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Chemical fruit composition of Tunisian date palm 'Deglet Nour' collected at maturation from four different oases in Djerid region

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Abstract: The Deglet Nour in Djerid Region is the most popular variety of date palm. Our study aims to provide information about physicochemical properties of dates Deglet Nour at Tamar stage from different oases in Djerid Region. The date fruits were collected from four different oasis at different locations in South Tunisia: Traditional Continental Oasis (TCO), Traditional Mountain Oasis (TMO), Modern Continental Oasis (MCO) and Modern date Palm Plantation (MPP). Fruit size and weight, Total Soluble Solids (TSS), pH, Titratable Acidity (TA), Dietary Fiber (DF), Protein content (MPT) and sugars were studied. The obtained results showed that physicochemical properties varied significantly according to the locations. Fruits from all oasis may be considered suitable for marketing as Deglet Nour dates from well-known producing areas. TSS, pH, TA, MPT and sugars were significantly important in dates from TMO oasis.

Key words: *Phoenix dactylifera*, physico-chemical proprieties, Deglet Nour, oases, Tamar stage, sugurs

INTRODUCTION

The date palm (*Phoenix dactylifera* L.) is the most important component of oases ecosystems. It plays a very important role in ecological terms because it helps to limit sand damage and protects the underlying crops against intense sunlight (Bouguedoura, 2010).

Socio economically, dates are well known as a staple nutritious food and source of wealth for many countries. The date sector in Tunisia is the symbol of fertility and prosperity of the Saharan and Pre-Saharan areas. This tree cultivated by humans for millennia flourishes in the oases of Southern Tunisia, since, its introduction by the Phoenicians. The Tunisian oases offer a healthy ecosystem where this tree produces very delicious and valuable fruits.

An important varietal diversity (more than 150 varieties) allows the production of dates over a period stretching from early October to the end of December. The most commercialized varieties are Deglet Nour, Allig, Khouat Allig and Kenta. The excellent conservation capacity of the Deglet Nour variety allows it to be marketed all year long. The dates Deglet Nour are semi-soft and exported to more than 57 countries on 5 continents. European markets are the most important. National production of dates for 2017-2018 seasons is estimated to 305,251 thousand tons. The amount of date exports during the 2016-2017 was about 109.8 thousand tons. Dates are largely consumed at Tamar stage due to their good storability and availability all over the year. In fact, date fruit maturation is characterized by changes in its physiological, biochemical and morphological traits which determine the qualitative characteristics of any cultivar. Dates are an excellent source of dietary fiber and contain considerable amounts of minerals, lipids and proteins. The date is an energetic fruit and has high nutritional value.

The objective of this study was to determine the physicochemical characteristics at Tamar stage of Deglet Nour dates produced at four oases of Djerid Region (Tozeur, Tunisia). Knowledge of chemical composition of such fruits would be very useful for determination of the fruit quality and marketing opportunities.

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MATERIALS AND METHODS

Origin of date fruits: Date fruits (cv. Deglet Nour) were hand harvested at the end of October at full maturity (Tamar) stage from four oasis (TCO: Traditional Continental Oasis, MPP: Modern Palm Plantation, TMO: Traditional Mountain Oasis, MCO: Modern Continental Oasis) from Tozeur Region (South of Tunisia).

TCO: Traditional Continental Oases, the culture were practiced under three stages; date palm, pomegranate, apple, pear, lemon tree and the third planted with vegetable and fodder crops. It is characterized by a high density of palms more than 200 trees/ha, the water cycle lasts every 8 days during the Winter while the Summer irrigation is done every day.

MPP: Modern Palm Plantation, just one culture is practiced, date palm. The planting density is about 8 m. The water cycle lasts 10 days during the Winter.

TMO: Traditional Mountain Oases, the culture were practiced on three stages; date palm, fruit trees dominated by pomegranate and olive tree. The lower stage is occupied by a mixture of different vegetable crops: squash, parsley, bee and forage crops. The water cycle lasts 6 days.

MCO: Modern Continental Oases, characterized by three stages: date palm which density of palms is between 100 and 150 trees/ha, lemon, apple, apricot trees and vegetable. The water cycle lasts 4 days during the Winter while the Summer irrigation is done every day.

The difference between these oases is based on climatic conditions in relation to their geographical positions their mode of cultivation and management. However, their mode of irrigation (submersion) and their cultural practices are the same in these different oases. The variety Deglet Nour is very popular and well appreciated nationally and internationally for its market value. At each oasis, five adult date palm trees in good sanitary condition were used for all analyses. Representative samples of 20 homogenous fruits were taken from each tree. The samples were collected from different regimes and in all four directions. Immediately, after harvesting, date fruits were analyzed for major physical properties and stored at -20°C until chemical analyses. Measurements and observations were taken twice per each fruit for each sample.

Morphometric characteristics of dates: Fruit weight was recorded using a precision balance (Melter AE 260). Then, the length and width of the fruit were then measured using a caliper micrometer (Metrologie MITUTOYO-Serie 530). For date external color, a color-difference meter (Minolta CR 300, Ramsey, NJ, USA) was used (C standard C.I.E. illumination, 0° viewing) and the results were expressed as CIEL*a*b* color space units. The mean values for the Lightness (L*), red/green coordinate (a*) and blue/yellow coordinate (b*) parameters were recorded for each fruit. The skin color was determined as L* or calculated as Chroma (C*) and Hue angle (H°) according to CIE. Color was measured on three randomized samples of 25 dates randomly selected from each oases. Chroma is the saturation or vividness of color. It is measured radially from the center of each quadrant with the a* and b* axes. The relationship was defined as follows:

$$C^*ab = \sqrt{a^{*2} + b^{*2}}$$

$$H \circ ab = \arctan g\left(\frac{b^*}{a^*}\right)$$

Where:

C*ab : Chroma (an indication of color saturation) and is equal to zero at the center of the color space and increases based on the distance from the center

H°ab : The hue angle and it is expressed in degrees. Starting from the +a* axis, 0° is +a (red), 90° is +b (yellow), 180° is -a (green) and 270° is -b (blue)

Physico-chemical characteristics of dates

Moisture content: Moisture (g water/100 g) was determined by drying 2 g of pulp in a tarred stainless capsule covered by lids at 105°C until constant weight was reached according to AOAC. Results were expressed as percent of fresh weight.

$$X = (\text{Fresh weight-Dry weight})/(\text{Fresh weight})\times 100$$

pH: pH values were determined using the method by Girard. About 50 g of date pulp were dipresed in a flask with 200 mL of boiling water (at 70°C for 30 min). After cooling, the flask was made up to volume by distilled water. The solution was used for the determination of the pH by using a pH benchtop meter (Fisher brand accumet AE 150).

Ash content: To remove carbon, about 1 g (powdered flesh) of sample in a porcelain container was incinerated in the muffle furnace at about 600°C for 3 h. The total ash was expressed in percentage of dry weight. The following formula was used to calculate the percentage (%) of ash:

$$\text{Ash } (\%) = \text{Initial weight-Final weight}\times 100$$

Protein content: Total nitrogen was determined by the Kjeldahl technique and protein content was expressed as the general factor 6.25.

Titratable Acidity (TA): Titratable acidity was assessed as outlined by AOAC 962.12 method (NF V 05-101 1974). Date extract organic acids which were neutralized and titrated with sodium hydroxide. A sample of 10 mL of date fruit extract was weighed, transferred to a 500 mL Erlenmeyer flask and diluted to 250 mL with deionised water. Using a standard solution of 0.1 N sodium hydroxide, the sample was titrated to the end point using phenolphthalein as indicator. The volume of 0.1 N sodium hydroxide used was recorded. The measurement was repeated at least three times and the total acidity was calculated using the following equation and expressed as concentration of citric acid (gL^{-1}):

$$\text{\% Acid (as anhydrous citric acid)} = \text{Volume of 0.1 N NaOH (mL)} \times 0.64/10$$

Water Activity (Aw): Water activity (aw) was determined based on the moisture content using an aw-meter (Novasina Lab Master-aw, Swiss) at 25°C. Samples were ground into thin pieces and filled into a dried cup, about 2/3 of its capacity. The filled cup was then placed in the measuring cuvette. After removing the measuring head, the Aw value of the sample was directly displayed.

Total Soluble Solids (TSS): About 5 g of date pulp were dispersed in a flask with 20 mL of water. The solution was used for the determination of the percentage of Total Soluble Solids (TSS) by using a hand refractometer. The refractometer was standardized with distilled water at 20°C. About 2 drops of juice at 20°C was dropped on the lens (sensitive surface) of the refractometer and measured.

Dietary fiber: Non-soluble and soluble Dietary Fibers (DF) were determined according to the AOAC enzymatic-gravimetric method by Prosky *et al.* Briefly, the defatted samples were gelatinized with heat-stable alpha amylase (A-3306, Sigma Chemical Co., St. Louis, MO, USA) (100°C, pH 6, 15 min) and then enzymatically digested with protease (P-5380, Sigma Chemical Co., St. Louis, MO) (60°C, pH 7.5, 30 min), followed by incubation with amylo-glucosidase (A-9268, Sigma Chemical Co., Poole, Dorset, UK) (60°C, pH 4.5, 30 min) to remove protein and starch. Then, the samples were filtered, washed (with water, 95% ethanol and acetone), dried and weighed to determine non soluble fiber. About 4 volumes of 95% ethanol (preheated to 60°C) were added to the filtrate and to the water wasting. Then, the precipitates were filtered and washed with 78% ethanol, 95% ethanol and acetone. After that the residues (soluble DF) were dried and weighed. The obtained values were corrected for ash and protein. Total DF was determined by summing non-soluble DF and soluble DF.

Sugar content: Sugars were extracted with ethanol solution (80%) according to Bouabidi *et al.* The extracts were centrifuged (2000×g, 30 min) and filtered (0.45 μm). Sucrose, glucose and fructose were analyzed with the High-Performance Liquid Chromatography (HPLC) system (Dionex PAD-HPAED) equipped with a quaternary pump, a pulsed amperometric detector and an injector valve type DIONEX. Sugars (sucrose, glucose and fructose) were identified by comparison of their retention times with a standard. They were quantified according to their percentage area, obtained by integration of the basis of peak areas of external standards consisting of glucose (2%), fructose (2%) and sucrose (2%) solutions. Total reducing sugars were obtained as the sum of glucose and fructose values. Each sample was analyzed in triplicate and quantification was carried out from integrated peak areas of the sample against the corresponding standard graph. Results were expressed as percentage of dry weight.

Statistical analysis: Analysis of Variance (ANOVA) was performed using SPSS for windows (SPSS Inc., Chicago, IL, USA). The mean values were further separated using Duncan's multiple range test ($p<0.05$). Correlation coefficients (r) were determined by Pearson correlation matrix method also using SPSS for windows. In order to find the interrelationship among the investigated fruit parameters, Principal Component Analysis (PCA) was carried out using function 'PCA' from the statistical XLSTAT Software Version 2014.4.01 (Addinsoft, France).

RESULTS AND DISCUSSION

Dates length, width and weight: The average weight obtained for the dates from different oases was 8.83, 9.12, 10.24 and 10.96 g, respectively for TCO, MPP, MCO and TMO (Fig. 1). Also, the fruit length varied, respectively between 4.01 mm from TCO and 4.31 mm from TMO. The average width varied from 1.78 mm (TCO) to 1.96 mm (TMO).

The changes in weight, length and width between dates collected from different oases were due to genetic and growth conditions. It was already demonstrated that variations in fruit characteristics depend on variety, environmental conditions and the field management practices.

Pearson test showed a very significant correlation ($r = 0.903$, $p<0.01$) between the length, width and weight of date fruit at Tamar stage. These values are in good agreement with those found by Tafti and Fooladi (2006) and Amoros *et al.* (2009).

Table 1: Colour values (reflectance measurements L*, H° and C*) at tamar maturity stage for dates 'Deglet Nour' rcollected from four different oases

	Color		
Oases	L*	Hue	C*
MCO	43.71±0.79c	40.49±1.03c	35.17±0.29b
TMO	43.78±1.15d	40.72±1.37a	36.16±0.46c
TCO	45.52±0.61b	46.91±0.65d	36.88±0.44d
MPP	38.73±0.62a	35.85±0.79b	27.01±0.39a

Means in the column followed by different letters are significantly different ($p \leq 0.05$) according to Duncan's multiple range test ±Stadard deviation
H° = Hue value = arc tg (b*/a*)
C* = Colour intensity (Chroma) (a*2+b*2)1/2
L* = Lightness

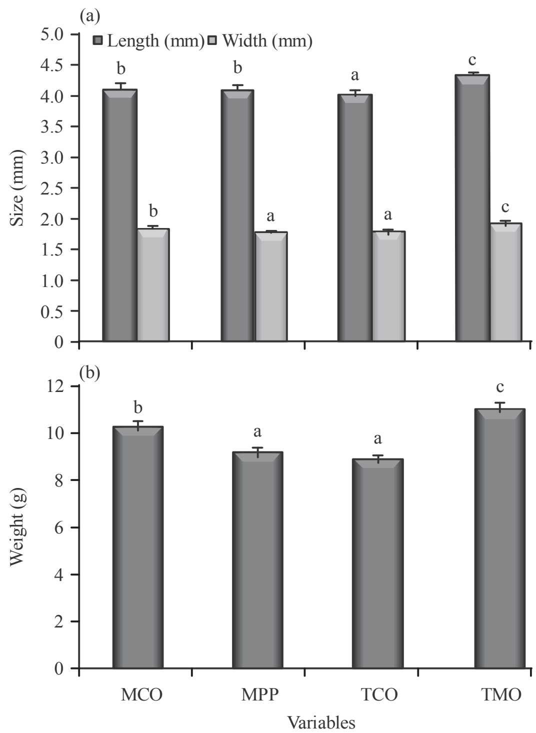

Fig. 1: (a, b) Length, width and weight of dates 'Deglet Nour' (Tamar stage) from four different oases. Vertical bars represent standard errors of the means and different letters indicate significant differences ($p<0.05$) between oases for the same parameter

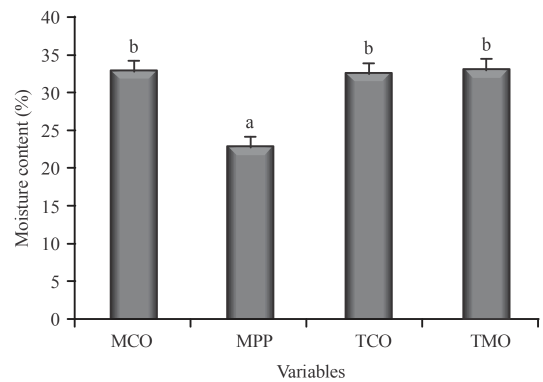

Fig. 2: Moisture content of dates 'Deglet Nour' (Tamar stage) from four different oases. Vertical bars represent standard errors of the means and different letters indicate significant differences ($p<0.05$) between the parameters of date fruit for each oases

Date external color: The date fruits showed low values of L* and C*: (MPP: L* = 38.73, C* = 27.01; MCO: L* = 43.71, C* = 35.17; TCO: L* = 45.52, C* = 36.88; TMO: L* = 43.78, C* = 36.16) (Table 1). The high content of water of these samples can be the cause of the low clearness (dark color) of these fruits by intensity of the phenomenon of non-enzymatic browning (reactions of Maillard) as different pigments were identified in date fruits; caratonoids, anthocyanins, flavones, flavonols, lycopene, carotenes, flavoxanthin and lutein (Gross *et al.*, 1983) (Fig. 1).

The C* (Chroma) values which changed from 27.01-36.88 was higher in the flesh than in the skin for all collected dates. Hue angle (h*) is expressed in degrees: 0° (red), 90° (yellow), 180° (green) and 270° (blue). In this study, the values of Hue angle for date fruits collected from MPP, MCO, TCO and TMO were 35.85, 40.49, 46.91 and 40.72, respectively.

The degradation of color and pigments depended on many factors including non-enzymatic and enzymatic browning and process conditions such as pH, acidity, oxidation, packaging material and duration (Gross *et al.*, 1983).

Moisture content in dates: The moisture content ranged from 23-33% (Fig. 2). It was significantly higher ($p<0.05$) in fruits from MCO, TCO and TMO (33%). Dates from MPP had significantly lower amount of moisture as compared to dates from other oases. Particular microclimate in modern date palm plantation, relatively dryer with more air movement, could be the cause of decreased date moisture. In other situations also, date moisture content ranged beteween 10-30% (Aidoo *et al.*, 1996). For fruits at ripening Tamar stage it ranged from 9.2-23.1% (Al Shahib and Marshall, 2002). Previous results showed that semi dry dates possessed more 30% moisture content and <20% in

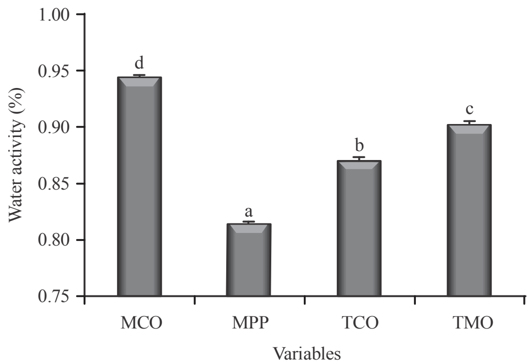

Fig. 3: Water activity of dates 'Deglet Nour' (Tamar stage) from four different oases. Vertical bars represent standard errors of the means and different letters indicate significant differences ($p<0.05$) between the parameters of date fruit for each oases

dry dates at Tamar stage. Our dates collected from MCO, TCO and TMO had more than 30% moisture content.

The moisture content decreased from stage to stage and reached at Tamar stage; around 24% but if the date fruit have a high percent of moisture content, this value can facilitate spoilage of fruit. In general, very low moisture percent may lead to dry dates not suitable to consumers (Ahmed *et al*., 1995).

Water Activity (Aw) of dates: Water activity of studied dates varied between 0.94 (MCO dates) and 0.81 (MPP dates) (Fig. 3). It varied significantly ($p<0.05$) between the samples collected from different oases. The date fruits of MCO oases have higher levels of water activity: Aw = 0.94. The low values of water Activity (Aw = 0.81) observed at the samples of MPP dates. This difference can be explained by the effect of rainfall. It was reported that when water activity was lower than 0.90 the production of toxins was inhibited and many bacterial species couldn't develop (Listner, 1975, Acott *et al*., 1976). Certain osmophilic yeasts were able to develop in substrates with low water activity ~0, 60 but for Aw values ranging between 0.80 and 0.88 the growth of yeasts and moulds was inhibited (Scott, 1957; Pitt, 1975).

Titratable Acidity (TA) and pH of dates: The pH of date extract at Tamar stage exhibited significant differences among oases (Fig. 4). Date fruits collected from TMO had the highest values and MPP dates had the lowest values. For fruits from MCO and TCO, values were 4.55 and 4.47, respectively.

Concerning TA, expressed as citric acid equivalent, TCO dates had high values (8.88) and MCO dates had the lowest values (7.84). Significant differences

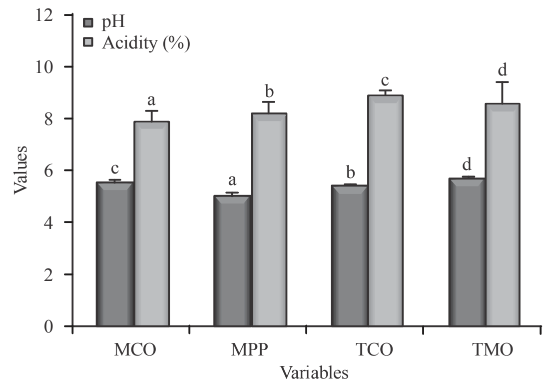

Fig. 4: pH and titratable acidity of dates 'Deglet Nour' (Tamar stage) from four different oases. Vertical bars represent standard errors of the means and different letters indicate significant differences ($p<0.05$) between the parameters of date fruit for each oases

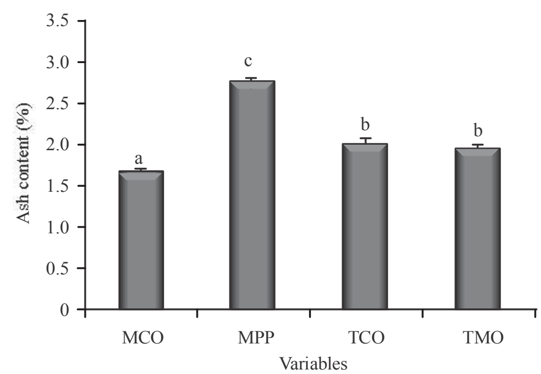

Fig. 5: Ash content of dates 'Deglet Nour' (Tamar stage) from four different oases. Vertical bars represent standard errors of the means and different letters indicate significant differences ($p<0.05$) between the parameters of date fruit for each oases

among samples were noted at Tamar stage. TA reflected fruit quality and indicated the sourness. It varied primarily with fruit development stages but did not respond to short term environmental changes (Besbes *et al*., 2004). As reported previously, date fruit extracts contained weak acids like citric acid and malic acid and sodium, potassium and calcium salts. Fruit pH increases at the high rate of respiration by accelerated acid metabolism and accumulated cations (Hasnaoui *et al*., 2011). The pH values obtained also reflected a significant extent to the microbial stability of the various varieties.

Ash content: The ash content in dates produced in different localities ranged from 1.5-3.0%. It was significantly higher in the dates from MPP (3%) and

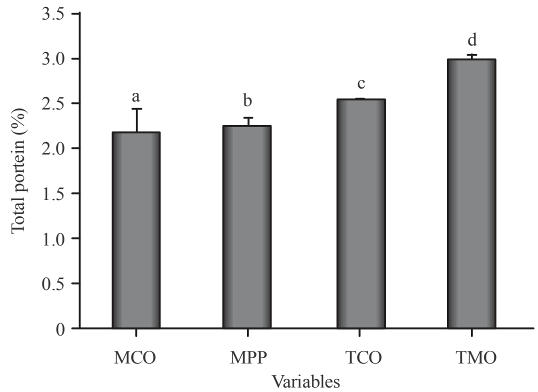

Fig. 6: Total protein content of dates 'Deglet Nour' (Tamar stage) from four different oases. Vertical bars represent standard errors of the means and different letters indicate significant differences ($p<0.05$) between the parameters of date fruit for each oases

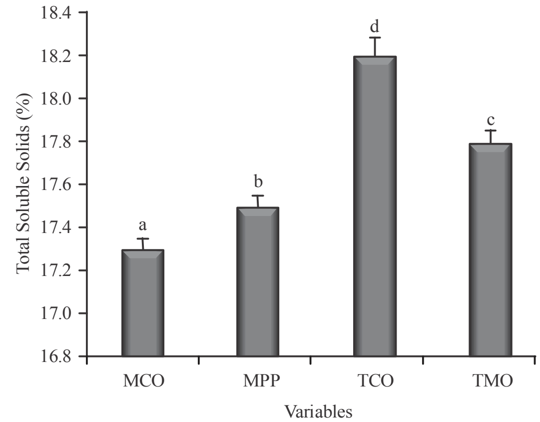

Fig. 7: Total soluble solids (Brix) of dates 'Deglet Nour' (Tamar stage) from four different oases. Data shown are the means of four replicates vertical bar represents ±standard error. 2. Values followed by an letters denote significant difference (at $p<0.05$) compared to previous

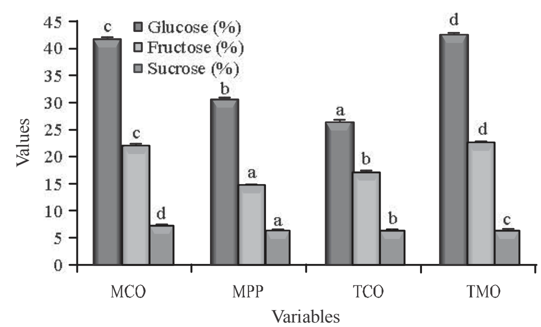

Fig. 8: Glucose, fructose and sucrose content of dates 'Dgelet Nour' (Tamar stage) from four different oases. Vertical bars represent standard errors of the means and different letters indicate significant differences ($p<0.05$) between the parameters of date fruit for each oases

significantly lower in dates collected from MCO (1.6%) (Fig. 5). According to Malah *et al.*, ash content of semi dry dates ranged from 1.35-1.95% while the dry dates content ranged between 1.6 and 1.7%. Our results agreed with finding of other scientists working on different dates (Al-Shahib and Marshall, 2003; Besbes *et al.*, 2008). The ash content was low compared to the weight of dry matter of fruit. This could be explained by the type of soil and the irrigation status, reflecting a fairly active synthesis of organic compounds by the vegetative parts of the date palm trees. The ash content depends on the state of soil fertility and the amendments made (Booij *et al.*, 1992).

Protein content: The protein level ranged from 2.17-3% (Fig. 6). It was significantly higher in date fruits produced in TMO (3%) and TCO (2.52%). Dates fruits of MCO and MPP had significantly lower protein levels, respectively 2.17 and 2.26%. According to Hasnaoui *et al.* (2011), the protein content varied between 1.9 and 3.3 g per 100 g dry matter. Our values were compatible with results reported by other researchers (Al-Hooti *et al.*, 1995) who obtained 1.7-2.4% of proteins according to the cultivars that they used. Elleuch *et al.* (2008) reported 2.10 and 3.03% for Deglet Nour and Allig cultivar of Tunisia. In fact, dates contain a higher percentage of protein than other fruits as apples, oranges, bananas and grapes containing, 0.3, 0.7, 1.0 and 1.0%, respectively (Al-Showiman, 1990).

Total Soluble Solids (TSS): The TSS of the dates collected from different oases ranged from 18.2-17.3°Brix (Fig. 7). Fruits collected from TCO had the highest average value (18.2°Brix). The TSS is a function of several factors of which total sugars and organic acids constitute the major part. The lowest contents of total soluble solids in the fruits of complete ripeness were detected in the dates of MCO (17.3%).

Sugar content: The composition and amounts of sugars of date flesh were mainly sucrose, fructose and glucose at about similar amounts (Fig. 8). They were found as predominant sugars in dates from different samples but with significant differences in proportions between dates collected from various oases. The majority of date samples were characterized by a high quantity of reducing sugars (glucose and fructose) and low or zero amount of sucrose. The rising activity of the enzyme invertase was related to the decrease of the sucrose content in the Tamar stage. Some Tunisian and Algerian cultivars were found

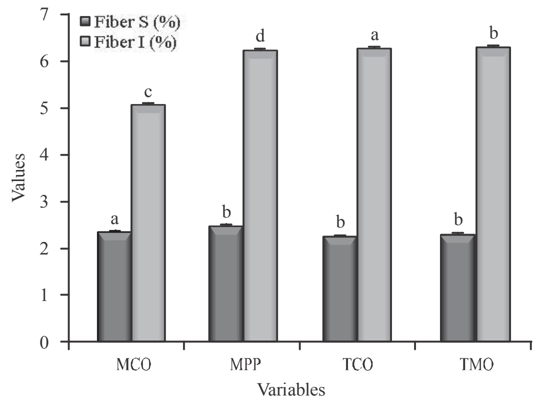

Fig. 9: Soluble and non soluble fibers of dates Deglet Nour from four different oases (Total dry matter (%))

rich in sucrose. The sugar fraction of Deglet Nour was essentially formed by non-reducing sugars (~53.59-58.40 g/100 g dry matter) (Besbes *et al*., 2008). Analysis of variance showed significant differences ($p<0.05$) for total sugar contents, reducing sugars (glucose and fructose) and sucrose. Glucose content varied from 26.5% for TO dates to 42.3% for TMO dates. Fructose content varied from 14.98% MPP dates to 22.5% TMO. Sucrose content varied from 6.17% MPP dates to 7.4% MO dates. The increase in the concentration of sugars at Tamar stage was related to the decrease in the water content of dates. Date flesh showed a high amount of non-reducing sugars (~54.79-75 g/100 g dry matter) with the exception of Deglet Nour (Hasnaoui *et al*., 2011). According to Dawson *et al*., the decrease of content of sucrose was related to the increase of values of humidity and the content of sugars was closely related to texture. At Tamar stage, date fruits had low sucrose content but high levels of reducing sugars in relatively equal amounts of glucose and fructose. For semi-soft dates (Deglet Nour) sucrose accumulated at the end of maturity (Hasnaoui *et al*., 2011). The geographical origin of the samples had an affect on the sugar content of dates as was the case of Deglet Nour collected from MOC, MPP and TMO oases.The difference may be due to environmental conditions under which the cultivars grow.

Results obtained for the variety Deglet Nour were in agreement with those reported by Booij *et al*. (1992) and were lower than those obtained by Besbes *et al*. (2008) for Deglet Nour cultivar.

Dietary fiber: The fiber content was high in date fruits collected from all the oases (Fig. 9). The soluble fibers average content in the date fruits collected from all the oases was 2.5%. Dates collected from MCO region had significantly lower non soluble fiber composition (5%). It was almost similar in dates from TCO, TMO and MPP (6%). In general, date flesh contains 1.55-2.01% of soluble fiber content. Analysis of variance of soluble and non soluble fiber content showed significant differences between samples ($p<0.05$). The soluble and non soluble content of studied dates varied between (1.4-3 g) and (5.3-7.1 g) on 100 g dry matter (Bousdira, 2007). The difference of content of soluble and non-soluble fibers of dates depending to the variety, maturity stage and the extraction technique and assay.

Correlations among variables: Significant correlations were found among pomological traits related to the fruit quality (Table 2). The total protein content (MPT) was highly and significantly correlated with the moisture content and pH ($r = 0.855$, $r = 0.824$, respectively). Significant relationships were observed between the pH and water activity and moisture content. The correlation coefficients were high ($r = 0.769$, $r = 0.943$). Also, good and significant correlations have been found between the fructose content and moisture content, pH glucose, water activity ($r = 0.774$, $r = 0.854$, $r = 0.908$, $r = 0.849$, respectively). Our results showed a very high correlation between fruit weight and fruit diameter ($r = 0.917$); therefore, both parameters can be used to predict each other. This relationship has been reported also by other researchers. Correlation between fruit weight and lenght was observed ($r = 0.903$) in agreement with previous work in apricot.

The sucrose content was highly correlated with the water activity, moisture content, pH, glucose and fructose ($r = 0.964$, $r = 0.73$, $r = 0.726$, $r = -0.829$, $r = -0.918$). A negative relationship was found between soluble fiber content and MPT, moisture content and pH with correlation coefficients (r) -0.930, -0.875 and -0.845, respectively (Table 2).

Our results were in good agreement with those found by Tafti and Fooladi (2006), Amoros *et al*. (2009). Pearson test showed a very significant correlation ($r = 0.775$, $p<0.01$) between the length and width of cultivars especially at tamar stage. The decrease in sucrose content was negatively correlated ($r = -0.768$, $r = -0.822$; $p<0.01$) with the increase in both glucose and fructose concentrations, suggesting a sharp increase in invertase activities which caused inversion of sucrose into glucose and fructose (Sahari *et al*., 2007). Whereas when we compared the sugar content of Deglet Nour with Gosbi, results showed a difference in the composition of glucidic fraction. Sucrose was not detected in this common variety (data not shown). The absence of sucrose was noted also in Alig in contrast with the results by Besbes *et al*. (2008).

Principal Component Analysis (PCA): The superposed representation variables and oasis samples (Biplot) on

Table 2: Correlation matrix among the studied variables

Variables	Length	Width	Weight	Acidity	Aw	TSS	H%	pH	MPT%	CD	FIBR_S	FIBR-I	Glucose	Fructose	Sucrose
Length	1														
Width	-0.067	1													
Weight	0.903	0.917	1												
Acidity	-0.048	-0.248	-0.336	1											
Aw	0.235	-0.419	0.402*	-0.251	1										
TSS	0.355	-0.161	-0.173	0.795^{k}	0.117	1									
H%	0.416*	-0.472	0.301	0.226	0.829^{k}	0.346	1								
PH	0.519^{k}	-0.394	0.426*	0.147	0.769^{k}	0.268	0.943^{k}	1							
MPT%	0.386*	-0.344	0.114	0.545*	0.474*	0.595*	0.855^{k}	0.824^{k}	1						
CD	-0.528*	0.190	0.014	-0.367	-0.352	-0.426*	-0.637^{k}	-0.654^{k}	-0.697^{k}	1					
FIBR_S	-0.570	0.323	-0.217	-0.484*	-0.429*	-0.587*	-0.845^{k}	-0.875^{k}	-0.930^{k}	0.739^{k}	1				
FIBR_I	0.190	0.231	-0.258	0.582*	-0.748^{k}	0.522*	-0.269	-0.174	0.166	-0.167	-0.273	1			
Glucose	0.462*	-0.095	0.679^{k}	-0.637^{k}	0.665^{k}	-0.369	0.442*	0.583^{k}	0.108	-0.077	-0.247	-0.501*	1		
Fructose	0.526*	-0.284	0.618^{k}	-0.337	0.849^{k}	-0.096	0.774^{k}	0.854^{k}	0.479*	-0.365	-0.573*	-0.468*	0.908^{k}	1	
Sucrose	0.287	-0.344	0.526*	-0.427^{k}	0.964^{k}	-0.241	0.730^{k}	0.726^{k}	0.337	-0.240	-0.343	-0.769^{k}	-0.829^{k}	-0.918^{k}	1

*The correlation is significant at 0.05 (bilateral). $^{*}p<0.05$ (2-tailed)

^{k}The correlation is significant at 0.01 (bilateral). $^{k}p<0.01$ (2-tailed)

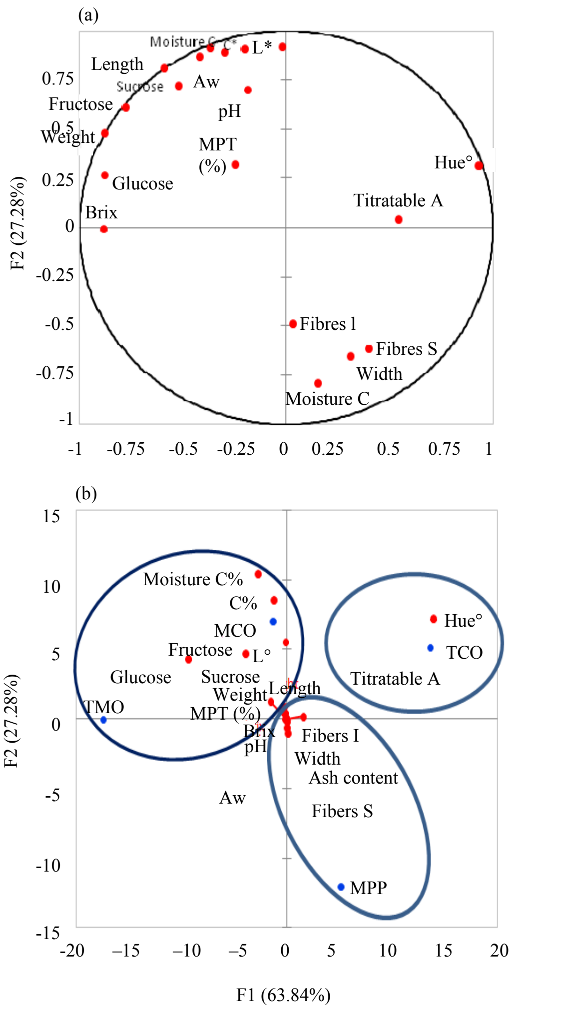

Fig. 10: Distribution of studied parameters and date samples on the factorial plane 1-2 of the ACP (a) Variable (Axes F1 et F2: 91.12%) and (b) Biplot (Axes F1 et F2: 31.12%)

the factorial plane 1-2, showed three different groups (Fig. 10). The first group is formed by dates from the oasis of TCO, characterized by a high variation between acidity and other parameters such as sugar content, fiber content, pH, brix and morphological parameters which resulted in a late maturing of dates "Deglet Nour". The second group is made up of dates from the oases TMO and MCO. In this group, we notice the presence of important values for the morphological parameters and for the sugar contents. The third group is formed by dates from the oasis of MPP. This group is characterized by a high content of fiber and ash content. For this group, maturation is early because of low spacing.

To obtain a broad view on the metabolic changes that occurred to date fruit collected from different oasis, the whole data set was subjected to Principal Component Analysis (PCA). The total variability is explained by 4 Factors (F1-F4) with the first two factors of the PCA showing correlation of 91.12% (Fig. 10). The first Factor (F1) was responsible for 63.84% of total variation while the second Factor (F2) explained only 27.28% of total variation, indicating that the maximum possible variation in fruit maturity indices was explained by the F1 (Fig. 10a). Positive scores in F1 corresponded to date fruits collected from MPP and TCO. Date fruits had high positives scores along F2 were semiripened fruits collected from MCO and TMO oasis (Fig. 10a, b). As the fruits advanced, there was a shift from right to left along F1 with increase in fruit fibers formation, width and ash content. The PCA showed that measured sugars accumulation have short distance to the color formation, during fruit maturity stage when high Brix and moisture content. In this study, increase in morphologic fruits, respectively was also characterized by a shift from right to left, reflecting the beginning of ripening process in fruit between TMO and MPP. High sugar as well as glucose-fructose (g/f) ratio corresponded with fruit collected from MCO and TMO oasis. More positive scores along F1 at MCO and TMO could be as a result of further synthesis and accumulation of sugars. Length, width and weight had short distance to the Chroma (C*) and redness (L*), suggesting that these compounds significantly contribute to fruit color evolution.

CONCLUSION

In this study, major biochemical and physico-chemical characteristics of Djerid Deglet Nour dates were studied. As expected, all the dates were rich in sugars, proteins, fiber and ash. A high variability was found in the set of dates collected from different oases evaluated with regard to traits related to fruit quality. Significant differences were observed for all quality attributes.

The physical measurements of the date fruits of cultivar ‘Deglet Nour’ grown in different oases in Southern Tunisia at Tamar stage showed that the fruits differed in weight, length and width. According to the chemical analyses, the dates were very rich in reducing sugars (fructose and glucose), proteins and ash, with a lower moisture content. Fiber contents were relatively low in fruits from Modern Continental Oasis (MCO) and Traditional Continental Oasis (TCO) while relatively high percentages were found in Traditional Mountain Oasis (TMO) and Modern Palm Plantation (MPP) dates. The profile resulting from the analysis of date palm fruits was generally characteristic for each oasis. Our findings showed that dates collected from TMO may be able to compete with the most marketed dates Deglet Nour. Accordingly, the farmer and consumer could take these dates into consideration.

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