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Assessment of physicochemical diversity in fruit of Mauritanian date palm (*Phoenix dactylifera* L.) cultivars

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Date palm is an important food and economical crop in Mauritania. Date palm cultivars show great diversity in fruit morphological characteristics in the 'Adrar' region of Mauritania. Fruits of twenty-eight date palm cultivars were collected at Tamar stage, from three different oasis of the 'Adrar' region in 2010 and 2011 and their physical and chemical diversity was assessed by using different data analysis techniques. Analysis of variance revealed statistically significant differences between cultivars for the 13 examined characters indicating the high diversity in the physicochemical properties of their fruit. Duncan's multiple range test allowed clustering of cultivars into different groups depending on the parameters. Principal component analysis and cluster dendrogram performed on the basis of studied parameters showed a distribution of date palm cultivars independently of their oasis origin and a continuous variation in their fruit physical and chemical traits. Date varieties under 'Ahmar' denomination showed diverse fruit properties. Characters that can discriminate the best cultivars were fruit water content, reducing sugars, total sugars, non-reducing sugars, ashes, calcium and magnesium contents. Results also give evidence of the existence of common date varieties such as 'Sekanni', 'Bou seker', 'Sembahmoud', 'Tenwazidi' and 'Sel medina' with fruit properties matching or even higher than the elite cultivar 'Ahmar'. The possible use of date palm fruits characteristics either in the description of local date palm germplasm or the valorisation of common date varieties are discussed.

Key words: Date palm, fruit, Tamar stage, variability, chemical composition, Adrar.

INTRODUCTION

Date palm tree (*Phoenix dactylifera* L.) is an important food and economical crop in Mauritania and all of North Africa. It presents a source of income to oases inhabitants, provides protection to under-crops

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(vegetables, henna, mint, alfalfa) from the harshness of the climate and reduces the damage from sand storms and wind erosion. Date palm is a perennial allogamous monocotyledon plant belonging to the *Palmaceae* family (Barrow, 1998). Female date palm produces fruit of single, oblong, one-seeded berry with a terminal stigma, a fleshy pericarp and a membranous endocarp. The date fruit goes through four distinct ripening stages usually referred to in terms derived from Iraqi Arabic as ''Kimri'', ''Khalal'' (sometimes referred to as ''Bisr'' or ''Blah''), ''Rutab'' and ''Tamar'' to represent the immature green, the mature full coloured, the soft brown, and the hard raisin like stages, respectively (Reuveni, 1986). Varieties of dates are commonly classified into ''soft'', "semi-soft" or ''semi-dry'' and ''dry'' dates, depending upon the time of harvest and associated water content (Chao and Krueger, 2007). The major chemical compound of date palm fruit are sugars consisting of glucose, fructose and sucrose, which can reach 88% in some varieties (Reynes et al., 1994; Al-Shahib and Marshall, 2003; Chaira et al., 2007; Elshibly and Korpelainen, 2009).

Date fruits also contain a number of organic acids, such as malic, citric, and oxalic acids, which are considered as contributors to flavour (Barreveld, 1993). Proteins, minerals, dietary fibres and vitamins were also reported in date palm fruits (Yousif et al., 1982; Al-Shahib and Marshall, 2002).Another interesting character that has not received much attention is the phenolic content of date palm fruit. Wu et al. (2004) reported that Deglet Noor and Medjool varieties have a high phenolic content. At present, more than 5000 cultivars of date palm are known to exist all over the world with variation in their genetic makeup (Ibrahim, 2008), but only a few important ones have been evaluated for their agronomic performance and fruit quality (Al-Hooti et al., 1997). In Mauritania, date palm culture is established between latitude 16.5° and 21° spanning, an area of 19687 ha. There are 2.6 million trees producing some 58 000 tons of dates annually and representing a source of income for 16% of the dwellers in the date-producing regions.

The main date-producing region in 2012 was 'Adrar' which accounted for almost 42% of the national production (Anonymous, 2013). Nearly half of the date's production is consumed freshly during the harvest season (June-August), the remainder is sold in the local market, processed or used as animal feed. Fruit processing technology (date packing, syrup, jam, paste) is still rudimentary. Date is also traditionally used as medicine (Leriche, 1954). Local date palm cultivars are numerous and well adapted to agro-ecological conditions. They result from an empirical selection carried out by the farmers. Cultivars denominations are strictly local and originating, most often from the place of cultivation, the colour or the shape of the fruit. In spite of this, genetic information among Mauritanian date palm is lacking. Previous studies have revealed the great phenotypic diversity of date palm cultivars in the 'Adrar' region of Mauritania, particularly for traits related to the vegetative parts of the tree suggesting the potential use of these parameters to identify individual cultivars or groups of cultivars (Ould Mohamed Salem et al., 2008; Ould Mohamed Ahmed et al., 2011).

Therefore, the search of many other markers is required to obtain a deeper comprehension of the genetic structure of local date palm germplasm and improve varietal identification. The aims of this study were to (1) estimate the genetic diversity of physical and chemical traits of the most popular and well-known date palm fruit in Mauritania, and (2) use different data analysis tools in order to synthesize the interrelationships between observations to allow precise characterization of date palm cultivars.

MATERIALS AND METHODS

Plant materials

The study included 28 date palm cultivars originating from different oases of the 'Adrar' region. They represent 25 date palm denominations and are the most common and well known genotypes in this region. Table 1 summarizes some characteristics of the studied cultivars. Fruits (2010 and 2011 harvests) were used at Tamar stage.

Character studied

The study was based on fruit physicochemical characters. Analyses were carried out on 20 randomly sampled mature dates per tree. Fruit weight (FW) was measured using an analytical balance and calculated as a mean of 20 mature fruits. Fruit water content (HU) was determined by drying 5 g of date pulp overnight in a vacuum oven at 80°C. Water content was then calculated using the following formula: % water = 100 x (initial weight - dry weight)/ initial weight. Sugars were extracted from 200 mg of date pulp with hot 80% ethanol. Ethanol was then allowed to evaporate at 80°C for 24 h and the volume was adjusted to 20 ml with distilled water. Reducing sugars (RS) were estimated in the pulp extract using the di-nitro-salycilic method (Miller, 1959). Non-reducing sugars (NS) analysis was based on the enzymatic hydrolysis of sucrose into glucose and fructose and calculation of both sugars before and after hydrolysis following the procedure described by Cerning-Beroard (1975). Both reducing and non-reducing sugars contents in date palm pulp were estimated from a calibration curve, using an equi-molar solution of glucose and fructose as standard.

Total sugars (TS) were obtained as the sum of reducing and non-reducing sugars concentrations. Total acidity (TA) was determined using 10 ml of fruit juice which were titrated against 0.1M sodium hydroxide solution using phenolphthalein as an indicator according to the official methods (AOAC, 1990). The total acidity of the juice was calculated using the formula: volume NaOH (ml) × 0.1 M × 0.067 and expressed as malic acid content. The pH measurements were performed using a calibrated digital pH meter (CyberScan 510, USA). Poly-phenols content (PC) was measured in 80% methanol extracts according to Singleton and Rossi (1965) method involving Folin–Ciocalteu reagent and gallic acid as standard. The concentrations were expressed as milligram of gallic acid equivalents (GAE) per 100 g of the fresh weight. Soluble tannins (ST) were measured in fruit tissue, including skin and flesh according to Taira (1996). The concentrations were calculated from a calibration curve obtained by measuring the absorbance of known concentrations of tannic acid. Ashes (AS) analysis was carried out by burning 1 g of fruit pulp in muffle furnace at 500°C for 8 h.

Table 1. List of the studied date palm cultivars from the 'Adrar' region of Mauritania with indication of their oasis origin and fruit color.

Denomination	Code	Oasis	Fruit color*
Ahmar	AHM1	Atar	Dark red
Ahmar	AHM2	Chinguitti	Dark red
Ahmar	AHM3	Ouadane	Dark red
Lemdina	LMD1	Atar	Dark yellow
Lemdina	LMD2	Ouadane	Dark yellow
Bezoul	BEZ	Atar	Dark yellow
Tiguidert	TGD	Atar	Light yellow
Adaghd	ADG	Atar	Light yellow
Amsakhsi	AMS	Atar	Light yellow
Tijib	TIJ	Atar	Light red
Bou seker	BSK	Atar	Yellow
Tamchkrert	TAM	Atar	Light yellow
Tembeda	TMB	Chinguitti	Yellow
Sel medina	SLD	Chinguitti	Light green
Boudjeire	BDJ	Chinguitti	Yellow
Sijoumen	SJM	Chinguitti	Yellow
Sembahmoud	SMB	Chinguitti	Light yellow
Sembahra	SBH	Chinguitti	Yellow
Enzer	ENZ	Chinguitti	Light yellow
Obedh	OBD	Ouadane	Yellow
Athmenmej	ATH	Ouadane	Light red
Tenterguel	TNT	Ouadane	Yellow
Sekanni	SKN	Ouadane	Yellow
Tenwazidi	TNW	Ouadane	Yellow
Tedaghdit	TDH	Ouadane	Yellow
Ntakech	NTK	Ouadane	Yellow
Temazad	TMZ	Ouadane	Yellow
Tenguedher	TGH	Ouadane	Yellow

(*) at 'Khalal' stage.

Mineral contents: Calcium (CA), potassium (KA) and Magnesium (MG) of the date ashes were analysed separately using an atomic absorption photometer (Shimadzu A 6800, Kyoto, Japan).

Statistical analysis

The analysis was performed using the XLSTATv.2013.4.04 statistical software. A normality test was performed on the data. The following characteristics became normal after a logarithmic transformation: non reducing sugars, calcium and magnesium contents. Data obtained from physicochemical traits were subjected to: 1. One way analysis of variance (ANOVA) to test for significant differences among date palm cultivars in each one of the 13 variables. When overall cultivar effects were significant, as indicated by F-tests, differences between individual cultivars were determined using Duncan's multiple range test at 5% probability level (Steel and Torrie, 1980), 2. Principal component analysis to determine the parameters with greater contributions to the total variability, and 3. Hierarchical cluster analyses to evaluate the relationship between different cultivars using the method of Un-weighted Pair-Group Method, Arithmetic Average (UPGMA).

RESULTS

Descriptive statistics

The means of the 13 measured physicochemical variables in 28 date palm cultivars are given in Table 2 and their corresponding summary statistics are shown in Table 3. Cultivars exhibited large variation for almost all the studied characters particularly, fruit weight (FW), water content (HU), total sugars (TS), reducing (RS) and non-reducing sugars (NS), tannins content (TC) and calcium content (CA) as shown by their coefficients of variation. The soft dates of Sembahmoud (SMB) and Lemdina 2 (LMD2) represented an exceptionally high fruit weight (10.7 and 10.3 g respectively) when compared with all other tested cultivars. The total sugar content ranged from 44.67% in Lemdina 2 fruit from Ouadane palm grove, predominantly as reducing sugars (39.33%) to 84% in Bou seker (BSK) fruit from Atar oasis with

Table 2. Means values of 13 physicochemical variables in fruit of 28 date palm cultivars from the Adrar region of Mauritania. Each value represents a mean of 3 replicates per year and averaged over two years (2010-2011).

Cultivar	Fruit weight	Water content	pH	Total acidity	Total sugars	Reducing sugars	Non reducing sugars	Poly-phenols content	Soluble tanins	Ash	Calcium content	Potassium content	Magnesium content
Ahmar1	7.6	4.5	6.8	0.13	74.29	66.03	8.25	473.3	1.24	3.07	0.40	0.12	0.08
Tiguidert	7	1.2	5.4	0.13	69.33	58.07	11.26	384.8	0.34	1.84	0.43	0.12	0.05
Lemdina1	6	32.5	7.0	0.06	50.78	41.74	9.04	255.3	0.11	1.52	0.38	0.10	0.31
Amsakhsi	3.8	5.4	6.4	0.10	76.36	72.17	4.20	542.0	0.79	2.24	0.21	0.13	0.37
Adaghd	6.3	4.5	5.9	0.07	80.37	34.50	45.87	517.5	0.93	2.33	0.34	0.14	0.41
Bezoul	5.4	9.3	6.5	0.13	73.94	65.45	8.48	504.2	0.30	2.07	0.19	0.11	0.20
Tijib	6.6	5.5	6.1	0.11	77.73	71.21	6.52	533.8	0.28	2.13	0.19	0.13	0.04
Bou seker	6.5	5.7	5.9	0.08	84.00	45.33	38.67	536.9	0.24	1.84	0.40	0.12	0.16
Tamchkrert	5.3	12.8	5.7	0.13	77.67	36.00	41.67	635.9	0.44	3.14	0.43	0.18	0.09
Tembeda	6.2	22.8	6.4	0.03	50.44	40.13	10.31	242.0	0.08	1.98	0.50	0.13	0.05
Sel medina	7.5	25.2	7.0	0.12	55.29	54.12	1.18	234.8	0.32	1.73	0.36	0.11	0.09
Boudjeire	6.2	16.0	6.5	0.06	57.60	55.20	2.40	338.9	0.23	1.32	0.48	0.08	0.03
Sijoumen	5	13.2	7.0	0.13	69.00	65.00	4.00	334.8	0.10	2.11	0.29	0.11	0.03
Sembahmoud	10.7	25.2	6.7	0.09	58.25	55.25	3.00	314.4	0.18	1.23	0.12	0.06	0.07
Ahmar2	6.7	7.8	6.8	0.14	65.00	61.30	3.70	343.0	0.68	1.95	0.15	0.10	0.10
Sembahra	7.6	12.0	6.4	0.03	70.50	39.75	30.75	411.4	1.03	1.62	0.26	0.11	0.10
Enzer	5.4	5.9	5.2	0.06	77.54	62.77	14.77	670.6	1.61	2.11	0.17	0.11	0.13
Obedh	5	19.3	6.7	0.10	65.60	62.13	3.47	378.7	0.12	1.34	0.13	0.08	0.14
Ahmar3	9	15.4	6.7	0.05	53.85	39.02	14.83	241.0	0.41	2.21	0.16	0.11	0.09
Athmenmej	8.7	15.2	6.1	0.10	69.83	63.13	6.70	486.9	0.81	1.95	0.18	0.10	0.11
Lemdina2	10.3	29.4	6.8	0.06	44.67	39.33	5.33	255.3	0.44	1.54	0.10	0.06	0.04
Tenterguel	7.3	10.6	6.5	0.13	78.69	68.69	10.00	371.6	0.20	1.95	0.20	0.10	0.15
Sekanni	7.2	14.6	6.7	0.10	54.51	49.02	5.49	276.7	0.17	2.68	0.20	0.11	0.10
Tenwazidi	7.4	11.1	6.3	0.13	66.92	15.19	51.73	419.5	0.72	2.25	0.26	0.12	0.08
Tadaghdit	8.8	4.1	6.5	0.05	66.37	52.51	13.85	528.7	0.91	2.10	0.20	0.11	0.07
Ntakech	6.85	16.2	6.9	0.09	55.00	45.00	10.00	421.6	0.69	1.52	0.22	0.09	0.13
Temazed	5.1	7.6	6.0	0.11	78.48	65.68	12.79	540.0	0.47	1.90	0.15	0.11	0.09
Tenguedher	7.5	3.2	6.5	0.08	72.33	64.83	7.50	541.0	0.87	1.99	0.11	0.10	0.07

45.33% as reducing sugars and 38.67% as non-reducing sugars while the percentage of reducing sugars (glucose + fructose) varied from 15.2% in Tenwazidi (TNW) date to 72.2% in Amsakhsi (AMS) date.

Non reducing sugars (sucrose) were found at their lowest concentration (1.2%) in the Sel medina (SLD) fruit, and at their highest concentration (51.13%) in Tenwazidi date from Ouadane oasis. The total phenolic content, as measured using Folin-Ciocalteu assay, showed that this content varied from 234.8 mg GAE/100 g dry weight in Sel

Table 3. Summary statistics of 13 physico-chemical characters of fruit of 28 date palm cultivars from the Adrar region of Mauritania.

Trait	Code	Unit	Min	Max	Mean	SD[a]	CV(%)[b]	*F*[c,d]
Fruit weight	FW	Gram	3.60	10.90	6.89	1.59	23.1	247.2
Water content	HU	Percent	1.1	32.7	12.71	8.22	64.6	14420.9
Juice pH	PH	-	5.1	7.2	6.41	0.47	7.33	35.6
Total acidity	TA	g/100 g FW[e]	0.03	0.14	0.09	0.03	33.3	182.5
Total sugars	TS	g/100 g FW	44.66	84.12	66.94	10.65	15.9	4993.1
Reducing sugars	RS	g/100 g FW	15.1	72.2	53.17	13.65	25.67	11006.1
Non reducing sugars	NS	g/100 g FW	1.16	51.76	13.77	13.9	100.1	26670.2
Poly-phenols content	PC	mg/100 g FW	234.8	670.6	53.5	0.13	30.9	65.9
Soluble tannins	ST	g/100 g FW	0.05	1.72	0.52	0.38	73.1	285.3
Ashes	AS	% FW	1.23	3.14	1.99	0.45	22.6	3905.8
Calcium	CA	g/100 g DW[f]	0.10	0.50	0.26	0.12	46.15	5710.7
Potassium	KA	g/100 g DW	0.06	0.18	0.11	0.02	18.18	181.7
Magnesium	MG	g/100 g DW	0.03	0.41	0.12	0.09	75.0	6565.9

[a]SD: standard deviation; [b]CV: coefficient of variation; [c]*F* values from one way ANOVA. [d] Statistically significant differences between cultivars at P< 0.001; [e]FW: fresh weight. [f]DW: dry weight.

medina cultivar to 670.6 mg GAE/100 g dry weight in Enzer cultivar. The pH of date juice varied slightly among tested cultivars with Enzer (ENZ) fruit having the lowest pH value (5.2) and Sijoumen, Sel medina and Lemdina1 date juices with the highest pH value (7.0). Calcium, potassium and magnesium were present in all examined date varieties with predominance of calcium. Their concentrations expressed as g/100 g DW were 0.10-0.50, 0.06-0.18 and 0.03-0.41 respectively for Ca, K and Mg. The highest calcium content (0.5 g/100 g DW) was observed in Tembeda variety from Chinguitti oasis and the lowest content (0.1 g/100 g DW) was scored in Lemdina cultivar.

Results of one-way analysis of variance indicated that the differences among date palm cultivars were statistically significant (P < 0.001) for all traits tested. Duncan's multiple range test at 0.05 probability level allowed the classification of tested cultivars into different groups depending on the character (data not shown). Physicochemical variables that can discriminate the best cultivars were fruit water content (HU) with 23 non overlapping groups, reducing sugars (RS) with 22 groups including two overlapping ones, calcium content (CA) with 22 groups including two overlapping ones, total sugars (TS) giving 21 groups including two overlapping one, non-reducing sugars (NS) with 21 groups including 3 overlapping ones, Ashes (AS) dividing cultivars into 20 clusters including two overlapping ones, and magnesium content (MG) dividing cultivars into 20 separate clusters. Correlations between physicochemical variables are summarized in Table 4. Characters with high positive correlation were poly-phenols content with total sugars (*r* = 0.83), potassium and ashes (*r* = 0.74), soluble tannins with poly-phenols (r = 0.59), while those with high negative correlation were total sugars and fruit water content (r = -0.79), poly-phenols content and fruit water content (*r* = -0.71), total sugars and juice pH (r = -0.61), poly-phenols content with juice pH (*r* = -0.68) and non-reducing sugars with reducing sugars (r = -0.7).

Principal component and cluster analysis

The PCA variable loadings, percentage and cumulative variance for the first three principal components are given in Table 5. The first three principal components accounted for 67% of total variation. The first component (PC1) accounted for 37% and had characteristics with high contribution as total sugars (0.4), poly-phenols content (0.39), fruit water content (-0.37), potassium (0.35), juice pH (-0.33), and ashes (0.3). The second component (PC2) had variables with high loading as reducing sugars (0.61), non-reducing sugars (-0.46), calcium (-0.39) and contributed 17.3% of the variation. The third component (PC3) explained 12.7% of the variation, with high factor contributions for soluble tannins (0.5), fruit weight (0.43), total acidity (-0.41) and calcium (-0.39). The graphic representation of cultivars on the planes 1-2 of principal component shows the physicochemical variation among date palm cultivars and how widely dispersed they are along both axes (Figure 1). To better understand the overall diversity of the date palm cultivars, the data were analysed by hierarchical cluster analysis which revealed the distribution of genetic diversity displayed in Figure 2. All cultivars fell within a large group at 80% similarity indicating continuous variation.

At an arbitrary similarity level of 97%, the obtained UPGMA-cluster dendrogram assembled cultivars from the 3 prospected oases into six clusters based on the 13 fruit physicochemical traits. The Cluster 1 grouped six cultivars from Atar oasis (AHM1, AMS, TJB, BEZ and

Table 4. Pearson coefficient correlation between 13 physicochemical variables of 28 date palm fruit from the Adrar region of Mauritania.

Variable	FW	HU	PH	TA	TS	RS	NS	PC	TC	AS	CA	KA
Water content (HU)	0.30											
Juice pH (PH)	0.25	0.54[a]										
Total acidity (TA)	-0.23	-0.28	0.02									
Total sugars (TS)	-0.44[b]	-0.79[a]	-0.61[a]	0.36								
Reducing sugars (RS)	-0.26	-0.33	0.01	0.33	0.36							
Non reducing sugars (NS)	-0.08	-0.28	-0.48[b]	-0.05	0.41[b]	-0.70[a]						
Poly-phenols content (PC)	-0.38[b]	-0.71[a]	-0.68[a]	0.16	0.83[a]	0.25	0.39[b]					
Soluble tannins (ST)	0.04	-0.49[a]	-0.35	-0.13	0.37	0.03	0.25	0.59[a]				
Ashes (AS)	-0.21	-0.47[b]	-0.25	0.37	0.40[b]	-0.04	0.35	0.40[b]	0.32			
Calcium (CA)	-0.28	0.04	-0.18	-0.04	-0.01	-0.29	0.28	-0.10	-0.19	0.19		
Potassium (KA)	-0.49[a]	-0.46[b]	-0.52[a]	0.19	0.52[a]	-0.16	0.55[a]	0.47[b]	0.15	0.74[a]	0.47[b]	
Magnesium (MG)	-0.39[b]	-0.08	-0.08	-0.09	0.27	-0.04	0.24	0.21	0.16	0.06	0.03	0.28

[a]Correlation is significant at the 0.01 probability level. [b]Correlation is significant at the 0.05 probability level.

Table 5. Factor loadings of the 13 physicochemical characters for the first three principal components (PC) and the percentage variance accounted for each component.

Trait	Code	PC1	PC2	PC3
Fruit weight	FW	- 0.24	- 0.06	0.43
Water content	HU	- 0.37	- 0.21	- 0.10
Juice pH	PH	- 0.33	0.08	- 0.17
Total acidity	TA	0.13	0.26	- 0.41
Total sugars	TS	0.40	0.18	0.01
Reducing sugars	RS	0.05	0.61	- 0.17
Non reducing sugars	NS	0.26	- 0.46	0.17
Phenol content	PC	0.39	0.15	0.21
Soluble tanins	TC	0.23	0.07	0.50
Ash	AS	0.30	- 0.09	- 0.16
Calcium	CA	0.08	- 0.39	- 0.39
Potassium	KA	0.35	- 0.25	- 0.26
Magnesium	MG	0.14	- 0.09	- 0.03
Eigen values		4.8	2.2	1.6
Percentage (%)		37.0	17.3	12.7
Cumulative (%)		37.0	54.3	67.0

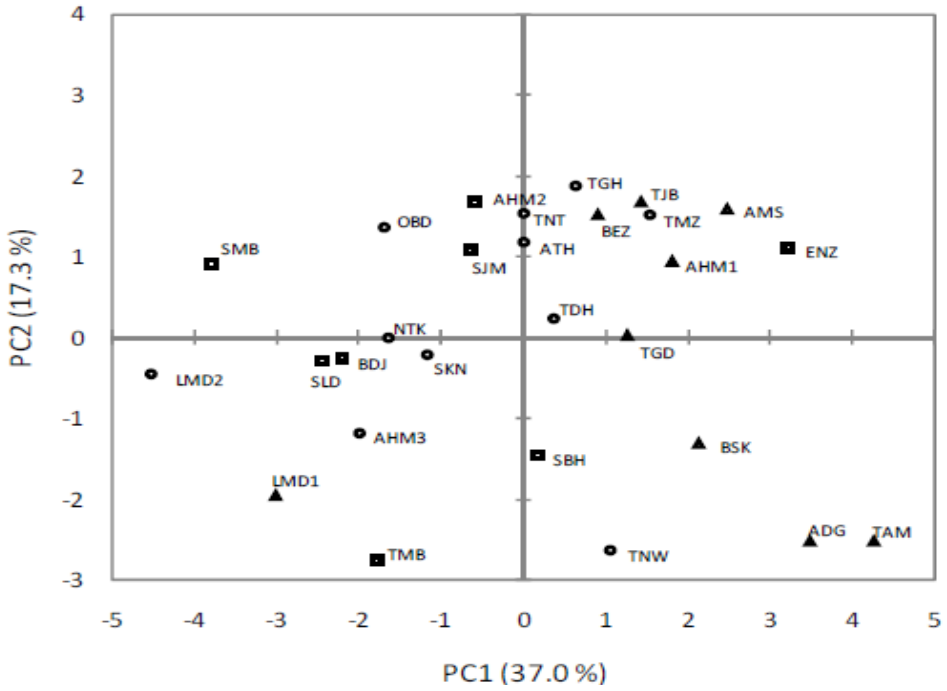

Figure 1. Dispersion of 28 Mauritanian date palm cultivars in the plot 1-2 of the principal component analysis based on 13 fruit physico-chemical parameters. ◘ Cultivars from Chinguitti; ▲ cultivars from Atar; ○ cultivars from Ouadane.

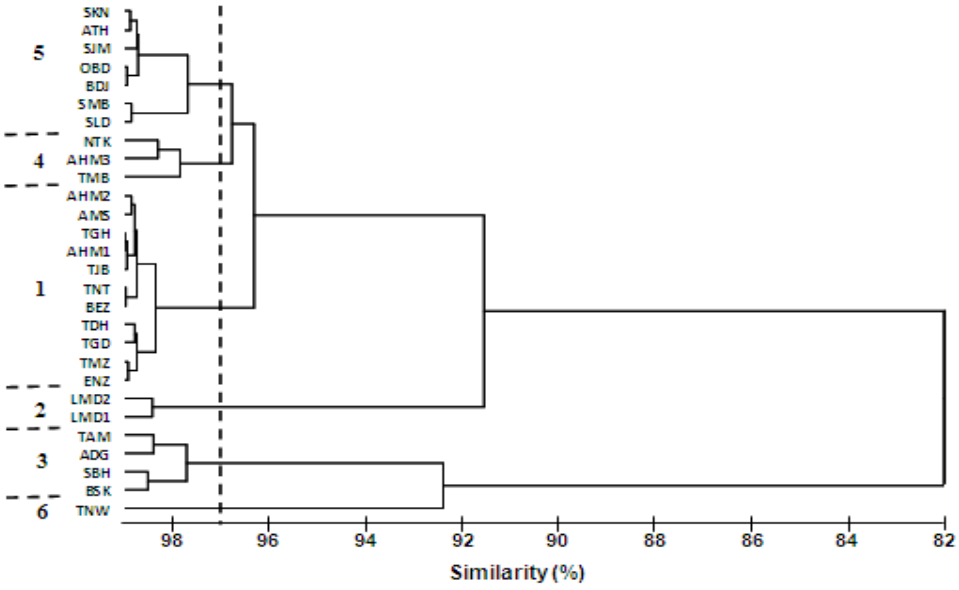

Figure 2. UPGMA-cluster dendrogram of 28 Mauritanian date palm cultivars based on 13 fruit physico-chemical traits. Dotted vertical line indicates similarity level at 97%.

TGD), two cultivars from Chinguitti oasis (AHM2 and ENZ) and four cultivars from Ouadane palm grove (TGH, TNT, TDH and TMZ). The cultivars LMD1 and LMD2 from Atar and Ouadane oases, respectively formed Cluster 2. Cluster 3 assembled three cultivars from Atar oasis (TAM, ADG and BSK) and SBH cultivar from Chinguitti. NTK and AHM3 cultivars from Ouadane and TMB from Chinguitti formed Cluster 4. The fifth cluster included

seven cultivars: SKN and ATH from Ouadane palm grove and SLD, SMB, BDJ, OBD and SJM from Chinguitti oasis. The Ouadane cultivar TNW was isolated from the other germplasm in Cluster 6 (Figure 2).

DISCUSSION

This study was undertaken to evaluate the extent and range of diversity of 13 fruit physical and chemical traits in 28 date palm cultivars including the most popular and well-known cultivars from the 'Adrar' region of Mauritania. Uni-variate and multivariate analysis employed showed large variations in their fruit physical and chemical properties. Total sugars contents in fruit of tested date palm cultivars are in general consistent with the reported data from other date palm countries like Tunisia (Reynes et al., 1994), Soudan (Elshibli and Korpelainen, 2009) and Egypt (Sakr et al., 2010). Indeed, sugars content as founded ranged from 44.66 for the Lemdina 2 soft date to 84% for Bou seker (the sweety) dry date. Sugar content of dates as reported for some word leading cultivars such as Deglet Noor, Medjool, Barhee ranged between 64 to 88% (Harrak et al., 2005; Chaira et al., 2007). Reducing and non-reducing sugars also showed considerable variation among tested date palm varieties. However, the pattern of their distribution, according to fruit consistency does not generally agree with the reported values.

Indeed, soft dates were reported to have little or no non-reducing sugar, while dry dates usually contain considerable amount. The semi-soft dates are in between (Cook and Furr, 1952). In our study reducing sugars (15.19 to 72.17%) were the dominant form of sugars compared to non-reducing sugars (1.16 to 51.76%) and have surprisingly been observed in a high amount in some well-known dry dates such as Amsakhsi (72.17%) and Tiguidert (58.07%). The range of total phenolics content of 234.8 to 670.6 mg GAE /100 g fresh weight detected in this study are similar to those reported by Al-Farsi et al. (2007) who showed that poly-phenols content ranged from 572 to 661 mg GAE/100 g FW in two date varieties consumed in the USA but much higher than values reported by Mansouri et al. (2005) and Chaira et al. (2009) who, respectively showed that poly-phenol content can vary from 2.5 to 8.4 mg of gallic acid equivalents GAE per 100 g of fresh fruit in some Algerian date varieties and from 3.8 to 9.7 mg GAE/100 g FW in some Tunisian date varieties.

However, intermediate poly-phenol content ranging from 172 to 246 mg of GAE/100 g of fresh weight was reported in some Omani date fruits (Al-Farsi et al., 2007). Several factor including cultivar, geographic origin, growing conditions, maturity of the tested dates, season, fertilizers, soil type, amount of sunlight received and conditions of storage, sampling and extraction could affect the phenolic content in dates and may justify the variation observed among studies (El Hadrami and el Khayri, 2012). Magnesium was found in high amount in tested date varieties compared to calcium and potassium. While our results are more or less comparable to those observed in others date varieties, they however do not follow the same order of predominance. Indeed, potassium is reported as the dominant mineral in fruit of date palm harvested at Tamar stage from Tunisia and UAE (Chaira et al., 2007; Ahmed et al., 1995).

Although, the pH of date pulp occurs in a narrow range of variation ($5.2 \leq pH \leq 7.0$), it revealed that dry date varieties such as 'Tiguidert', 'Enzer', 'Tamchkrert', 'Adaghd' and 'Bouseker' exhibited the lowest pH values while soft dates like 'Sel medina', 'Sijoumen', 'Lemdina 1, 2 and 3' and 'Ahmar 1 and 2' showed the highest pH values. Semi-soft date such as 'Bezoul', 'Tijib' varieties have intermediate values. The significant positive correlation ($r = 0.54$; $p = 0.01$) observed between juice pH and fruit moisture of different tested date varieties supports greatly this finding. A similar trend was observed in 21 date varieties from Tunisia (Reynes et al., 1994). The pattern of variation found by ordination and classification analysis showed a distribution of date palm cultivars independently of their oasis origin and the presence of continuous variation among date palm cultivars analysed.

Studies of date palm diversity using DNA markers also showed the presence of continuous variation (Zehdi et al., 2005; Khierallah et al., 2011). Similar finding were reported in some Brazilian Guava (*Psidium guajava*) accessions using biochemical and agronomic traits (Santos et al., 2011). The study also revealed that Ahmar denomination (that is, red coloured) is probably given to genetically different cultivars. Indeed, AH1, AH2 and AH3 exhibited different fruit properties while they have the same denomination. This could be the result of traditional interchange of genetic material among date palm groves. Thus, considering that fruit colour is usually considered by farmers in the denomination of cultivars, it is not excluded that some date palm cultivars are grown in different palm groves under the same denomination while they are genetically different and vice versa. Ould Mohamed Salem et al. (2008) and Ould Mohamed Vall et al. (2011) have previously reported differences in vegetative and reproductive traits among individual referred to as 'Ahmar' collected from different oases of Mauritania.

The presence of homonymous and synonymous cases in date palm has been previously evidenced in some Algerian date palm cultivars using isozymes markers (Bennaceur et al., 1991) and in other species such as pomegranate using fruit physicochemical traits (Mars and Marrakchi 1999). Unfortunately, despite the high genetic diversity of date palm germplasm in Mauritania, only few cultivars benefit from an economic interest such as Ahmar and Lemdina for semi-soft and soft dates, respectively and Tiguidert for dry dates. This represents a risk of genetic erosion of date palm biodiversity and

causes considerable shortfall for farmers who depend on common date varieties. Our results give evidence of the existence of date palm cultivars such as Sekanni, Bouseker, Sembahmoud, Tenwazidi, Sel medina with fruit properties matching or even higher than Ahmar and Lemdina. They are also characterized by a good availability and an interesting aptitude for the conservation (A. Ould Mohamed Salem, University of sciences, technology and medicine, Nouakchott, personal communication).

In Tunisia, the physicochemical characterization of 21 date palm fruits from Jerid region resulted in the selection of varieties (Menakher, Boufaggous) with large fruit, interesting weight and high levels of pulp for date industry (Reynes et al., 1994). In our case, the evaluation of fruit organoleptic and sensory parameters such as firmness, taste, aroma, texture and flavour will allow a better understanding of the quality of the analysed date varieties and their possible use for commercial and/or technological purposes. This is the first study on physical and chemical properties of date palm varieties from Mauritania. Findings obtained will be of great interest in local date palm germplasm management and conservation.

Conflict of Interests

The authors have not declared any conflict of interests.

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