of 11.55 ± 0.52 mg·100 g^{-1} DW and 8.67 ± 0.38 mg·100 g^{-1} DW, respectively. However, the 'Boufeggous' variety from Tata had a lower content, with a value of 8.52 ± 0.37 mg·100 g^{-1} DW. The difference in anthocyanin content between date varieties from different provinces was statistically significant ($P \leq 0.001$). Our results show that the dates studied are richer in anthocyanins compared to the results obtained by Al-Farsi et al. (2005), who reported that the anthocyanin content varied between 1.52 mg·100 g^{-1} DW and 0.24 mg·100 g^{-1} DW in varieties of Omani dates. Differences in anthocyanin content are related to the color of these varieties (Al-Farsi et al., 2005). The sun-drying dates influence the quality of anthocyanins (Wrolstad, 2004). Anthocyanin degradation can be facilitated by enzymes such as glycosidases and polyphenol oxidases (Generalić Mekinić et al., 2019).

Antioxidant activity

The antioxidant capacity of various extracts from the studied Boufeggous varieties was determined based on the IC_{50} (Fig. 5), which is the concentration required to reduce 50% of the DPPH radical. Notably, the lower the IC_{50} value, the greater is the antioxidant activity of the compound (Hebi and Eddouks, 2016). According to our results, the IC_{50} recorded for BHT (0.011 ± 0.005 mg·mL^{-1}), used as a reference molecule, was higher than those of the various extracts studied. The Boufeggous variety from Figuig showed the most significant antiradical activity (IC_{50} = 0.013 ± 0.001 mg·mL^{-1}), while the Tata variety exhibited lower antioxidant activity with an IC_{50} of 0.15 ± 0.21 mg·mL^{-1}. Statistical analysis of the obtained results revealed highly significant differences between the various extracts ($P \leq 0.001$). The antioxidant activity of dates has been extensively discussed by Liolios et al. (2009), who reported an IC_{50} of 17 µg·mL^{-1}. In contrast, Taouda, Chabir, et al. (2014) reported IC_{50} values ranging from 0.007 to 0.33 mg·mL^{-1}. These values are within the range of our results. However, Sadeghi et al. (2015) studied the antioxidant activity of six date palm cultivars and found that the IC_{50} values ranged from 0.236 g·L^{-1} to 0.579 g·L^{-1}, which differs from our findings.

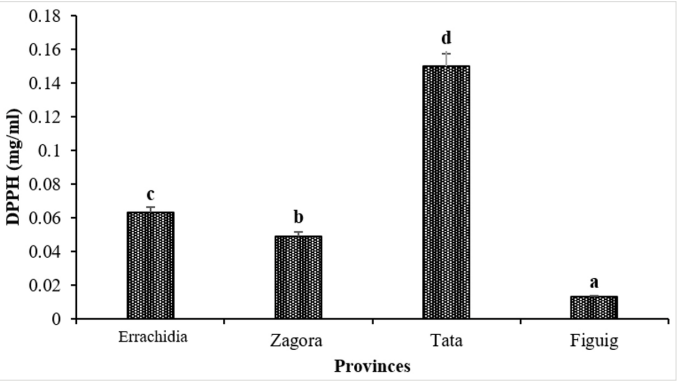

Figure 5. Distribution of pulp to date weight ratio (P/D). Values followed by the same letters are not significantly different according to the Tukey test ($P < 0.05$)

FRAP Test

FRAP tests are widely used to assess antioxidant components of foods. They measured the iron-reducing capacity of antioxidants. The FRAP values of the Boufeggous extracts from Tata and Zagora (163.18 ± 3.17 and 112.83 ± 3.85 µmol·100 g^{-1} DW, respectively) are higher than those of Errachidia and Figuig (104.43 ± 3.32 and 64.49 ± 1.34 µmol·100 g^{-1} DW, respectively) (Fig. 6). The higher FRAP values of Boufeggous extracts from Tata and Zagora may be due to their higher phenolic compound contents. For Boufeggous dates, the FRAP values differ from those obtained by Bouhlali et al. (2015), who reported 627.99 ± 27.59 µmol TE·100 g^{-1} of dry sample. It has been shown that differences in the antioxidant properties of different date varieties can be due to variations in agro-climatic conditions, varieties, and countries of origin (Al-Jasass et al., 2015).

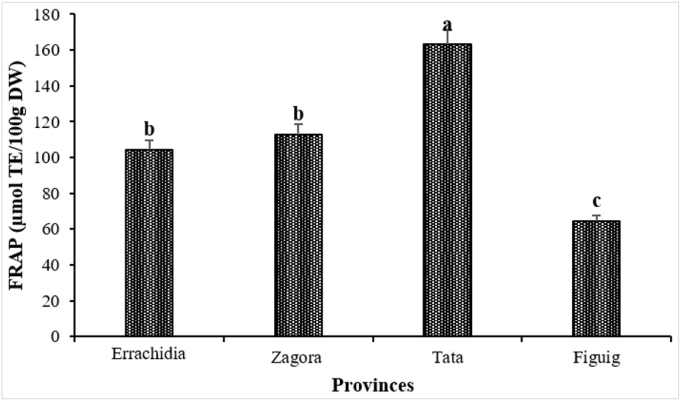

Figure 6. FRAP Test of the Boufeggous variety from different studied provinces. Values followed by the same letters are not significantly different according to the Tukey test with a $P < 0.05$

Multivariate Analysis

Multivariate analysis of the various parameters of the studied dates (PCA) showed that the percentage of information projected onto the two principal components, PC1 and PC2, was approximately 42.23% and 20.87% of the total variation, respectively (Fig. 7).

The first projection axis is represented by the parameters measuring the size of the dates (length, width, and weight), along with a contribution from the total polyphenol content, tannin content, and antioxidant activity (FRAP). This indicates that the Boufeggous dates from Zagora and Figuig were large, with significant total length, pulp weight, and flesh thickness, compared to the dates from the two provinces of Tata and Errachidia, which were smaller in size. The second projection axis was represented by the following chemical components: anthocyanin content, DPPH, flavonoid content, and FRAP. This shows that the dates from Tata are rich in total polyphenols, with significant antioxidant activity (FRAP and DPPH). This was followed by dates from the Zagora province with a relatively significant content of these components. The dates from these two provinces (Tata and Zagora) exhibited very low levels of flavonoids and anthocyanins.

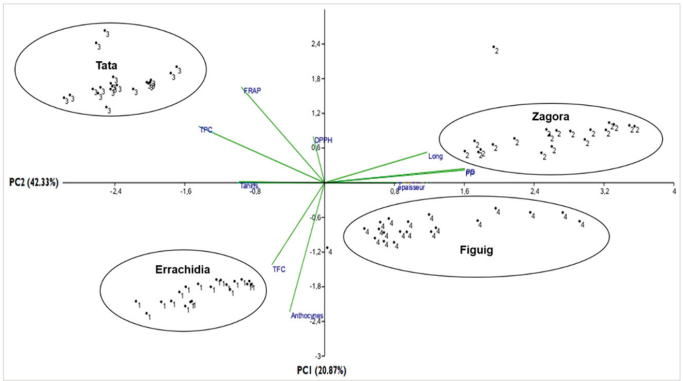

Figure 7. Principal Component Analysis (PCA) representation of the various parameters of Boufeggous dates from different provinces of Morocco. TFC: Total flavonoid content TPC: Total polyphenol content FRAP: Ferric Reducing Antioxidant Power long: Length of dates PP: Pulp weight épaisseur: Pulp thickness Tanins: Tannin content anthocyanes: Anthocyanin content DPPH: Antioxidant activity

On the other hand, dates from the other provinces (Errachidia and Figuig) were richer in these two components (flavonoids and anthocyanins) and very low in total polyphenols, FRAP, and DPPH. From the entire set of samples studied, it is evident that Boufeggous dates differ in size, depending on the harvest province. In addition, they exhibit significant variations in their chemical composition and antioxidant activity. These results reinforce the hypothesis that geographical sites affect the morphological and phytochemical characterization of the species under study.

Conclusion

The quantitative and qualitative characteristics of 'Boufeggous' dates (*Phoenix dactylifera* L.) grown in south-eastern Morocco revealed significant differences. The pomological characteristics of Boufegous dates vary according to the harvesting area. This study shows that date flesh is a potential source of health-promoting phenolic compounds. In addition to highlighting the natural antioxidant activity, we demonstrated that Boufeggous cultivars from Tata and Zagora possess good storage capacities. The results showed that dates from different provinces exhibit a wide range of biological characteristics. For example, dates grown in Zagora and Figuig have larger caliber, heavier pulp, and thicker flesh than those grown in Tata and Errachidia. Dates from Errachidia and Tata have higher levels of phenolic compounds, flavonoids, condensed tannins, and anthocyanins, which significantly contribute to their antioxidant properties, a crucial attribute for their preservation. The data show that the dates produced in these two provinces are of superior quality, albeit they are smaller in size. These results confirm the impact of geographical location on the morphological and phytochemical characteristics of the studied dates.

This study provides fundamental information indicating that date flesh is a potential source of phenolic compounds with numerous health benefits. These results offer promising prospects for the valorization of these products and promotion of the Boufeggous cultivar in the provinces studied. The identification of these specific characteristics could also guide future efforts to improve agricultural practices and optimize the quality of dates grown in these provinces. Further research could explore

the correlations between cultivation practices, environmental conditions, and the properties of dates from various cultivars, as well as the potential applications of these phenolic compounds in nutraceutical products.

Data availability

The data sets produced and/or processed as a result of this research are accessible from the respective authors upon request.

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CREDit Authorship Contribution Statement

Abdelfattah Goubi: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing – Original Draft Preparation, Visualization. **Dounia Amghar:** Conceptualization, Validation, Data curation, Writing – Review and Editing. **Abdellatif Boutagayout:** Software, Validation, Writing – Review ad Editing. **Eimad dine Tariq Bouhlali**: Methodology, Software. **Houria Nekhla:** Formal analysis, Investigation. **Lahsen El Ghadraoui:** Resources, Writing – Review and Editing, Supervision. **Raja Guemmouh:** Conceptualization, Writing – Review ad Editing, Supervision, Project Administration.

Declaration of Competing Interest

The authors declare that there are no conflicts of interest.

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