



Physico- chemical characterization and associated antioxidant capacity of fiber concentrates from Moroccan date flesh

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Abstract

The aim of this research was to investigate physico-chemical and some functional properties (water and oil holding capacity, emulsion capacity and stability) and associated antioxidant capacity of date fiber concentrates (DFC) from five potential Moroccan cultivars. The main chemical composition of date flesh was also analyzed. Date flesh had high amount of reducing sugars (fructose and glucose), total and insoluble dietary fiber and natural antioxidants (polyphenol and flavonoid). DFC exhibited high proportions of insoluble dietary fiber and presented a relatively low amount of protein, ash, fat, total phenolic and total flavonoid content. DFC also showed high water-holding and oil-holding capacities (~ 6.1- 8 g water/100g and 5.34-6.4 g oil/100g, respectively). Emulsion capacity of DFC was in the range of 17.5 to 23 ml/100 ml. DFC showed also high emulsion stability (~ 34.5 - 38 ml/100 ml). DFC was shown to possess an antiradical capacity. In fact, antiradical efficiency (AE) ranged between 1.26 and 7.09 × 10⁻³ of DFC, which were considered suitable for antioxidant dietary fiber production. Findings of this investigation revealed essential information that could be advance the possibility to use DFC as an ingredient for the food industry.

Keywords: Moroccan date, Date fruit, Date chemical composition; date fiber concentrates; antioxidant capacity.

Introduction

The fruits of the date palm (*Phoenix dactylifera*L.) are very commonly consumed in many parts of the world and a vital component of the diet and a staple food in most of the Arabian countries. Date fruits pass through several distinct stages of ripening, the Arabic terms- Kimri, Khalal, Rutab and Tamar- are used to represent, respectively, the immature green, the mature full colored, the soft brown and the hard raisin-like stages of development (Barreveld, 1993; Ahmed & Ahmed, 1995). In Moroccan oases, dates are consumed at the Tamar stage probably because of its good storability, sweet taste and lower astringency.

The production of dates in the Arab countries accounts for 82.25% of the total world production while Morocco is the 13th date producing country with an average annual production of 72.700 tons (FAOSTAT, 2009). In Figuig oasis located at the South-East region, the estimated number of date palm trees is 190.000 representing 2.8 % of total Moroccan date palm agricultural areas (Hakkou&Bouakka, 2004). In this oasis, the date production faces a wide range of problems, including the predominance of low quality dates and absence of their transformation industries, inadequate packaging, inappropriate preservation methods and changes in local consumers' habits.

As revealed by several publications, dates flesh is rich in sugars (glucose, fructose and sucrose), dietary fibers, minerals, protein and vitamins (Sawaya *et al.*, 1983; Ahmed & Ahmed, 1995; Al-Hooti *et al.*, 1995; Aidoo *et al.*, 1996; Ismail *et al.*, 2006; El Arem *et al.*, 2011). In recent decades, the interest in food rich in dietary fiber (DF) increased and the importance of this food constituent has

led to the development of a large market for fiber - rich products. Among the different fiber-rich foods, dates fruits are one of the main sources of DF. The amount of DF coming from date fruits differs to a great extent depending on the cultivar, the ripening stage, analytical methods and processing conditions. Holland *et al.* (1991) reported that the DF content ranged from 6.5 % by Southgate method to 3.4% by Englyst method. Al-Mukhtar (1994), using an enzymatic method, showed that the DF for combined dates of cvs. Hallawi and Sayer was 8 %. Limited information on Moroccan date's fruit and its ability to transformation on new products are available in the literature and, therefore, studies on date flesh are relevant to generate physicochemical parameters that would help the process industry to design new food products, quality control and development of date's sector in Morocco. In this paper, chemical composition of date flesh of the most produced and consumed cultivars (Assiane, Aziza bouzid, Boufeggous, Boufeggousgharas and Mejhoul) from Figuig oasis located in South-East of Morocco, was investigated . The corresponding date fibers concentrates (DFC) of those five cultivars were extracted and their chemical composition as well as some functional and antioxidant properties were also investigated to promote the industrial use of dates as a new source for the production of fiber concentrates.

Material and methods

Plant material

Five Moroccan cultivars of date fruit, namely Assiane, Aziza bouzid, Boufeggous, Boufeggousgharas and Mejhoul 1 were procured from Figuig oasis and one cultivar Mejhoul 2 from Tafilalet region. The fruits were collected at Tamar stage (full ripeness) at the end of

2009 harvest season. They were sorted, cleaned, pitted and stored in a refrigerator at $\pm 4^{\circ}\text{C}$ for three months until analysis.

Extraction of dietary fibers (DF)

Extraction procedures used were according to the method of Borchani *et al.* (2010). Date fiber concentrates (DFC) were extracted from a mixture of hot water and date paste with a relative dates / water = 1: 6 (w / v). The mixture was kept at 70°C for 15 minutes in a stainless steel pot and then filtered through a fine mesh of 0.318 mm diameter to separate insoluble residues. These extraction and filtration were repeated 7 times until the residue was completely free of sugars. The insoluble residue obtained was dried and milled to give the DFC then stored at $\pm 4^{\circ}\text{C}$ for 7 days until physicochemical analysis.

Physico-chemical analysis of date pulp and date fiber concentrates (DFC)

Proximate composition (dry matter, ash, lipid and protein content) was determined according to the method described by Association of Official Analytical Chemists (AOAC, 1997). Protein was analyzed according to Kjeldahl method (AOAC, 1997) and factor 6.25 was used for conversion from total nitrogen to crude protein. Lipid content was determined by Soxhlet extraction using petroleum ether solvent (AOAC, 1997).

Total soluble sugars were assessed by the dinitrosalicylic acid (DNS) method (Miller, 1959). Concentrations of insoluble and soluble dietary fibers were determined according to Englyst method (Englyst *et al.*, 1994).

Water activity (a_w) of date flesh was measured at 25°C by a Novasina Aw Sprint apparatus (Novasina Aw Sprint TH-500, Switzerland).

The concentration of total phenolics, expressed as gallic acid equivalents (GAE mg/ 100 g of sample, dry weight), was determined colorimetrically using Folin-Ciocalteu reagent as described by Al-Farsi *et al.* (2005) using a UV-1601 spectrophotometer (Shimadzu).

Total flavonoid content of date flesh and DFC was determined according to Zhishen *et al.* (1999). One ml of the extract was placed in a 10-ml volumetric flask containing 5 ml distilled water. Then 0.3 ml of 5 % sodium nitrite was added; after 5 min, 0.3 ml of 10% aluminum chloride was added. After 6 min, 2 ml of 1 M sodium hydroxide were added and diluted to volume with distilled water. Immediately the solution absorbance was measured at 510 nm using a spectrophotometer. Measurements were calibrated to a standard curve of prepared quercetin solution and the total flavonoid content was expressed as quercetin equivalents (QE mg / 100 g of sample, dry weight).

The capacity of extracts from DFC to reduce the radical 2, 2-diphenyl-1-picrylhydrazyl (DPPH) was assessed using the method of Masuda *et al.* (1999) with some modification. One hundred fifty μl of a solution of DPPH in methanol (0.004 %) were mixed with 1 ml DFC

extract during 30 min and the absorbance was recorded at 517 nm. The scavenging activity of extracts was evaluated according to the formula: percent scavenging = $[A_0 - (A_1 - A_S)] / A_0 \times 100$, where A_0 is the absorbance of DPPH alone, A_1 is the absorbance of DPPH + extract and A_S is the absorbance of the extract only. The parameter EC50, which reflects 50% depletion of DPPH free-radical, was expressed in terms of grams of date fiber concentrates equivalent per gram of DPPH in the reaction medium. The time necessary to reach the steady state at EC50 (TEC50) was calculated. The antiradical efficiency (AE), an index defined by Sanchez-Moreno *et al.* (1998) which combines both factors, was also calculated in order to recognize the combined effect of both parameters: $AE = 1/EC_{50} \text{TEC}_{50}$.

Analysis of some techno-functional properties of DFC

Water-holding capacity (WHC): Water-holding capacity (WHC) was determined according to Robertson *et al.* (2000). One hundred mg of DFC were added to 10 ml distilled water and stirred overnight at 4°C . Then the mixture was centrifuged in 50ml graduated tube at 14,000 g for 20 min. Water-holding capacity (WHC) was expressed as g of water held per g of sample.

Oil-holding capacity (OHC): Oil-holding capacity (OHC) was determined according to Lin *et al.* (1974). In 50 ml graduated centrifuged tube, 100 mg of DFC were mixed with 15 ml of corn oil. The prepared solution was homogenized for 30 second every 5 min for 30 min and then centrifuged for 25 min at 1600 g. The supernatant obtained was carefully removed. OHC was expressed as g of oil held per g of sample.

Emulsion capacity (EC): Twenty ml of 7% (w/v) sample suspension, prepared beforehand and 20 ml of the corn oil were stirred for 5 min and then centrifuged in 50 ml graduated tube at 3000 g for 5 min (Yasumatsu *et al.*, 1972). Emulsion capacity was calculated as the ratio of the volume of emulsified layer in the supernatant and the volume of whole layer in centrifuged tube.

Emulsion stability (ES): Emulsion stability was evaluated according to Chauet *et al.* (1997). Emulsions prepared by the above procedures were heated at 80°C for 30 min, cooled to room temperature and centrifuged in 50 ml graduated tube at 1200 g for 5 min. ES was calculated as volume of remaining emulsified layer in the supernatant / original emulsion volume.

Experimental design and statistical analysis

Means were based on three replications. Values of different parameters were expressed as the mean \pm standard deviation. Student - Newman - Keuls test was performed using statistical analysis package SPSS 10.0 for Windows (SPSS Inc., Chicago, USA) at $p < 0.05$, to evaluate the significance of differences between mean values.

Results and discussion

Proximate composition of date flesh

The proximate composition of date fleshes of the five studied cultivars are given in Table 1. All cultivars

Table 1. Chemical composition of studied date fleshes

Component	Assiane	Aziza bouzid	Boufeggous	Boufeggousgharas	Mejhoul 1	Mejhoul 2
Dry matter (%)	73.91 ^e ± 0.98	71.63 ^d ± 0.03	63.46 ^c ± 0.017	74.51 ^f ± 0.06	59.09 ^a ± 0.075	61.77 ^b ± 0.43
Wateractivity	0.558 ^a ± 0.017	0.599 ^b ± 0.001	0.676 ^c ± 0.016	0.544 ^a ± 0.012	0.748 ^d ± 0.034	0.603 ^b ± 0.007
Total dietary fibers ^(a)	13.63 ^f ± 1.12	11.95 ^e ± 2,22	9.97 ^c ± 0,45	10.6 ^d ± 1.02	8.62 ^b ± 0.98	7.81 ^a ± 1.1
Insoluble dietary fibers ^(a)	8.98 ^f ± 0,93	7.99 ^e ± 2,02	5.6 ^a ± 0,22	7.82 ^d ± 1,35	6.46 ^b ± 0,98	6.65 ^c ± 0,78
Soluble dietary fibers ^(a)	4.65 ^f ± 0,24	3.96 ^d ± 0,2	4.37 ^e ± 0,23	2.78 ^c ± 0,33	2.16 ^b ± 1,09	1.16 ^a ± 0,18
Ash ^(a)	2.63 ^{bc} ± 0,00	2.24 ^a ± 0.125	2.60 ^{bc} ± 0.005	2.37 ^{ab} ± 0.04	2.41 ^{ab} ± 0.175	2.88 ^c ± 0.025
Totalsugars ^(a)	71.81 ^a ± 1.9	81.33 ^b ± 1.3	74.46 ^c ± 2,1	67.4 ^d ± 0.06	68.45 ^e ± 1.02	65.30 ^f ± 0.75
Total phenolic ^(b)	249.290 ^b ± 0.005	171.390 ^a ± 0.004	224.74 ^b ± 0.01	353.92 ^c ± 0.03	265.78 ^b ± 0.002	222.95 ^b ± 0.007
Total Flavonoids ^(b)	71.260 ^b ± 0.0021	47.788 ^a ± 0.0043	45.044 ^a ± 0.0007	84.956 ^c ± 0.0021	53.047 ^a ± 0.0014	43.280 ^a ± 0.0007

Means ± SD (n=3). Values within the same row, followed by the same letter, are not statistically different ($p < 0.005$) as measured by Student - Newman- Keuls. (a): g/100g dry weight, (b): mg gallic acid equivalents (GAE) /100g dry weight, (c): µg quercetin equivalent (QE) / 100g dry weight.

showed high content of total sugars (~ 65.30 - 81.33% dry matter basis) and significant amounts of total dietary fibers (TDF) (~ 7.81- 13.63 % dry matter basis) and low contents of ash (2.24 - 2.88% dry matter basis). Analysis of variance of total sugars, dietary fibers (DF) and ash revealed significant difference ($p < 0.05$) between various cultivars. Hasnaoui *et al.* (2011) reported that the sugar fraction of date flesh of cvs. Assiane, Boufeggous, Boufeggousgharas and Mejhoul was essentially formed by reducing sugars (glucose and fructose in comparable proportion) in except of cv. Aziza bouzid characterized by its richness of sucrose. The low sugar content of Mejhoul and Boufeggousgharas cultivars can be explained by non enzymatic browning during storage favorite by their high amount of water. In except for cv. Mejhoul 1 that presented high value of water activity (0.748), the studied dates had a relatively low a_w value, ranging between 0.544 (cv. Boufeggousgharas) to 0.676 (cv. Boufeggous) ($P < 0.05$). This low a_w allowed the protection of dates from all bacterial alterations.

The studied date fruit presented total dietary fiber (TDF) content in the range 7.81- 13.63g /100g dry weight basis (Table 1). Assiane cultivar presented the highest value (13.63 %) followed by Aziza bouzid and Boufeggousgharas cultivars, while the Boufeggous and Mejhoul cultivars had the lowest values. Insoluble dietary fiber (IDF) was the major fraction, ranging between 5.6% (cv. Boufeggous) and 8.98 % (cv. Assiane). Holland *et al.* (1991) reported that TDF values were about 9-11% using Southgate method and 5- 6 % for Englyst method. Thus, our results are in the same range with those given by the Southgate method and higher than the upper estimate for Englyst method. Alshahib and Marshall found that the percentage of TDF of 13 date's varieties from various countries was in the range of 6.4-11.5%, depending on the varieties and the degree of ripeness. Besbes *et al.*

(2008) reported that TDF contents from second - grade dates (from Degach region in Tunisia) of cvs. Allig, Degletnour and Kentichi were 8.70, 7.95 and 18.83 g / 100g dry matter basis, respectively. While, Elleuch *et al.* (2008) found that cvs. Degletnour and Allig date by-products, from the same region, contained higher amounts of TDF: 14.4 % and 18.4% respectively. The differences observed between results of the two studies can be explained by differences of texture of date used in the experiments and differences caused by season, local variations in conditions and time of harvesting and storage.

Analysis of variance of total phenolic content showed a significant difference ($P < 0.05$) between the studied date's cultivars and ranged from 171.4 mg of GAE /100 g to 353.92 mg of GAE /100 g dry weight basis). cv. Boufeggousgharas had the higher amount of total phenolic (353.92 mg of GAE/100 g dry weight basis) followed by cv. Mejhoul1 (265.78 mg of GAE/100g dry weight basis), cv. Assiane (249.29 mg of GAE/100 g dry weight basis), cv. Boufeggous (224.74 mg of GAE/100g dry weight basis) and cv. Mejhoul 2 (222.95 mg of GAE/100g dry weight basis). Aziza bouzid cultivar showed the lowest level of total phenolics content (171.4 mg of GAE/100g dry weight basis). Besbes *et al.* (2008) reported similar results for Allig, Degletnour and Kentichi date cultivars from Tunisia (431.5 mg GAE/ 100g, 681.8 mg GAE/ and 280.6 mg GAE/ 100 g dry weight basis respectively). Al-Farsi *et al.* (2007) reported total phenolic values between 172 and 246 mg of GAE/ 100 mg fresh weight for Omani dates. Wu *et al.* (2004) reported higher values of total phenolic for tow date cultivars studied (572 and 661 mg of GAE/100 mg fresh weight). Sanchez-Zapata *et al.* (2011) found that cv. Mejhoul date paste also showed a high amount of total phenolics (225 mg GAE/100 g fresh weight). However,

Table 2. Chemical composition of studied dates fiber concentrates (DFC)

Contents	Assiane	Aziza bouzid	Boufeggous	Boufeggousgharas	Mejhoul 1	Mejhoul 2
Dry matter (%)	87.71 ^a ± 0.18	90.21 ^d ± 0.06	89.74 ^c ± 0.01	95.57 ^f ± 0.69	91.89 ^e ± 0.07	89.30 ^b ± 0.005
Total dietary fibers (a)	90.76 ^a ± 2.02	95.23 ^e ± 1.001	92.91 ^d ± 2.016	92.85 ^c ± 1.4	92.91 ^d ± 2.51	91.40 ^b ± 1.75
Insoluble dietary fibers (a)	88 ^c ± 1.09	85.82 ^a ± 0.15	86.71 ^b ± 2.05	89.14 ^d ± 0.68	86.92 ^b ± 0.8	90.70 ^e ± 0.003
Soluble dietary fibers (a)	2.76 ^b ± 0.5	9.41 ^f ± 0.45	6.2 ^d ± 0.12	3.71 ^c ± 0.16	5.99 ^e ± 0.2	2 ^a ± 0.92
Total sugars (a)	0	0	0	0	0	0
Total phenolic (b)	1.02 ^e ± 0.00	0.55 ^a ± 0.125	0.74 ^c ± 0.005	0.93 ^d ± 0.04	1.06 ^e ± 0.175	0.64 ^b ± 0.025
Total Flavonoids (c)	1.06 ^b ± 0.00	0.66 ^a ± 0.125	0.73 ^a ± 0.005	1.39 ^c ± 0.04	0.98 ^b ± 0.175	0.72 ^a ± 0.025
Protein (a)	10.40 ^d ± 0.03	11.19 ^e ± 0.125	8.47 ^a ± 0.05	13.59 ^f ± 0.05	9.02 ^b ± 0.175	9.33 ^c ± 0.09
Fats (a)	1.13 ^c ± 0.95	0.98 ^{ab} ± 0.089	1.08 ^b ± 0.01	0.97 ^a ± 0.098	1 ^b	1.011 ^b
Ash (a)	2.71 ^a ± 0.45	3.53 ^{bc} ± 0.32	4.035 ^c ± 1	3.5 ^b ± 0.98	3.03 ^{bc} ± 0.	3.035 ^{ab} ± 0.007

Means ± SD (n=3). Values within the same row, followed by the same letter, are not statistically different ($p < 0.005$) as measured by Student - Newman- Keuls. (a): g/100g dry weight, (b): mg gallic acid equivalents (GAE) /100g dry weight, (c): µg quercetin equivalent (QE) / 100g dry weight.

Mansouri *et al.* (2005) who studied seven Algerian date palm fruits and Biglari *et al.* (2009) who studied Iranian date's fruits found much lower total phenolic contents (2.49 - 8.36 mg GAE/ 100g for Algerian date fruits and 2.89 - 6.41 mg GAE / 100g for Iranian varieties). These variations in total phenolic contents could be related to various factors. One such factor may be the difference of genetic potential of individual cultivars for polyphenol biosynthesis (Kallithraka *et al.*, 2004). Maturity, season, geographic origin, fertilizer, soil type, storage conditions and amount of sunlight received may also be critical in this respect (Al-Farsi *et al.*, 2007).

Total flavonoids content (TFC) of studied date varied significantly ($p < 0.05$) from 43.28 to 84.95 mg in term of quercetin equivalents/ 100g dry weight. The order of TFC of dates was: Mejhoul 2 < Boufeggous < Aziza bouzid < Mejhoul 1 < Assiane < Boufeggousgharas. These values were higher than those reported by Biglari *et al.* (2008) for Iranian date varieties in except of Kharak cultivar that contained higher TFC (81.7 mg of catechin equivalent (CEQ) / 100g dry sample). For seven different varieties of ripe date palm fruits from Algeria, different types of flavonoids were identified mainly flavones, flavanones and flavonol glycosides (Mansouri *et al.*, 2005).

Chemical composition analysis of date fiber concentrates (DFC)

Chemical composition and yields of the DFC obtained are given in Table 2 and 3 respectively. DFC exhibited low moisture content (Table 2) ranged from 4.43 % (cv. Boufeggousgharas) to 12.29 % (cv. Assiane) but showed higher amounts of TDF ranging between 90.76 % (cv. Assiane) and 95.23 % (cv. Aziza bouzid) which is close

to levels measured in DFC from cvs. Degletnour (22%) and Allig (92%) date's fruits from Tunisia (Eilleuch *et al.*, 2008). Our results of TDF are notably higher than those reported in Mango dietary fiber 28.1 % (Vergara *et al.*, 2007) and in grape skins (54.1- 64.6 %) (Bravo & Saura, 1998). Studied DFC contained a higher proportion of insoluble dietary fibers (IDF) ranging from 85.82% (cv. Aziza bouzid) to 90.70% (cv. Mejhoul 2) and lower content of soluble dietary fibers (SDF) ranging between 2 (cv. Mejhoul 2) and 9.41% (cv. Aziza bouzid). The differences between IDF and SDF contents of studied DFC were significant ($p < 0.05$) as exhibited by Students-Newman Keuls test. Similar pattern has been reported for other fiber preparations, such as citrus peel fibers (47.6 % IDF and 9.4 % SDF) (Chau & Huang, 2003), guava fiber (39.2 - 50.1 % IDF and 1.8 % SDF) (Jimenez *et al.*, 2001a; Jimenez *et al.*, 2001b). For certain Food applications, DFC should have a balanced content of soluble and insoluble fraction, in the case of mango dietary fiber, the two fiber types are present at almost equal levels 13,8% (IDF) and 14,25% (SDF) (Vergara *et al.*, 2007). The extraction yield of TDF varied significantly ($p < 0.05$) from 51.6 % (cv. Assiane) to 72.55% (cv. Mejhoul 2).

The extraction yield (table 3) of SDF varied between 4.6 (cv. Assiane) and 15.44 % (cv. Aziza bouzid). The yield of IDF ranged from 69.81 to 98 %. Dry matter yield varied also significantly between the cultivars ($p < 0.05$). In fact, DFC from Assiane cultivar showed higher level (7.75 %). This can be explained by the fact that cv. Assiane has higher IDF amounts than the other cultivars (Table 1). Protein content is an important parameter in a dates fibers concentrates, ranging between 8.47% (cv.

Table 3. Evaluation of different types of extract yields

Yield %	Assiane	Aziza bouzid	Boufeggous	Boufeggousgharas	Mejhoul 1	Mejhoul 2
Dry matter	7.75 ^f ± 1	6.5 ^c ± 1.03	7.3 ^e ± 2.06	7.07 ^d ± 1.13	5 ^a ± 2.4	6.2 ^b ± 1.7
Total fibers	51.60 ^a ± 0.3	51.80 ^b ± 0.05	68.03 ^e ± 0.34	61.93 ^d ± 0.001	53.90 ^c ± 0.85	72.55 ^f ± 0.01
Insoluble DF	75.94 ^c ±	69.81 ^b ±	98.03 ^f ±	80.60 ^d ±	67.27 ^a ±	84.56 ^e ±
Soluble DF	4.6 ^b ± 3.15	15.44 ^f ± 1.03	10.35 ^d ± 1.34	9.43 ^c ± 0.06	13.86 ^e ± 0.02	3.74 ^a ± 2.13
Proteins	23.36 ^e ± 1.9	18 ^c ± 1.25	21.77 ^d ± 1.04	39.38 ^f ± 0.008	13.71 ^a ± 1.6	17.38 ^b ± 1.00

Means ± SD (n=3). Values within the same row, followed by the same letter, are not statistically different ($p < 0.005$) as measured by Student - Newman- Keuls.

Table 4. Efficient concentration (EC_{50}) and antiradical efficiencies (AE) of DF concentrate

Cultivars	IC_{50} (g / ml)	EC_{50}^A (g/ mg DPPH)	AE ^B
Assiane	0.0056 ± 0.002	0.141 ± 0.007	7.09 ^f ± 0.856
Aziza bouzid	0.022 ± 0.0316	0.548 ± 0.058	1.824 ^b ± 0.789
Boufeggous	0.0315 ± 0.002	0.790 ± 0.397	1.265 ^a ± 5.10
Boufeggousgharas	0.0106 ± 0.0046	0.265 ± 0.022	3.773 ^c ± 1.318
Mejhoul 1	0.0094 ± 0.003	0.236 ± 0.001	4.237 ^d ± 0.10
Mejhoul 2	0.0086 ± 0.063	0.217 ± 0.015	4.608 ^e ± 1.341

Results are means ± SD .values of the same column, followed by the same letter, are not statistically different ($P < 0.05$) as measured by Student - Newman- Keuls

Boufeggous) and 13.59% (cv. Boufeggousgharas). These values are also higher as compared to other fibers such as Mango: 4.2 % (Vergara *et al.*, 2007) and *Citrus sinensis* peel: 2.2 % (Chau & Huang, 2003); but with similar values to those obtained by Bravo and Saura-Calixto (1998) for grape skins: 11.6- 14.4%. Similar values have been reported for other DFC from other date's cultivars such as cvs. Allig and Degletnour (Elleuch *et al.*, 2008) Differences between proteins content of different dates fibers concentrates are due to varieties and methods of analysis and extraction. The yield of protein varied between 13.71 % (cv. Mejhoul1) and 39.38 % (cv. Boufeggousgharas). This can be explained by the presence of a portion of protein that binds strongly to DF: cell wall (O'Neill and Selvendran, 1985) and another portion that is insoluble (initially insoluble) and/ or denatured by hot water during extraction of DF). The ash content of DFC varied between 2.71 % (cv. Assiane) and 4.035 % (cv. Boufeggous). These values are lower compared to the other fruits fiber concentrates such as grape skins (5.7-9.2g/100g (Bravo & Saura-Calixto, 1998; Elleuch *et al.*,

Total flavonoid content (TFC) of date fiber concentrates varied also significantly between cultivars, from 0.66 (cv. Aziza bouzid) to 1.39 (cv. Boufeggousgharas) µg in term of quercetin /g dry weight basis. Fruits with high antioxidant capacity generally contain more antioxidant compounds and most of these has been showed to be phenolic compounds and in particular flavonoids (Wang *et al.*, 1996; Connor *et al.*, 2002; Guo *et al.*, 2003).

The averages of antiradical efficiency (AE) based on DPPH (diphénylpicryl-hydrayl) assay was tested in extractable polyphenols obtained from DFC are given in table 4. The DFC of cv. Assiane showed the highest level of AE (7.09×10^{-3}) while cv. Boufeggous date exhibited the lowest level (1.265×10^{-3}). The order of AE of DFC was : Boufeggous < Aziza bouzid < Boufeggousgharas < Mejhoul 1 < Mejhoul 2 < Assiane. Analysis of variance (ANOVA) showed strong difference between all types of DFC since the $p < 0.0001$ indicating that the types of dates are different based on the antiradical efficiency. Our results are relatively in the range with those determined in fibers extracted from guava fruit (7×10^{-3} - 9×10^{-3}) (Jimenez *et al.*, 2001a; Jimenez *et al.*, 2001b) but lower than the value obtained by Vergara *et al.* (2007) for mango DF (15×10^{-3}).

Technological properties of DFC

Water holding capacities (WHC), oil holding capacity (OHC), Emulsion capacity (EC) and Emulsion stability (ES) are given in Table 5.

Table 5. Technological properties (water holding capacity (WHC), oil holding capacity (OHC), emulsion capacity and emulsion stability) of DFC.

Parameter	Assiane	Aziza bouzid	Boufeggous	Boufeggous gharas	Mejhoul 1	Mejhoul 2
Emulsion capacity (ml /100 ml emulsion)	22.5 ^b ±0.55	22.5 ^b ±0.61	17.5 ^a ±2.08	22.5 ^b ±0.6	22.5 ^b ±0,5	23 ^c ±1,03
Emulsion stability (ml /100 ml emulsion)	38 ^e ± 2.828	36.25 ^c ± 1.06	34.5 ^a ± 0.707	37 ^d ± 1.5	37 ^d ± 0.98	36 ^b ± 2,4
WHC(g water/100g)	6.55 ^c ± 0.065	7.91 ^d ± 0.50	7.98 ^e ± 0.03	6.08 ^a ± 0.075	6.62 ^b ± 0.1	6.08 ^a ± 0.36
OHC(g water/100g)	5.51 ^c ± 0.76	5.45 ^b ± 0,58	5.70 ^d ± 0.61	5.34 ^a ± 0.53	5.44 ^b ±0,06	6.38 ^e ± 0,512

Means ± SD (n=3). Values within the same row, followed by the same letter, are not statistically different ($P < 0.005$) as measured by Student - Newman- Keuls.

2008) reported 2% of ash for DFC from cvs. Degletnour and Allig.

The total phenolics content (TPC) in date fiber concentrates varied significantly between cultivars ($p < 0.05$).it varied from 0.55 to 1.06 mg galic acid equivalent / g dry weight basis. The highest TPC was obtained in cv. Mejhoul1 DFC and the lowest TPC was found in the cv. Aziza bouzid DFC (Table 3). Our results are several folds lower than other DFC such as mango (16.1mg /g dry sample), Mexican lime peel (10.55 and 19.9 mg/g) Ubando-Rivera *et al.* (2005) and in commercial grape skin fiber (20 mg/g) Saura-Calixto (1998).

The result of WHC shows that cvs. Boufeggous and Aziza bouzid had the highest WHC (7.98g of water/g dry weight) and (7.91g water /g dry weight) respectively, followed by cvs. Mejhoul 1(6.08 g water /g dry weight), Boufeggousgharas (5.82 g water /g dry sample), Assiane (5.74 g water /g dry sample) and Mejhoul 2 (5.43 g water /g dry sample). Those result are similar to those reported by Elleuch *et al.* (2008) for Allig and Degletnour cultivars (7 and 6.4 g water/g dry sample respectively) but lower than WHC of dry citrus peel fiber ranging between 15.5 and 16.7g of water/g of dry sample (Chau & Huang, 2003). Dietary fiber has an important effect on this technological property because it holds water by

adsorption and absorption phenomena. Some water is also retained outside the fiber matrix (free water). This property is related to the chemical and physical structure of the plant polysaccharides (Sanchez *et al.*, 2011). These hydration properties of date paste determine their optimal usage levels in foods as they provide desirable texture properties. OHC is another important parameter which in DFC ranged between 5.51g of oil/g dry sample (Assiane) and 6.38 g of oil/g dry sample. These values were lower than those obtained by Elleuch *et al.* (2008) for cvs. Allig and Degletnour (~ 9.7g oil/g sample) but higher than those reported in other DFC, *e.g.* mango fiber concentrates (1- 1.5g of oil/ g of dry sample) (Vergara *et al.*, 2007) and some date by-product. As reported by Sanchez *et al.* (2010), OHC of Mejhoul date paste was 0.53g of oil/g of dry sample. In view of that, DFC may be suitable in products where emulsifying properties are not required. Emulsion capacity (EC) is a molecule's ability to act as an agent that facilitates solubilization or dispersion of two immiscible liquids. Emulsion stability (ES) is the ability to maintain the integrity of an emulsion (Sanchez *et al.*, 2010). Emulsion capacity of DFC was in the range of 17.5 ml/100 ml (cv. Boufeggous) and 23.00 ml/100 ml (cv. Mejhoul 2) and their ES was in the range of 35 ml/100 ml (cv. Boufeggous) and 40 ml/100 ml (cv. Assiane). This EC is lower than tiger nut fiber (70.33), chia fiber (53.26 ml/100 ml), fiber-rich passion fruit powders (52.58 ml/100 ml) and *Phaseolus lunatus* fibrous residue (49.3 ml/100 ml) (Sanchez *et al.*, 2010). The study of these properties shows that DFC could be used as technological ingredient in food to avoid syneresis, to stabilize products with a high percentage of fat and emulsions and to modify the texture and the viscosity of formulated products by virtue of their water holding capacity, oil holding capacity, emulsion capacity and stability.

Conclusions

This study showed that date flesh could be considered as potential source of sugar, fiber and phenolic compounds which have many health benefits and could be used for added value. DFC extracted from the five studied date cultivars contained high content of total dietary fibers. Date flesh can be successfully used to obtain a dietary fiber concentrates which is a potential source of valuable nutrients. The properties of this DFC suggested that it could be used in food industries as an important source of dietary fiber and natural antioxidants (polyphenol content) and as a functional ingredient for stabilization of food product with high content of fat and emulsion by virtue of their high WHC and OHC.

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