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Article

Comparative Study of Physicochemical and Phytochemical Properties of Some Algerian Date Palm Fruit (Phoenix dactylifera L.) Cultivars

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Abstract: Algeria, the world's third-largest date producer, has thousands of date palm cultivars, but little is known about the nutritional value and composition of these cultivars. Ten native date cultivars from different oases were discriminated via their physical and chemical properties as well as phytochemical composition and their antioxidant capacity. High significant varietal differences were observed in the studied characteristics, permitting for distinguishable ranks among date cultivars. The highest morphological traits (fruit size and pulp content) were noted for Arechti, Cherka and Feggus cultivars. High antioxidant activity was detected in Arechti, Timdjuhart and Feggus, while the high phenolic compounds were found in Feggus, Arechti and Timdjuhart. Principal Component Analysis revealed a consistent grouping of Arechti, Timdjouhart and Feggus from the rest of cultivars.

Keywords: Phoenix dactylifera L., Algerian dates, Date's characteristics, Principal Component Analysis (PCA)

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1. Introduction

The date palm (Phoenix dactyliferaL.), belonging to the Arecaceae family, is one of the oldest cultivated fruit crops and used for thousands of years, it was extensively grown in northern Africa and Middle East [1,2].

Dates are the fruits that show multidirectional pro-health effects [3]. This requires more studies on its components. The content of the date in primary metabolites has been widely studied. Indeed, this fruit is rich in sugars and dietary fiber, it also contains significant amounts of vitamins and minerals, but it is low in lipids and proteins. Studies on its content of secondary metabolites, in particular phenolics, remain modest. Indeed, some researchers have highlighted the role of polyphenols in the antioxidant activity of dates [4,5].

The date fruit is considered as an important subsistence crop in arid and semi-arid regions, and plays a key role in socioeconomic strategy for many countries in these regions [1,6,7]. Approximately, 3000 different cultivars of date palm have been utilized for global date production, by which about 60 cultivars are extensively cultivated [7,8].

The date palm cultivation involves a strategic place in the oasis economy of the Algerian Sahara [7], it employs more than 60% of the local population directly as operators, or indirectly as actors upstream or downstream of the sector [7]. Algeria is classified as the third largest date fruit producer in the world [9]. Its production exceed more than 1.24 million tons produced from about 20 million palm trees [9]. Date fruits are commonly

consumed in Algeria. Numerous cultivars are marketed in different price ranges. However, several cultivars of the date palm in Algeria are currently threatened with extinction. "Natural" and other human factors are put forward to explain this genetic erosion (The impact of the Bayoud disease, which destroyed a large number of date palms in the West, the salinity of the soil in some regions, the national and international market forces) [34, 10]. The establishment of research strategies focused on assessing the genetic diversity of local date palm populations has become imperative. Despite having significant potential, the endemic species of the Eastern and Western oases are unfavorably threatened by genetic erosion [35]. In this context, our study aims to contribute to the conservation and sustainable management of date palm genetic resources through the characterization of their diversity.

The PCA-based grouping of the studied date palm accessions provides a valuable framework for identifying genetically and morphologically distinct germplasm. These findings can support the establishment of conservation priorities by highlighting unique or underrepresented accessions while also guiding the selection of complementary parental materials for future breeding programs. Consequently, the characterization of local date palm diversity contributes directly to the sustainable conservation and utilization of these valuable genetic resources, thereby addressing the challenges posed by ongoing genetic erosion.

The date palm in Algeria is cultivated in several oases in the south of the country over an area of 168,000 hectares spread over 2 million km2. An inventory of around 1,000 cultivars propagated from seed or offshoots reveals a clear difference in the country's distribution between the eastern, central, and western oases. While most cultivars are limited to their original location, some, like Deglet nour cv., are found in two or three areas and account for over 60% of the national date production [7,8,11]. Furthermore, cultivars are not dispersed equally throughout oases because they are compatible with a range of soil type, temperature, and humidity. Moreover, they usually do not yield well when grown outside of their native habitat. There are sporadic palms known as "khalts" or "dgouls" that are grown from seeds in the oasis. A significant resource for growers looking to pick novel cultivars, khalts comprise up to 10% of the date palm population [12].

According to the cultivar and growth conditions, date fruits vary in shape, size, and weight. These physical dimension characteristics are often used when describing fruits and have been taken as essential criteria in the sorting processes [13]. Knowledge of qualitative and quantitative composition of date fruits is needed to users, particularly processors, packers and traders, because it affects the potential use of the raw material. From the consumer's point of view, chemical composition relates to nutritional significance and health benefits [14]. Other characteristics of the date fruit can be associated to or governed by its chemical composition. Any development of the date sector should begin with an assessment of local cultivars, describing their physico-chemical characteristics. Therefore, and because of the growing importance of the crop in Algeria, the objective of this study was to assess the physical, chemical and phytochemical properties of ten date cultivars grown in two different Algerian oases, Ziban and Saoura oases.

2. Materials and Methods

2.1. Plant material

The ten cultivars of Algerian date palm fruits: Abdel'Azzez, Arechti, Tantboucht, Djouzia, Litima, Timdjuhart, Feggus, Kahlaya, Hamraya and Cherka, originated from two different phoenicicole basins namely Ziban, located in the south-east of Algeria, and Saoura, located in the south-west of Algeria, were used in this study. Samples were collected at least from three individual palm trees for each cultivar. Dates were harvested in "Tamr" stage, in November 2023. Each sample was collected randomly to assure good representation, and each sample was cleaned by remove foreign matter and taken in polyethylene bags with labels, and stored in a refrigerator until analyses.

2.2. Morphological characteristics

The samples consist of 12 dates randomly taken. Morphological measurements were realized on each fruit: Fruit weight was first recorded using a precision scale, and the length and diameter of the fruit were then measured using a micrometer calliper. After pitting, the weight, length, and diameter of the pit were measured as described above. Finally, the fresh and dry pulp weight recorded.

2.3. Physicochemical and biochemical analysis of date samples

All measurements were performed in triplicate. For each cultivar of date, pH and electrical conductivity measurements were performed using a pH meter in the aqueous date solution according [1]. Water content was obtained by drying samples at 105°C during 24 hours which was followed by calcination in muffle furnace for 5 hours at 550°C to obtain total ash and organic matter, OM (% Ash = 100 - % OM) [15]. Total sugar was identified by [16] method; results were expressed in percentage of fresh weight.

2.4. Spectrophotometric determination of phenolic compounds and antioxidant activity of date extracts

All experiments were conducted in triplicate. Date extracts, used for phenolic composition and antioxidant capacity analyses, were prepared according to [17] with some modifications as follow; Thirty grams of pulp were soaked in 100 mL of methanol-water (80:20, v/v); using the orbital shaker under laboratory conditions, for 3h. The mixture was filtered and then, evaporated to dryness using a rotary evaporator, at 40°C, to afford the crude extract. The samples were kept in the refrigerator until analysis.

The Folin-Ciocalteu assay was used to determine the total phenolic content (TPC)of the obtained extracts according to the method described by [18]. The TPC was expressed as gallic acid equivalent on dry weight basis of extract (mg GAE/100g DW).

The amount of total flavonoids (TFC) in the extracts was estimated using the methodology of [19] based on the formation of a complex flavonoid-aluminium, having the absorption maximum at 430nm. Concentration of flavonoids was expressed as mg of quercetin equivalent per 100g of dry weight of extract (mg QE/100gDW).

Radical scavenging activity of date extracts against stable DPPH. (2-diphenyl-2-picrylhydrazyl hydrate) was determined using the protocol of [20]. The method is based on the reduction of the stable free radical DPPH in the presence of a hydrogen-donating antioxidant, and the formation of the non-radical form (DPPH-H) as a result of the reaction. This reduction can be monitored at 517 nm by measuring the bleaching of DPPH (violet) to DPPH-H (yellow). The percentage of inhibition was calculated as follows:

$$DPPH = \left(\frac{Abs\ \ Cont - Abs\ \ Ext}{Abs\ \ Cont}\right) * \ \ 100$$

Where: Abs Ext is the absorbance of date extract and Abs Cont is the absorbance of the positive control (DPPH).

The antioxidant activity of the date extracts was expressed as an IC50 value defined as the concentration (mg/mL) of the extract that inhibited the formation of DPPH radicals by 50%.

2.5. Statistical analysis

Excel Stat 2014 Statistical Software was used to run the analyses. All data were subjected to an analysis of variance (ANOVA) and Tukey's multiple comparison tests, considering a 95% significance level. Parameters means values were used to perform principal component analyses (PCA) as well as the correlation analyses to test whether the variables are correlated in the population.

3. Results and discussion

3.1. Biometric characterization of date cultivars

On the figure below (Figure 1) is illustrated the different cultivars of dates used in this study.

Characters like weight, length and diameter of fruit, seed or pulp are of importance in differentiation between the cultivars. These characters are shown in (Table1) for the different cultivars tested in this study.



Figure 1. Photos of date palm fruits cultivars studied

The dimensions of date samples demonstrated significant differences among the cultivars as shown in the (table 1). The lengths of date cultivars ranged from 29.25 mm for Tantboucht to 49.25 mm for Arechti. Arechti had also the greatest diameter, 26.71 mm, whereas the lowest, 19.73 mm, was observed for Kahlaya. The average of fruit length was 38.76 mm and 24.03 mm of pit length. Arechti cultivar exhibited the highest pit length (28.97 mm), whereas Cherka seeds had the greatest pit diameter (10.93 mm). The average of date weight was (11.57 g). Arechti showed the maximum fruit weight (18.42 g) which was significantly higher than all other cultivars while Litima had the least fruit weight (7.39 g) significantly lower than of the other cultivars. All the studied cultivars seem fleshy, the Arechti cultivar was the fleshiest (92.62%) followed by Hamraya (91.82%) and Feggus (89.79%). Farmers commonly used these physical characteristics to evaluate the quality of the cultivars. They can be influenced by climate factors and some cultivation practices along with intrinsic differences among the cultivars.

Table 1. Biometric characterization of date cultivars

Date cultivars	Date lenght	Date width	Pitlenght	Pitwidth	Date weight	Pitwheight	Fleshweight	Flesh/ Date (%)
Abdel'Azzez	33.76±1.17^{c}	20.48±1.32^{de}	22.76±0.37^{ef}	9.17±0.36^{cd}	8.45±0.69^{bc}	1.19±0.08^{bc}	7.22±0.64^{cd}	85.44
Arechti	49.25±1.82^{a}	26.71±1.01^{a}	28.97±1.17^{a}	8.44±0.46^{de}	18.42±2.44^{a}	1.27±0.13^{b}	17.06±2.37^{a}	92.62
Tantboucht	29.25±0.59c	23.82±1.21b	20.27±0.84f	9.9±0.42bc	10.26±0.84bc	1.3±0.16b	8.91±0.71cd	86.84
Djouzia	38.89±0.79b	21.29±0.58cd	23.06±1.42de	9.01±0.48cd	11.03±0.39b	1.12±0.19bc	9.88±0.24c	89.57
Litima	31.25±1.03c	20.03±0.50d	20.76±0.88ef	7.68±0.38ef	7.39±0.83c	0.80±0.11c	6.51±0.73d	88.09
Timdjuhart	39.45±2.52b	20.21±1.23d	23.86±1.33cd	9.83±0.66bc	9.83±2.02bc	1.54±0.27b	8.24±1.93cd	83.83
Feggus	39.73±2.11b	23.51±1.37bc	23.35±1.68cd	10.19±0.65ab	15.58±2.89a	1.51±0.28b	13.99±2.63b	89.79
Kahlaya	38.91±2.54b	19.73±1.64d	23.00±0.51de	9.56±0.27cd	8.12±0.88bc	1.32±0.10b	6.77±0.82d	83.37
Hamraya	41.16±1.54b	19.97±1.11d	26.02±2.04bc	6.95±0.47f	9.79±1.20bc	0.78±0.17c	8.99±1.05cd	91.82
Cherka	45.97±3.17a	22.93±1.32bc	28.29±2.52ab	10.93±1.14a	16.83±2.09a	2.14±0.54a	14.64±1.55ab	86.98

Values are means of 12 determinations. Different letters indicate significant differences ($p< 0.05$) according to Tukey's test.

3.2. Physicochemical characteristics of date cultivars

Physicochemical characterization of dates is considered as important for their storage, processing, and commercialization. The proximate physicochemical composition value of date cultivars studied is summarized in (Table 2).

Table *2*. Physicochemical characterization of date cultivars

Date cultivars	Moisture (%)	Ash (%)	pH	Conductivity (ms)	Sugar (%)
Abdel'Azzez	22.02cd±1.58	5.20ab±0.03	6.46ab±0.46	2.87ab±0.32	28,24f±0.23
Arechti	25.03c±1.06	4.00bc±0.03	6.44ab±0.48	3.38a±0.63	54,28d±0.21
Tantboucht	35.01ab±1.52	4.00bc±0.01	5.93ab±0.48	3.22a±0.61	77,12b±0.09
Djouzia	22.01cd±1.21	5.30a±0.02	5.76ab±0.53	2.68bc±0.35	37,4e±0.12
Litima	25.01c±2.03	4.02bc±0.02	6.10ab±0.42	3.20a±0.23	87.21±0.19
Timdjuhart	34.67ab±2.43	4.01bc±0.05	5.98ab±0.47	2.42bc±0.23	67,08c±0.08
Feggus	36.33a±1.06	3.16cd±0.03	6.63a±0.62	2.44bc±0.35	49de±0.32
Kahlaya	18.02d±2.03	4.73ab±0.01	5.76ab±0.33	2.05c±0.19	24f±0.09
Hamraya	19.01d±2.02	2.63d±0.07	5.38ab±0.33	3.01b±0.24	26.65f±0.12
Cherka	30.66b±2.03	3.19cd±0.08	6.06ab±0.37	3.13ab±0.31	32ef±0.08

Values with different sub-scripts in the same row are significantly different ($P \leq 0.05$).

Moisture content ranged from 18.02% in Kahlaya to 36.33% in Feggus. It seems that all date cultivars are good for conservation, and therefore a good marketing. Variations in moisture content have been reported among different date palm cultivars grown within the same country, as well as for the same cultivar cultivated in different regions. The differences observed in moisture content among the cultivars investigated in the present study are likely attributable to both genetic and environmental factors. Genotypic characteristics influence fruit texture and water-holding capacity, whereas environmental conditions, including temperature, relative humidity, irrigation practices, and soil characteristics, can affect water accumulation during fruit development. In addition, the harvest stage is known to strongly affect fruit moisture, as water content progressively decreases from the Khalal to the Tamar stage owing to dehydration during ripening. Therefore, the

variability observed among cultivars probably reflects the combined effects of genotype, terroir and fruit maturity at harvest [14, 31, 32]. The moisture of some cultivars was as low as 10% and as high as 35% in other cultivars [21,22].

In this study, ash content was observed, with a range between 2.63% and 5.30% for Hamraya and Djouzia cultivars, respectively. Djouzia and Abdel'Azzez exhibited the highest ash content among the date samples. There were significant differences ($p< 0.05$) among the ten cultivars tested. The ash content was higher than what reported by [13,23–26]. The ash content indicates the total inorganic mineral, which was suggested to be low in date fruits. Differences in ash content may be associated with the mineral composition of the soil and the capacity of each genotype to absorb and accumulate mineral elements. Previous studies have shown that soil fertility, irrigation water quality and environmental conditions contribute significantly to mineral accumulation in date fruits, explaining part of the variability observed between cultivars grown in different oases or geographical regions [33].

In contrast to moisture and ash contents, little variation in pH values was observed among the cultivars; pH values ranged from 5.38 to 6.63. The values of the electrical conductivity of the date cultivars studied are between 2.05 and 3.38. Our results showed a similar trend to those reported in other date cultivars, who studied chemical compositions of date palm [25, 27].

Significant ($p < 0.05$) varietal differences existed in proximate composition among cultivars, with some exceptions. Significant variations between the cultivars of moisture content, electrical conductivity and ash provide information on a great varietal diversity.

The carbohydrates in date fruits are the most prevalent compounds as they provide a rich source of energy to the human system, which have been widely studied. These sugars are mainly reducing carbohydrates (glucose, fructose, mannose, and maltose), non-reducing sugars such as sucrose and small amounts of polysaccharides [28]. Among the cultivars tested, the total sugars ranged from 26.65% in Hamraya to 87.21% in Litima. These differences in this parameter could mainly due to cultivar variations [25]. Besides genetic variability, sugar accumulation is closely associated with the physiological stage of fruit ripening. During maturation, sucrose is progressively hydrolysed into glucose and fructose through the action of invertase, while water loss contributes to the concentration of soluble sugars. Consequently, differences in harvest maturity may substantially influence the total sugar content observed among cultivars. Environmental conditions, particularly temperature and water availability during fruit development, may further modulate carbohydrate accumulation [36].

3.3. Biochemical characterization of date extracts

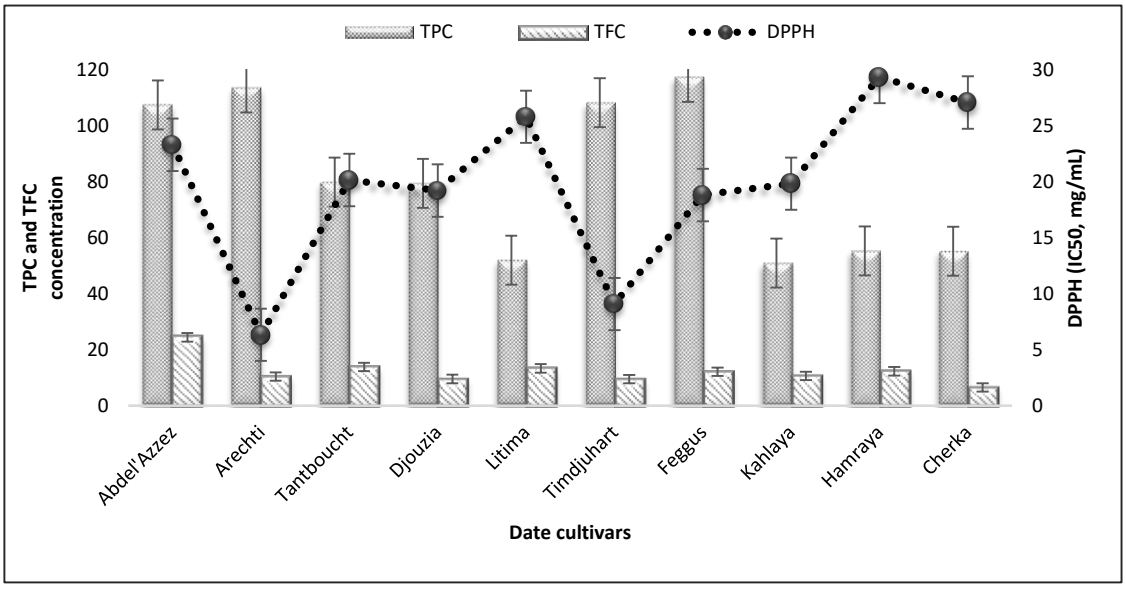
On the Figure 2 are illustrated the different concentrations of total phenolics, total flavonoids, and DPPH scavenging capacity (expressed as IC50) of date extracts.

The amount of TPC varied in the date extracts investigated and ranged from 50.95 to 117.3 mg GAE/100 g DW. Among extracts, extremely high TPC was detected in Feggus cultivar (117.3 mg GAE/100 g DW), followed by the cultivar Arechti (113.5 mg GAE/100 g DW), while the cultivar Kahlaya had the lowest value (50.95 mg GAE/100 g DW). The order of TPC in date extracts is: Feggus > Arechti > Timdjuhart > Abdel'Azzez > Tantboucht > Djouzia > Hamraya > Cherka > Litima > Kahlaya. A study [29] with five different ripe date palm fruit cultivars harvested from Ouargla (Algeria) revealed that phenolic contents between 41.8 to 84.73 mg GAE/100 g DW. Other investigations reported values varied from 172 to 246 mg GAE/100 g of fresh weight of Omani dates [30]. However, Biglari et al. (2008) noted TPC values between 2.89 and 141.35 mg GAE/100 g DW sample for extracts of date palm fruits of Iran. The quantitative role in the TPC may be explained by the difference in the cultivars of date and by the total variation in growing conditions, wider genetic variation and the methods of extraction. Previous studies have demonstrated significant variations in phenolic content among date cultivars, including Algerian genotypes, highlighting contribution of cultivar characteristics and environmental factors to phenolic accumulation [36].

Significant differences in TFC were observed among the studied cultivars ranging from 6.49 (in Cherka) to 24.42 mg QE/100 g DW in Abdel'Azzez. The order of TFC in date

samples is: Abdel'Azzez > Tantboucht > Litima > Hamraya > Feggus > Kahlaya > Arechti > Djouzia > Timdjuhart > Cherka. According to [36], flavonoid accumulation is also known to be genotype-dependent and highly responsive to environmental conditions.

In the current study, the ability of date extracts to scavenge DPPH radical was based on their IC50 values, defined above as concentration of methanolic extracts of date cultivars to decrease the absorbance at 517 nm of DPPH radical solution to half of its initial value. These IC50 values of the different date extracts are illustrated in (Figure 2). It can be seen from the figure that IC50 values ranged from 6.32 to 29.35 mg/mL. The lowest value of IC50 (6.32 mg/mL) was detected in Arechti cultivar and it corresponds to the highest antioxidant activity, followed by Timdjuhart with IC50 equal to 9.08 mg/mL; while the highest value of IC50 (29.35 mg/mL) was showed in Hamraya cultivar. The antioxidant activity in the methanolic extracts of date cultivars decreases in this order: Arechti < Timdjuhart < Feggus < Djouzia < Kahlaya < Tantboucht < Abdel'Azzez < Litima < Cherka < Hamraya.



TPC: total phenolic content expressed as mg gallic acid equivalent per 100g of dry weight, TFC: total flavonoids content expressed as mg quercetin equivalent per 100g of dry weight.

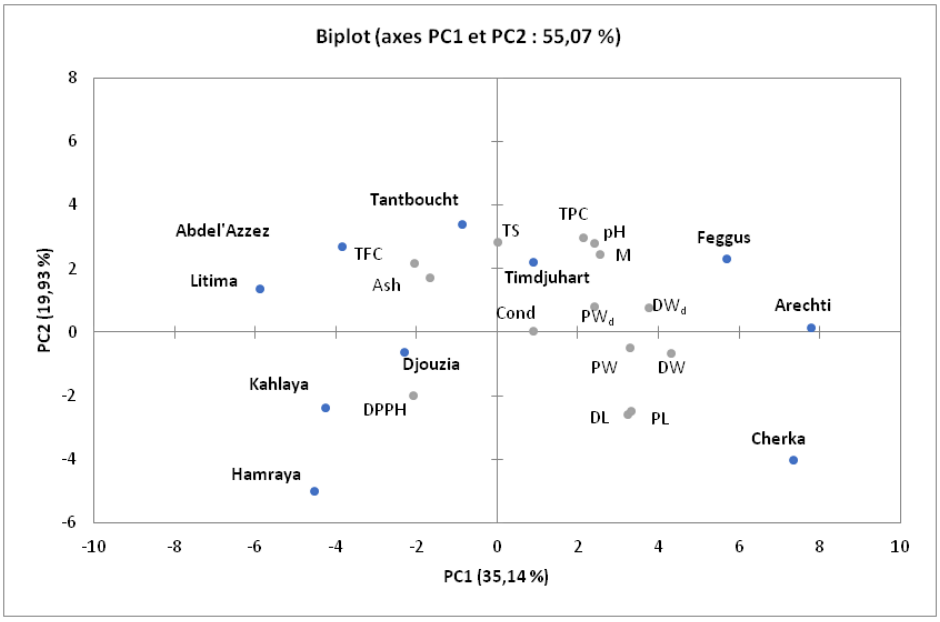
Figure 2. Concentration of total phenolics, total flavonoids, and DPPH scavenging capacity of date extracts

All ten extracts of palm date fruit contain a remarkable quantity of TPC and TFC, and show significant antioxidant activities. The IC50 values are different for all the ten extracts, despite the variation in the TPC. In the current study, no significant correlations were observed between TPC and TFC in the date extracts tested (r = 0.085). Moreover, the TFC do not correlate with the antioxidant activity (r = 0.041); slight correlation was observed between TPC and DPPH (r = 0.487). Our finding showed a similar trend to those reported in other date cultivars (Zineb et al., 2012). According to these authors, this no significance has been explained by the fact that the date fruit contains an important quantity of ascorbic acid which varies according to the different cultivars, that interferes in the quantification of TPC values. On the other hand, the antioxidant activity depends on the structural conformation of phenolic compounds. The latter is generally influenced by the phenolic compounds in the samples and by the different mechanisms involved in the radical–antioxidant reactions. The antioxidant activity in date fruits is likely influenced by the extraction and analytical methods and by genetic and environmental factors. The absence of a strong correlation between TPC, TFC and antioxidant activity suggests that antioxidant capacity cannot be attributed solely to the total concentration of phenolic compounds. The qualitative composition of phenolics, including their molecular structure, degree of

polymerization and hydroxylation pattern, may play a more important role than their total amount. Moreover, other bioactive constituents naturally present in date fruits, such as vitamin C, carotenoids and Maillard reaction products, may contribute synergistically to the overall antioxidant activity [36].

In order to better understand the interactions between the physicochemical and biochemical parameters and the morphological characteristics, the implementation of the PCA could be an interesting solution. The obtained PCA model explained 55.05% of variability found in the analyzed data: Component 1 (PC1, Fig. 03) of the PCA accounted for 35.14% of the variance and was expressed by the morphological characteristics (DL, 0.720; DWd, 0.834; PL, 0.739; PWd, 0.538; DW, 0.954; PW, 0.730) and moisture (M, 0.566). While component 2 (PC2, Fig. 03), which included total sugar (TS, 0.624), pH (0.619), TPC (0.657), TFC (0.483) and DPPH (0.459), accounted for 19.93% of the variance.

The results of the PCA (Figure 3) highlighted a significant correlation between the morphological parameters: DL correlates with PL (r = 0.967) and DW (r = 0.776); DWd correlates with DW (r = 0.880); PL correlates with DW (r = 0.787) and PWd correlates with PW (r = 0.905). It was observed also, a correlation between moisture (M) and pH (r = 0.445) and with total sugar (TS, r = 0.551). Through (Figure 3), it can be also seen that phenolic compounds (TPC) was correlated with DPPH (r = -0.698) and no significant correlation with TFC (r = 0.293).



DL, PL, DWd, PWd, DW, PW: length, width and weight of date and pit, respectively; M: moisture; TS: total sugar; Cond: conductivity.

Figure 3. Biplot illustrating the relationship between physico, bio-chemical and morphological attributes of ten date cultivars

Additionally, an individualization of three different groups of dates was obtained. Group I: of dates (Arechti, Timdjouhart and feggus) with positive correlation and containing high phenolic compounds with a strong antioxidant capacity; Group II: consisting of dates (Abdel'Azzez, Litima and Tantboucht) containing high flavonoids content with average antioxidant capacity and Group III: containing the other dates with negative correlation and low content of phenolic compounds (TPC, TFC) and average antioxidant capacity.

The PCA clearly demonstrates that cultivar discrimination cannot be explained by a single trait but rather by the combined influence of morphological, physicochemical and biochemical characteristics. The clustering of cultivars suggests that genotype is the primary determinant of fruit composition, whereas environmental conditions associated with the terroir and the maturity stage at harvest probably modulate the expression of

these characteristics. Similar observations have recently been reported for date palm cultivars cultivated under different agroecological conditions, highlighting the strong interaction between genetic and environmental factors [32].

4. Conclusions

Overall, our results provided insights into the biometric parameters, physicochemical composition, and bioactivity of ten date palm cultivars growing in the Ziban and Saoura oases (Algeria). The studied date cultivars exhibited significant variations in the different analyzed parameters, including morphological, physicochemical, and biochemical characteristics. The extracts obtained from these dates contained considerable amounts of bioactive compounds and showed good antioxidant activity, which may contribute to their potential health-promoting properties. The PCA analysis revealed that the Arechti, Timdjouhart, and Feggus cultivars exhibited specific characteristics that distinguished them from the other studied cultivars.

However, since the investigated cultivars originated from different oasis environments, the contribution of environmental factors cannot be completely separated from genetic effects. Therefore, further studies involving the cultivation of different cultivars under similar environmental conditions or multi-location trials are required to better evaluate the genetic contribution to the observed variability.

Future investigations should also focus on the isolation and identification of individual phenolic compounds in these date cultivars. Moreover, in vivo studies are needed to further validate their antioxidant properties and elucidate their mechanisms of action.

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