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Variability of physicochemical properties of 'Deglet Nour' date fruits collected from different oases in Djerid Region, Tunisia

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ABSTRACT

Purpose: Quality and physical characteristics of date palm changes during growth and maturation stages of fruits in main production areas in the south of Tunisia. **Research Method:** The effect of season, ripening date and climatic conditions (temperature and relative humidity) on physicochemical characteristics of fresh dates "Deglet Nour" grown at four different oases were evaluated using multivariate analysis. **Main findings:** Dates from Traditional Mountain Oases (TMO) had the highest values of length, width, weight, moisture content for the two seasons. Those from Modern Palm Plantation (MPP) had the highest values of fiber content, water activity, glucose and fructose in 2014. In 2014 and 2015, date palm fruits of Modern Continental Oases (MCO) had the highest values of sucrose. The lower values of the different parameters were registered for dates from Traditional Continental Oases (TCO). Meteorological data from the experimental station recorded higher temperature and relative humidity during fruit maturation (July, August and September) in 2014 compared to 2015. Results showed that the good quality of dates was obtained in oases TMO that had higher relative humidity and lower temperature compared to other oases (MPP, MCO, and TCO). Such changes may have resulted from earlier pollination and higher temperatures during the maturation period. Considering the two seasons 2014 and 2015, the highest thermal coefficients were observed in MCO (3726 and 3704, respectively) and the lower ones in TCO (3083 and 3025, respectively). **Research limitation:** No limitations were founded. **Originality/Value:** Seasons and oases climate significantly affected the physical and biochemical quality characteristics of date palm fruits. This engendered in the longest maturity period recorded in TCO. MPP where we recorded the highest spring temperatures, showed the shorted development cycle.

INTRODUCTION

South Tunisia is the main region producing date palm (*Phoenix dactylifera* L.) fruits (Besbes et al., 2009). More than 300 cultivars of date palm are present in Tunisia. Deglet Nour production in Djerid region is the most planted date palm variety (70% of the 5.9 million trees in all oases) because of its characteristics for both nutritional and sensorial properties (MARHP, 2016).

In Tunisia, the export value of dates is around 486.5 million dinars annually (113.800 tons of Deglet Nour fruits). The Djerid region (governorate of Tozeur) is one of the important areas producing high quality of Deglet Nour fruit (Fruits, 2016).

Cultivar growing in this hot arid region faces environmental stress such as drought, salinity, and heat, which limit tree growth and productivity (Youssef & Awad, 2008). One of the major problems in some zones of the Djerid region is a regression in quantities and qualities of Deglet Nour fruits. The most likely reason for regression in quantities and quality of Deglet Nour fruits is the impact of climate change and cultural practices (Shabana & Al Sunbol, 2007). Disturbances in the timing of fruit tree development have been observed as a result of recent climate change. The major effect of temperature should be the advancement of the phenological stages (the period of maturity will be advanced from 3 to 5 weeks), which can pose quality problems of the product by the advancement of the sensitive stages (Lavelle et al., 2008). High temperatures cause a high risk of scalding and disturbance of flowering, pollination and fruiting periods (Seguin & Stengel, 2002). The fruits of the date palm go through distinct development stages known locally as kimri, khalal, rutab and Tamar. Commercially, these fruits are consumed at khalal and Rutab stages as fresh fruits and at Tamar stage as dried fruits (Singh et al., 2012). The development duration of date fruits and their physical and chemical characteristics vary greatly with seasons and environments (Al-Farsi et al., 2007). Given the above, the objective of this study was to evaluate the morphological and biochemical properties of dates «Deglet Nour» from four oases at the Djerid region (southern Tunisia) during the maturation stages for two consecutive seasons.

MATERIALS AND METHODS

Experimental sites

Samples of date palm fruits (Deglet Nour (DN) variety) were collected, during 2014 and 2015, at different development stages at four oases in Djerid region.

- TCO: Traditional Continental Oases: three strata system: date palm, other fruit trees (pomegranate, apple, pear, lemon tree), and vegetable and fodder crops. It is characterized by a high density of palms with more than 200 trees/ha. The water cycle lasts eight days.
- MPP: Modern Palm Plantation: monospecific cultivation: only date palm trees are grown. The distance between trees is about 8 m, giving about 150 palm trees/ha. The water cycle lasts ten days.
- TMO: Traditional Mountain Oases: three strata system dominated by pomegranate and olive trees. The lower stage is occupied by a mixture of different vegetable crops: squash, parsley and forage crops. The number of palm trees is about 200 ha^{-1}. The water cycle lasts six days.
- MCO: Modern Continental Oases: three strata system where the density of palm trees is between 100 and 150 ha^{-1}. The water cycle lasts four days.

The differences between these oases are based on climatic conditions about their geographical positions, their mode of cultivation and management (Table 1). Irrigation system (submersion) and cultural practices are the same in these different oases.

Table 1. Average of heat units for 2014 and 2015 at different Djerid oasis (calculated from the data recorded by the meteorology stations at TMO, TCO, MPP and MCO)

Date palm oases	Heat Units (°C) 2014	Heat Units (°C) 2015
MPP	3456.44	3376.8
TCO	3542.54	3493.49
MCO	3726	3704.68
TMO	3083.52	3025.14

Table 2. Development stages recorded for Deglet Nour dates sampling

Date of sampling	June	July	August	September
Stage of sampling	S3 Kimri	S4 Khalal	S5 Rutab	S6 Tamar

Phenological characteristics

Dates of pollination and fruit maturity (Tamar stage) were recorded for all oases for the two seasons.

Date samples Collection

Fruit samples were taken monthly and for the different phenological stages (Table 2) according to the method of Girard (1980). Samples were taken from 5 different trees for each oases. Twenty homogeneous fruits of each sample were individually analyzed for morphological and physicochemical characteristics.

Morphometric characteristics

Fruit weight measured with an analytical balance, Fruit length and width were recorded for all sampled fruits at the different maturation stages with a vernier caliper. Measures were taken twice per each fruit on twenty fruits for each sample.

Physicochemical characteristics

The date fruit color was determined by a Minolta CR 300 color-difference meter (Ramsey, NJ) (C standard C.I.E. illumination, 0° viewing) (Artés et al., 2000). The CIE Lab coordinates (L*, a*, b*) were recorded. L* measured the lightness ranging from black to white on a scale of 0 to 100; a* the greenness to redness on a scale of -100 to +100; and b* measuring the blueness (-100) to yellowness (+100). When the a* and b* values increase, the color saturated, while when they approach zero they indicate neutral colors white, grey or black. The external husk color was determined as L*(lightness), or calculated as Chroma (C*=[(a*P 2 P + b*P 2 P)P 0.5P]) and Hue angle (H°= arctg b*/a*)).

The pH values were determined using the method Girard (1980). To determine the fruit titratable acidity, 25 grams of date fruit were homogenized with 100 mL of distilled water. The mixture was heated into water bath at 90°C for 30min and filtered. The whole mixture was then filtered and titrated with O.1N NaOH with phenolphthalein as indicator. Titratable acidity was expressed as percent of tartaric acid. To measure water fruit content, 05grams of pulp were placed 24 hours in a stove at a temperature of 105°C.The water activity (aw) was determined by an aw-meter (Novasina Lab Master-aw, Swiss). The date palm samples were analyzed for acid and neutral detergent fiber by the method of Prosky et al. (1988), (AOAC, 1995) and insoluble fiber by the modified enzymatic-gravimetric method.

The total sugars were determined by HPLC. Date fruits (3g) were prepared with aqueous ethanol solutions (800 mL L^{-1}) by shaking at 50 °C for 30 min (Bouabidi et al., 1996). The filtrate was then centrifuged. After centrifugation, the supernatant was concentrated using a rotary evaporator at 40°C. Sucrose, glucose and fructose were analysed using highperformance anion exchange chromatograph (HPAED-PAD) equipped with a quaternary pump, a pulsed amperometric detector and an injector valve type DIONEX, according to the method described by Bouabidi et al. (1996).Total Sugars(sucrose, glucose and fructose) standards were run to identify sample peaks. After comparison of retention time with the standards, the peaks were identified. The amount of total sugar in the date samples was quantified using calibration curves obtained from different concentrations of sucrose, glucose and fructose standards, which are the major sugars in date palm. They were quantified according to their percentage area, obtained by integration of the peaks.

Statistical analysis

Data were analyzed using ANOVA and a comparison of the means by a test of multiple comparisons (test of Newman-Keuls). The ANOVA was performed by the "STATISTICA" software. Pearson correlation coefficients (r) were determined using Statistica program. Principal component analysis (PCA) was used as a projection method from the statistical XLSTAT software which to determine the interrelationship among the investigated fruit parameters.

RESULTS AND DISCUSSION

Phenological characteristics

The two-year phenological record show differences among fruit maturity date from an oasis to another (Table 3). Differences were noted since the pollination date. MPP, where we recorded the highest spring temperatures, seemed to be the earliest in fruit development. So pollination was applied at April 04th and 08th for respectively 2014 and 2015. In TMO oases, the coolest spring temperatures were recorded and pollination were conducted on April 10th and 15 for 2014 and 2015, respectively.

It was observed that the phonological behavior of the fruit was usually somewhat variable from an oasis to another and from year to year. Date fruits of TMO take longer time to reach their final growth stage compared to other date palm fruit from TCO, MCO, MPP oases. The observation of fruit development and ripening allowed the conclusion of the existence of a relationship between the date development cycle and the oasis climatic conditions. Different date samples were taken during the fruit ripening process, and the last sample was collected in full fruit maturity in the four oases. In our case, date fruits « Deglet Nour » required an average of 185-196 days to reach their final size (Table 3). As for pollination, the fruit maturity was precocious in the MPP as compared to TCO and TMO. In fact, 189 and 192 days were necessary for dates Deglet Nour for the completion of maturity during 2014 and 2015, respectively. The TMO seems to have a significant influence on the period required for fruit maturity with a delay of 10 days on the fruit maturity date for both campaigns 2014 and 2015. The first mature fruits were harvested at October 07, 2014 in the MCO Oasis. The latest ones were harvested on October 21, 2014 at the Mountain Oasis (Table 3).

These differences could be attributed to the differences of climate conditions in 2014 and 2015 in the Djerid region. Many environmental factors influenced the growth and development of fruit (Bindi et al., 2001), but the maturation time and on the duration of fruit development is regulated mainly by climatic factors related especially to temperature and humidity (Zaid & De Wet, 2002). The highest heat unit values in 2014 and 2015 were found in MCO oases (3726) and (3704.68), respectively. The lowest values were observed in TMO oases (3083.52) and (3025.14), for 2014 and 2015, respectively. Hot season and zero precipitation during the development of date fruit were reported as optimum conditions for date fruit ripening. The number of heat units (degree days) needed to ripen the fruit varies with cultivar and ranges between 2100 and 4700 for early and late-ripening cultivars, respectively. From blossoming to ripening, the temperature optimal daily varied from 21°C for early ripening cultivars to 24°C for mid-season cultivars, and 27°C for late-ripening cultivars (Rygg, 1975). Zaid and De Wet (2002) have summarized the climatic requirements of date palm. To have a good quality of the fruit on date palm, the production must have high temperatures (an average of 30°C, low humidity, ample sunshine and adequate supplies of underground water or irrigation (Purseglove, 1972).

Table 3. Temperature and relative humidity recorded during 2014 and 2015 at different oases

Oases	Years	Date of pollination	Heat Units (°C)	Days after pollination (DAP)	Date of sampling	Temperature	Humidity
MCO	2014	05-avr	3726	89	03-juil	31.03	41.06
				124	07-août	32.39	39.67
				150	02-sept	30.04	43.86
				185	07-oct	23.43	46.90
	2015	10-avr	3704.68	91	10-juil	32.08	39.82
				115	03-aout	32.66	45.14
				149	06-sept	29.09	45.94
				188	15-oct	23.77	53.11
MPP	2014	04-avr	3456.44	90	03-juil	27.62	44.07
				125	07-août	26.83	37.88
				152	03-sept	26.05	44.12
				189	10-oct	22.55	44.78
	2015	08-avr	3376.8	100	17-juil	26.59	43.33
				146	01-aout	27.46	40.54
				176	01-sept	29.91	47.77
				192	17-oct	24.6	48.12
TCO	2014	07-avr	3542.54	87	03-juil	31.70	41.02
				122	07-août	32.42	41.49
				149	03-sept	30.01	46.04
				190	14-oct	23.00	49.22
	2015	12-avr	3493.49	96	17-juil	32.07	39.18
				142	01-aout	32.58	46.30
				172	01-sept	27.73	50.33
				193	22-oct	24.18	54.91
TMO	2014	10-avr	3083.52	91	10-juil	28.87	37.02
				122	10-août	30.05	37.36
				155	12-sept	29.06	39.50
				194	21-oct	23.33	41.68
	2015	15-avr	3025.14	94	18-juil	31.92	39.98
				133	26-août	30.80	40.43
				169	01-sept	27.01	38.20
				196	28-oct	23.00	40.48

Data were recorded by the meteorological station simplemented at TMO, TCO, MPP and MCO.

Morphological characteristics

The evolution of fruit length, width and weight during the ripening period in 2014 and 2015 are reported in Table 4. For all fruit morphological characteristics, statistical analyses showed significant differences (*P*<0.05) at all phenological stages for the two seasons. High temperatures three months after pollination (Khalal stage) were registered and considered to be factors that greatly influence the ripening of Deglet Nour at the four oases. Deglet Nour fruit reaches their maximum length in September and October depending to the oases: 4.84-4.6 cm; 4.74-3.94 cm; 4.74-3.85 cm and 4.5 cm for TMO, MCO, MPP and TCO in 2014 and 2015, respectively.

Fruits increase in width from 0.57 to 2.32 cm and from 0.64 to 1.92 cm in 2014 and 2015 season, respectively. The weight of date palm fruit increased progressively in the four oases from 0.93 to 13.74 g and from 2.74 to 12.35 g in 2014 and 2015 season, respectively. In the first 4-5 weeks, date fruit became green at kimri stage and characterized by 27.5 mm length × 17.8 mm in diameter and 5.8g as average weight. In the khalal stage, the fruit characterized by 32.5 mm in length and 21 mm in diameter and the weight fruit became 8.7g. The hottest month in the oasis was July when temperatures go up to 44.4°C. The lowest temperature recorded during the study period was 15.1°C for October 2014 and 2015. From September to October, we marked a decrease of four regions date fruits length, width and weight. However, in TMO the date fruits had, at harvest date, the highest fruit length and width compared to all others (4.3-1.96 cm). TCO has the lower length and width significantly in 2014 than 2015 season (4.01-1.78 cm). Then, the width of the fruits decreased from 2.32 to 1.78 cm and from 1.92 to 1.7 cm in 2014 and 2015 season, respectively. However, the weight of date palm fruit increased from 13.74 to 8.83g and from 12.35 to 8.83g in 2014 and 2015 season, respectively. Few years ago, El-Arem et al. (2012) reported that, during the maturation period, the length of Deglet Nour varied from (4.30 ± 0.17–4.10 ± 0.11), width from (1.90 ± 0.17–1.60 ± 0.11 cm) and weight from (11.88 ± 0.16–10.49 ± 0.17 g) values from besser to tamar stage, respectively.

Mature TMO dates had the highest weight (10.9 g). However, TCO dates had the lowest fruit weight (8.83g). Differences observed for the same cultivar are mainly due to the climate conditions and harvesting period (Somayeh et al., 2012). The relative humidity is high throughout the two years 2014 and 2015. It was respectively, on average (14-78%) and (14-85%).

Date fruit color changes to green, red, light brown to dark brown during development. Results from this study showed that the highest parameters L*, Chroma and H° were recorded in MCO at stage 3for the two seasons 2014 and 2015 (48.89 ±0.58, 23.79 ±0.65, 72.55 ±0.69), (54.2 ±0.41, 12.86 ±065, 85.94 ±0.44), respectively (Table 4). The highest values of these parameters at the next stage were observed in TCO (45.52 ±0.61, 46.91 ±0.65, and 36.88 ±0.44), (43.18±0.69, 50.74±0.45, 50.91±0.37) in 2014 and 2015, respectively. These differences can be explained by variability on the ripening stage from an oasis to another. Elleuch et al. (2008) reported that 'Deglet Nour' fruit at tamar stage has a L* = 31.71 ± 0.57 these values are comparable to this study. El-Zoghbi (1994) reported that metabolic and physiological changes occur in date fruits during growth, development and ripening. These variations could be related to genotype, branch size, temperature and heat units, light and water potential, carbohydrate supply and hormonal changes, especially gibberellin, auxin and ethylene levels. The green color of Deglet Nour fruit was observed at the khimri and Khalal stages, red color was observed at rutab stage and yellow color were observed at tamar stage. At the khimri and khalal stage, MPP and MCO fruits had red color; TMO and TCO fruits had yellow color (in the two seasons). The change to the red color of MCO and MPP Deglet Nour fruits at the fourth stage (in two seasons) has been recorded earlier.

The third development stage of date fruit (rutab) corresponded to light green color with a slight yellowish tinge which is an indicated by the C* values. At the kimri and khalal stage, date fruits from all the four different oases showed lightness values in a narrow range, but at the rutab and tamar stages, the lightness values decreased. However, by the fourth stage, the MCO and MPP fruits had developed a reddish color indicated by a higher L* values (45.92 ±0.4/46.60 ±0.25, in 2014 and 2015, respectively). TMO and TCO fruits were yellow in color with a lower L*values (43.18 ±0.69/45.18 ±0.63 in 2014 and 2015, respectively). Mean values of L*, hue and C* of TMO fruits ranged from (52.21 ±0.93/30.55 ±0.76/60.38 ±0.63) in 2014 (54.72 ±0.45/12.01 ±0.64/69.61 ±0.54) in 2015, respectively. The L*, C* and hº Color Space can be grading ripe category of date fruits according to its color to more than color such as(yellow, light red and dark red), according to Chroma (C*) and hue angle (hº) for each variety of date fruits. Date color can be related to the moisture, sugar content and level of acidity through the color and saturation for date fruit (Ibrahim et al., 2014).

Table 5. Physical characteristics of dates ”Deglet Nour” at the different stage from different oases in two seasons (2014 and 2015)

Oases	Years	Sampling date (DAP)**	Moisture Content (%)	pH	Water A (%)
MCO	2014	89	80.86±0.01b	3.92±0.0d	0.53±0.01a
		124	82.54±0.00c	4±0.00c	0.72±0.01a
		150	73.17±0.02c	6.01±0.0b	0.69±0.00a
		185	32.69±0.01c	5.55±0.01c	0.94±0.01d
	2015	91	78.31±0.1a	4.95±0.02c	0.84±0.00b
		115	63.80±0.1a	5.98±0.0c	0.74±0.00a
		149	37.19±0.1d	5.76±0.2c	0.77±0.01b
		188	26.59±0.1c	5.83±0.1c	0.72±0.00a
MPP	2014	90	82.94±0.01d	3.25±0.00a	0.97±0.01c
		125	83.35±0.01d	3.60±0.0b	0.86±0.1b
		152	61.78±0.01a	6.21±0.0d	0.87±0.00b
		189	22.73±0.02a	5.12±0.01a	0.81±0.01a
	2015	100	78.53±0.01b	5.08±0.5d	0.98±0.00d
		146	69.56±0.01c	6.12±0.0d	0.86±0.01c
		176	24.87±0.01b	5.15±0.02a	0.87±0.00d
		192	26.70±0.01d	5.18±0.03a	0.81±0.00d
TCO	2014	87	80.30±0.01a	3.59±0.01c	0.98±0.00d
		122	82.26±0.02b	3.63±0.02a	0.93±0.00d
		149	73.17±0.1c	5.65±0.01a	0.98±0.00c
		190	32.35±0.1b	5.47±0.0b	0.87±0.01b
	2015	96	79.34±0.1c	4.90±0.0b	0.83±0.00a
		142	67.61±0.1b	5.82±0.0b	0.83±0.01b
		172	22.02±0.1a	5.43±0.02a	0.71±0.00a
		193	16.84±0.01b	5.47±0.0b	0.76±0.00b
TMO	2014	91	81.65±0.01c	3.57±0.0b	0,68±0.01b
		122	80.61±0.1a	3.63±0.02a	0,88±0.00c
		155	68.69±01b	6.06±0.01c	0,98±0.00c
		194	32.83±0.2d	5.75±0.0d	0,88±0.01c
	2015	94	80.17±0.1d	4.88±0.00a	0.87±0.00c
		133	72.42±0.02d	5.45±0.0b	0.87±0.00d
		169	31.48±0.01c	6.17±0.0d	0.78±0.00c
		196	16.74±0.01a	6.26±0.0d	0.78±0.00c

Fruits in each column followed by different letters (a, b, and c) indicate significant differences ($P < 0.05$) using the test of Newman-Keuls. **: DAP: days after pollination

Physical characteristics

The moisture content of dates 'Deglet Nour' varied from 83.35 to 22.73% in 2014, and from 82.54 to 16.74 in 2015, respectively (Table 5). During development, fruits decrease in moisture content. The last stage of date growth, TMO had the highest moisture content (32.83- 26. 7% in 2014 and 2015, respectively). MPP and TCO had the lowest moisture content (22.73-16.74% in 2014 and 2015, respectively). These results are comparable to Booij et al. (1992), Sawaya et al. (1983) and Elleuch et al. (2008). Some differences were attributed to varieties, agro-environmental conditions (Ahmed et al., 1995; Al-Hooti & Jiuan 1995; Gasim, 1994). El-Arem et al. (2012) reported that the values of moisture content of Deglet Nour varied from 65.50 to 21.95 % at besser to tamar stage, respectively.

Date palm of TMO, possessed higher pH (5.75- 6.26) in 2014 and 2015, respectively, and MPP showed the lowest values in these two seasons (5.12- 5.18).The fruit dates of MCO revealed a slightly acid pH equal to 5.83 compared to that of the fruits of the TMO 6.26. The dates of the MPP and TCO region present the most acid pH values 5.18 and 5.47 respectively (Table 5). Good quality fruits of date palm had a pH of 6.43 (Khali et al., 2007). It increased from a stage to another (Jarrah, 1983; Rastegar et al., 2012). El-Arem et al. (2012) showed that fruit pH was 5.84 at besser stage, 6.34 at rutab stage and 6.85 at tamar stage. TMO possessed the high quality of fresh Deglet Nour in 2015 (6.26).

The high values of water activity (a_W) were observed at the samples of MCO (0.94) and MPP (0.81) in 2014 and 2015, respectively. Fruit of date palm is characterized by a low fatty acid content (0.66) which protects them against all bacterial development (Besbes et al., 2009). Guerin et al. (1978) showed that relative humidity is important for the stability of a product. Indeed, the water content of food is directly related to the moisture of the air.

Biochemical characteristics

The highest TSS (total soluble solids) concentration was recorded in TCO (18.2) in 2014 and in MCO (17.7) 2015. However, in MCO, the date palm had the lowest TSS fruit (17.3) in 2014, and in 2015 MPP has the lowest TSS fruits (16.4). The results (Table 6) showed that TSS increase gradually to the tamar stage. The TSS increased gradually from (2.5-17.3) in MCO, from (2.5-17.5) in MPP, from (2-18.2) in TCO, from (2.8-17.8) in TMO and from (3.2-17.7) in MCO, from (3.1-16.4) in MPP, from (3.5-16.9) in TCO, from (3.3-17.1) in TMO respectively, during fruit development.

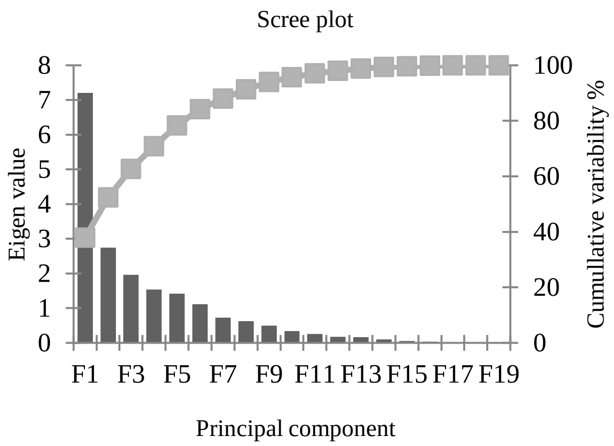

Fig. 1. Scree plot of variance explained by each factor of the principal component.

Table 6. Biochemical quality characteristics of dates "Deglet Nour" at the different stage from different oases in two seasons (2014 and 2015)

Oases	Years	Sampling date (DAP)**	TSS° (%)	Fiber S (%)	Fiber I (%)	Glucose (%)	Fructose (%)	Sucrose (%)
MCO	2014	89	3.6±0.01a	1.16±0.00c	11.69±0.00a	20.02±0.43c	8.19±0.1c	0.085±0.001a
		124	9±0.02c	1.18±0.00b	9.14±0.01b	27.41±0.52c	8.89±0.24d	0.17±0.002a
		150	12.6±0.00b	1.67±0.00d	4.92±0.01a	41.69±0.35b	20.77±0.24b	6.27±0.009a
		185	17.3±0.01a	2.50±0.1c	4.70±0.01a	48.74±0.45c	24.31±0.35c	8.86±0.002d
	2015	91	6.2±0.1b	1.34±0.00d	11.22±0.00b	12.41±0.00b	4.61±0.43d	0.085±0.009a
		115	9.6±0.2a	1.61±0.00c	9.66±0.00c	40.82±0.17d	18.51±0.52c	0.72±0.01b
		149	14.8±0.1c	1.87±0.00d	5.69±0.00a	30.78±0.08b	15.05±0.35b	5.75±0.003a
		188	17.7±0.2d	2.34±0.00c	5.06±0.00a	41.64±0.26c	22.06±0.45c	7.40±0.006d
MPP	2014	90	3.7±0.01b	0.96±0.01b	12.33±0.01b	14.33±0.28a	4.84±0.12a	0.11±0.005b
		125	10.1±0.01d	0.99±0.01a	9.36±0.01c	23.83±0.43a	7.04±0.24c	0.17±0.002a
		152	12.4±0.00a	1.16±0.01a	7.65±0.01c	41.87±0.33b	21.62±0.24c	6.99±0.001c
		189	17.5±0.01b	2.79±0.00d	6.17±0.01b	57.95±0.59d	30.09±0.58d	8.71±0.007b
	2015	100	5±0.1a	1.06±0.00b	12.38±0.00d	12.03±0.002b	4.52±0.28c	0.085±0.002a
		146	10.6±0.1b	1.38±0.00b	9.63±0.00c	38.11±0.009c	19.04±0.35d	0.17±0.004a
		176	13.2±0.1a	1.66±0.00c	6.87±0.00c	32.69±0.09c	16.34±0.33d	6.18±0.001b
		192	16.4±0.1a	2.45±0.00d	6.17±0.00b	30.71±0.08b	16.91±0.53a	6.17±0.002a
TCO	2014	87	3.8±0.01c	0.59±0.00a	15.01±0.01d	18.60±0.43b	7.12±0.12b	0.085±0.002a
		122	8.9±0.01b	1.18±0.01b	8.82±0.01a	25.57±0.35b	7.39±0.24b	0.17±0.002a
		149	14.7±0.02d	1.50±0.00c	6.88±0.00b	31.19±0.43a	13.85±0.12a	6.17±0.008a
		190	18.2±0.03d	1.98±0.01a	6.52±0.00c	38.12±0.14a	17.53±0.44a	8.80±0.006c
	2015	96	9.9±0.1d	0.89±0.00a	11.03±0.00a	12.08±0.17c	3.44±0.43a	0.085±0.001a
		142	12.9±0.1d	1.18±0.00a	8.84±0.00a	34.77±0.00a	12.23±0.42a	0,17±0.01a
		172	14.3±0.12b	1.5±0.00b	6.84±0.00b	33.07±0.17d	16.09±0.43c	7.46±0.009c
		193	16.9±0.12b	2.19±0.00a	6.25±0.00c	26.50±0.00a	14.98±0.42b	6.46±0.007b
TMO	2014	91	3.9±0.01d	1.19±0.01d	14.18±0.01c	14.64±0.48a	5.42±0.24a	0.085±0.003a
		122	6.6±0.01a	1.30±0.01c	11.96±0.00d	25.20±0.45b	7.57±0.28c	0.17±0.002a
		155	13.7±0.03c	1.38±0.02b	7.74±0.01d	47.89±0.48c	24.65±0.33d	6.81±0.017b
		194	17.8±0.01c	2.18±0.02b	6.88±0.01d	39.92±0.07b	18.51±0.44b	6.89±0.02a
	2015	94	7.2±0.12c	1.17±0.00c	12.17±0.00c	10.58±0.00a	3.93±0.43b	0.085±0.003a
		133	10.8±0.12c	1.38±0.00b	10.96±0.00d	34.85±0.08b	11.92±0.34b	0.17±0.005a
		169	14.8±0.12c	1.42±0.00a	6.99±0.00d	26.68±0.00a	16.87±0.43a	6.31±0.001b
		196	17.1±0.1c	2.24±0.00b	6.28±0.00d	42.30±0.07c	22.50±0.43d	6.94±0.003c

Fruits in each column followed by different letters (a, b, and c) indicate significant differences ($P < 0.05$) using the test of Newman-Keuls. **: DAP: days after pollination.

During all the maturation stages, the soluble fiber content of date flesh samples ranged from 0.65 to 2.79% and from 20.58 to 4.7%, for insoluble fiber in 2014 and 2015, respectively. The insoluble fiber was initially higher at khalal (S3) stage then sharply decreased during rutab and finally lowest at tamar stage (S6) in all date palm of the four oases (Table 6).Highest fiber insoluble was recorded in TMO in the two-seasons (2014-2015), at khalal, rutab and tamar stage (11.96-7.74-6.88%), (10.82-7.28-6.99%), respectively. Lowest fiber insoluble values (8.82-6.88-6.52%), (8.84-6.84-6.25%) were recorded in TCO, in 2014 and 2015, respectively. The date palm fruit of MPP possessed the highest values of soluble fiber in 2014 than 2015 season (2.79-2.45%). But TCO has the lowest values of soluble fiber (1.98-2.19%) in the two seasons (2014-2015).

According to Al-Farsi and Lee (2008), the dates contain an average total fiber content of between 3.57 g/100 g and 10.9 g/100 g, which are divided into soluble fibers (0.4-1.3 g/100 g) and insoluble fibers (3.03-7.4 g/100 g). The date palm collected from MPP, TMO, MCO and TCO oases indicated that variation in the region, and climatic conditions could make an impact on the fruit quality and nutritional values. The results are comparable to those reported previously, with some differences related to date variety and agro-climatic and environmental conditions (Ahmed et al., 1995; Elleuch et al., 2008; Gassim, 1994).

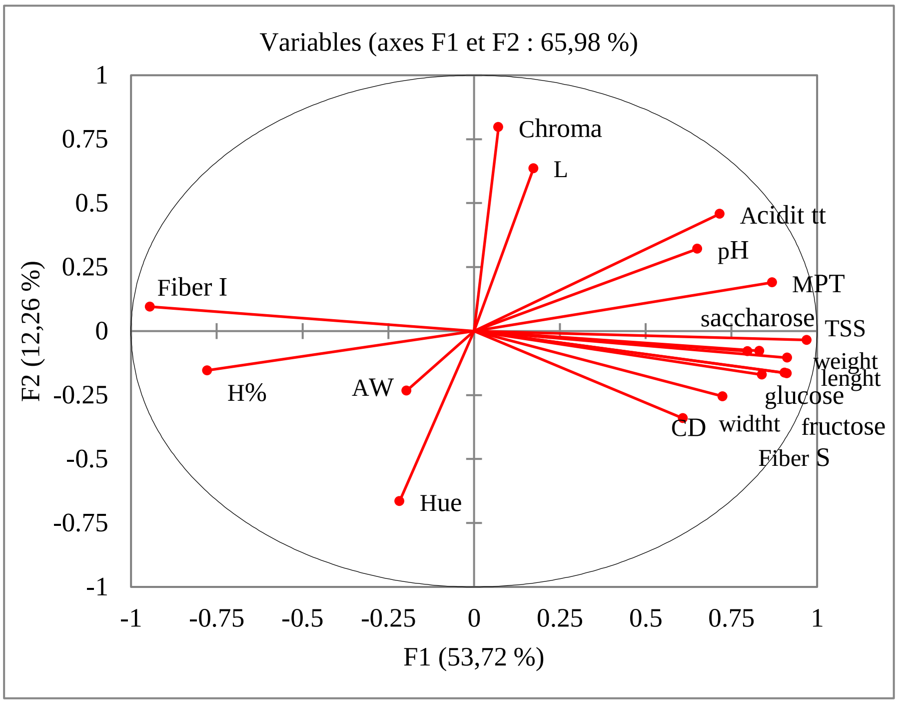

Fig. 2. Circle of correlation of variables (F1 and F2) during two study seasons

(Length : length of dates, width : width of dates, weight : weight of dates, H% : Moisture content, ACI : total acidité, TSS : total soluble solids, SAC : sucrose, MPT : protein content, AW: activité de l'eau)

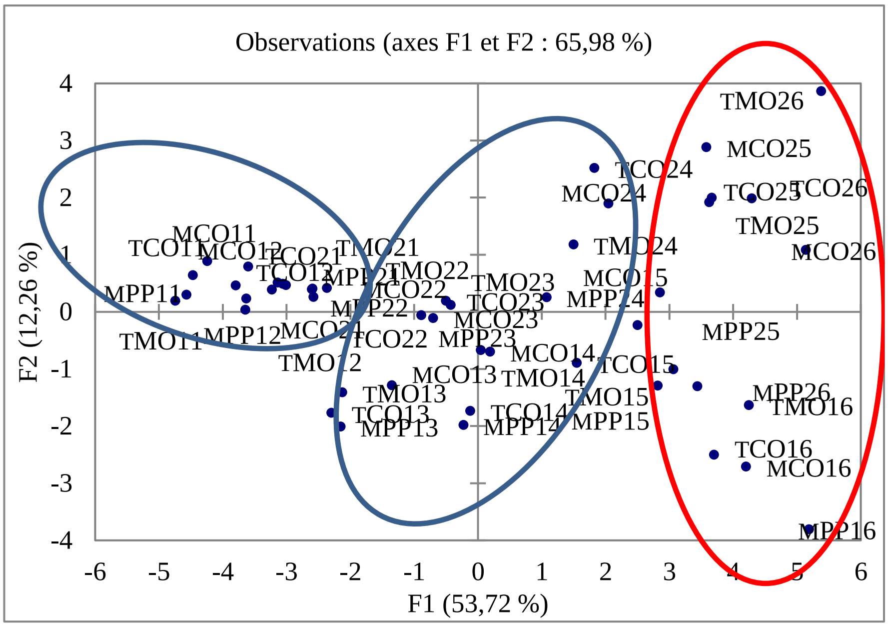

Fig. 3. Projection of observations on the factorial plan of two study seasons

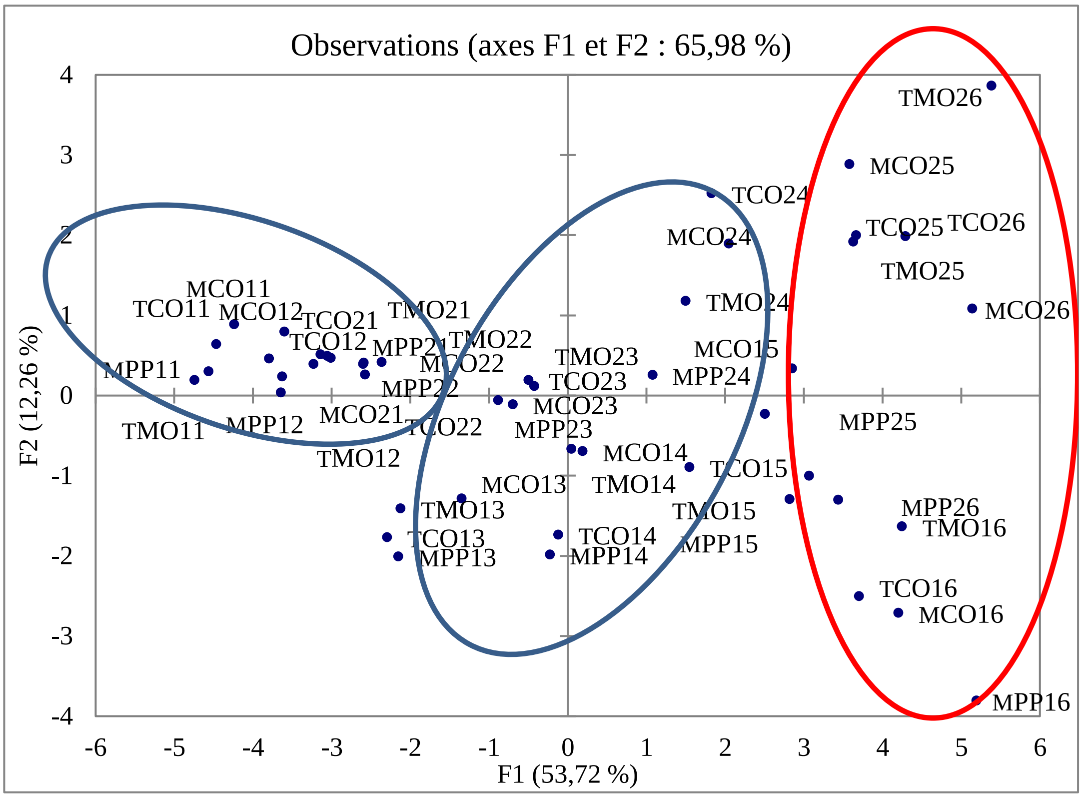

Fig. 4. Projection of the best-represented variables on the factorial plane 1-2 of two study seasons

Total dietary fiber contents varied significantly between 8.09 g/100g and 5 g/100g (dry matter basis) in Deglet Nour (Besbes et al., 2009). Ripening condition, location, year of development and method of studies can make the difference of characteristics (Besbes et al., 2009).

The composition and amounts of sugars of date are shown in (Table 6). Sugars varied within oases and stages of maturity. Sucrose, fructose and glucose are the main sugars in date. Significantly differences were observed in sugars content in dates from a different stage of maturation and in proportions between the regions. In season 2014, the high quantity of reducing sugars (glucose and fructose) ranged from 57.95 to 30.09% in MPP. Whereas, the elevated sucrose contents in MCO was about8.86%. The lower quantity of reducing sugars ranged from 38.12 to17.53% in TCO. Whereas, the lower sucrose contents in TMO was about6.89%.

The high content of reducing sugars and low values of sucrose was observed in the date palm fruit in the two seasons. To have a good quality of date fruit, we should have a high temperature during maturation and development stage. The content of sucrose in the tamar stage decrease because of the rising activity of the splitting enzyme invertase (Barreveld, 1993). Bousdira (2007) reported that the values of glucose in date 'Deglet Nour' was over than 34%, the fructose content ranged from 21 to 30% and the amount of sucrose ranged from 0 to 12%. Reynes et al. (1994), Ahmed et al. (1995), and Bouabidi et al. (1996) showed that the values of glucose in date 'Deglet Nour' ranged from 26% to 47%, the values of fructose ranged from 23% to 46% and the amount of sucrose ranged from 10% to 24%. However, Baliga et al. (2011) found that the chemical composition of dates in sugars ranged from 52.6-88.6 (g/100g) Glucose 17.6-41.4, Fructose 13.6-36.8, Sucrose 0.5-33.9.

Significantly differences were observed in the percentage of reducing sugars and sucrose for all the dates' fruits of the different regions.

Multivariate analysis

Correlation of parameters was used to study the interrelationships among some major maturity chemical characteristic and climate conditions. Analytic results were reveled significant (*$P<0.05$*) strong relationships were observed among the investigated parameters. A good correlation were showed significantly (*$P<0.05$*) between TSS and sugars (sucrose: r^2 =0.803; fructose: r^2=0.726; glucose: r^2 =0.687), pH (r^2 =0.708), soluble fiber (r^2 =0.798). There were also correlations between soluble fiber and sugars (sucrose: r^2 =0.785; fructose: r^2=0.738; glucose: r^2 =0.669), and very good correlations between glucose and fructose (r^2 =0.967). Negative relationships (*$P<0.05$*) were observed between moisture content and TSS (r^2 = -0.837), as well as between moisture content and soluble fiber (r^2 = -0.829), then high negative correlations with sucrose (r2 = -0.93).

The highest positive correlation has been observed in the case of length with width and weight (r=0.744), (r=0.915), respectively, followed by TSS with pH (r=0.708). Significant positive correlations were found for the two successive years between insoluble fiber and moisture content (r=0.756), between fructose and TSS, soluble fiber and glucose (r=0.726), (r=0.738) and (r=0.738), respectively, while the highest negative correlation have been observed in the case of insoluble fiber with TSS (r= -0.919) and in the case of fructose with insoluble fiber (r=-0.707). The correlation coefficient was significant only in physicochemical parameters of date palm fruit for the two successive years. These differences can be due to environmental conditions or to the coexistence of different genotypes. Finally, some cropping techniques such as fertilization and irrigation can affect the weight, length and diameter of the date. In general, good fertilized and irrigated palms produce dates with better length, diameter and date weight than poorly maintained dates (Munier, 1973). The length of date fruits increased when pH increased and became an acid pH: TMO>MPP> TCO> MCO. Dry dates would be slightly more acid by contribution to dates soft and semi-soft.

The length of date fruit increased when the sucrose content increased: MCO> TCO> MPP> TMO (Munier, 1973; Nixon et al., 1973; Sawaya et al., 1983) agree that the variability of sugars content of dates according to variety, climate, and stage of maturation.

The weight increased when the sucrose content increased: MCO> TCO> MPP> TMO, the sugar content increased with the ripening of the fruit. It is also known (Abdel-Nasser & Harhash, 2007; Ahmed IA et al., 1995; Ahmed et al., 2014) that the softening of the texture of dates is mostly a result of the reversal of sucrose to fructose and glucose.

A negative correlation was found between the moisture content and the sucrose content. This often indicated that dry dates had the most sucrose values and the soft dates were not richer in total sugars than the dry dates. The first (TMO, MPP) rich in glucose and the second (TCO, MCO) were rich in sucrose (Ben Salah & Hellali, 2003). According to Awad et al. (2011), dry date varieties contain high levels of sucrose. On the other hand, soft dates are very rich in reducing sugars; half-soft dates contain as much sucrose as reducing sugars. Dates fruit had low sucrose content were rich in glucose content (TMO, MCPP). Dates fruit had rich sucrose content were dry dates (TCO, MCO), and dates had low values of sucrose are soft dates. The high Brix content reflects the richness of dates studied in carbohydrate.

This study was carried out with the aim to contribute the physic-chemical of date palm fruit collected from different oases of Djerid region. All the studied parameters (Insoluble and soluble fiber, sugars, moisture content, TSS and pH) were subjected to principal component analysis (PCA). Moreover, the agreement between the results of the ACP and the statistical analysis reveals that the difference between morphological and physico-chemical parameters was observed in dates fruit collected from various oases. High temperature and low humidity during ripening of date fruit observed in some different oases can be the cause of similarities or variation in the physico-chemical composition.

CONCLUSION

The present study, conducted during two years on date fruit of Deglet Nour cultivar in Djerid Oases, permitted to conclude that the high length, width and weight of fruits were observed at modern oases. Deglet Nourdate fruits collected from Traditional Continental Oases were very rich in sucrose, TSS and soluble fibers. The composition of dates varied according to phenological stages and the sampling region.

Variation of climate condition (temperature and humidity) in oases could induce more disorders in composition and quality of date fruit, as well as significant changes in TSS, sugars content, total fiber content and water activity than in morphological characters (length, width and weight). So, climate change could affect directly and indirectly the production and quality of date fruits in different oases.

CONFLICT OF INTEREST

The authors have no conflict of interest to report.

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