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Full Length Research Paper

Chemical properties of 11 date cultivars and their corresponding fiber extracts

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Date palm fruit from 11 Tunisian cultivars (*Phoenix dactylifera* L.) were analyzed for their main chemical composition. Results showed that date fruits were rich in sugar (79.93 - 88.02 g/100 g dry matter), fiber (8.09 - 20.25 g/100 g dry matter) and ash (1.73 - 2.59 g/100 g dry matter). Mineral fraction was dominated by potassium and sugar fraction was dominated by reducing sugar (glucose, fructose) except for Deglet Nour, Kentichi and Bajo which are rich in sucrose. Date fiber concentrates (DFC) were extracted and analyzed for their proximate content (moisture, fiber, protein, lipid and ash) and some functional properties such as water holding capacity (WHC) and oil holding capacity (OHC). DFC presented high dietary fiber content (90.71 - 93.92 g/100g dry matter). Protein and lipid contents (dry matter basis) ranged between 3.66 and 6.06 g/100 g and between 0.35 and 1.08 g/100 g, respectively. DFC presented high WHC (6.20 g water/g dry fiber) and high OHC (1.80 g oil/g dry fiber). Results showed that dates could be a valuable source of highly techno-functional fibers that could be used in food formulations.

Key words: Composition, date, fiber, functional properties, oil holding capacity, water holding capacity.

INTRODUCTION

Nearly 2000 cultivars of date palm (*Phoenix dactylifera* L.) are known in the world, but only some are evaluated for their performance and their fruit quality (Al-Hooti et al., 2002). Date palm fruit is well known as a staple food in Tunisian Sahara. It is composed of a fleshy pericarp and seed (Besbes et al., 2004). The world production of dates has increased extensively during the last 30 years. In fact, the production has tripled from 1 915 615 tones in 1975 to 6 002 040 tones in 2005 (FAOSTAT, 2006). Tunisia is now the 10th producing country of valuable dates and the first exporting country (in value) in the world. Date production was remarkably improved and reached an average of 120 000 tones/year with domininance of Deglet Nour variety (60% of total production) which has a highly appreciated sensory quality leading to a high marketing value.

This progress in production, at national and international scales, is unfortunately accompanied by a considerable increase in lost of dates during harvest, storage, or during conditioning process. Lost of dates could reach more than 30% of the whole production. This constitutes about 30 000 tones/year in Tunisia and nearly 2 000 000 tones/year in the world. The lost of dates are not consumed by human for several reasons which include low quality, hard texture, contamination by champignons or insects. These date by-products are generally rejected or in some limited cases, used for animal feed. The commercial value of Tunisian dates is about 200 Tunisian millimes per kilogramme (12 Euro Cents/Kg), which can be considered as real economic loss as these by-products are rich in some components that could be extracted and valorized. Dates are rich in certain nutrients such as fiber (≈ 8.1 - 12.7% dry matter basis) and contain small amounts of protein, fat, ash and polyphenol (Al-Shahib and Marshall, 2002; Elleuch et al., 2008). They also provide a good source of rapid energy due to their

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Abbreviations: a_w, Water activity; **DF**, dietary fiber; **DFC**, date fiber concentrates; **OHC**, oil holding capacity; **WHC**, water holding capacity.

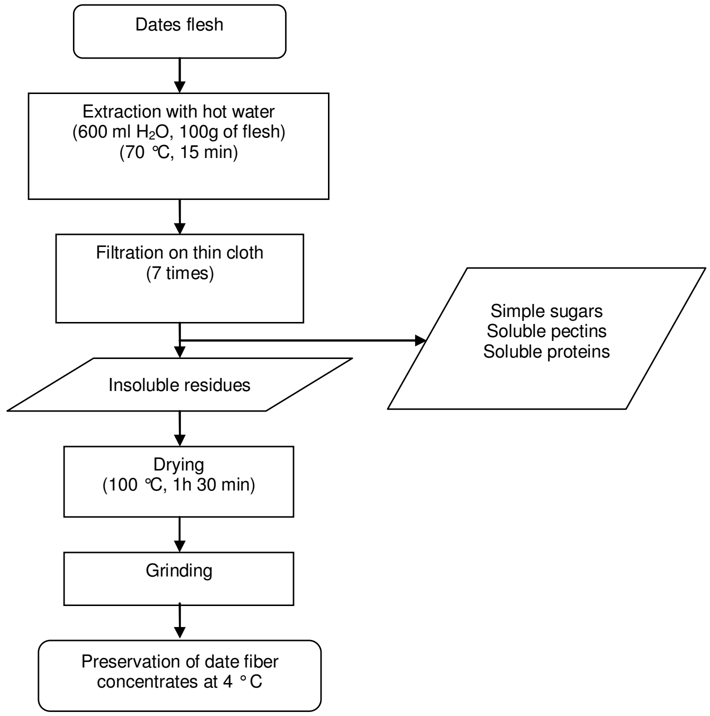

Figure 1. Preparation of fiber concentrates from date by-products.

high carbohydrate content (≈ 70 - 80%). Most of the carbohydrates in dates are in the form of fructose and glucose, which are easily absorbed by the human body (Al-Farsi et al., 2007).

Fibers are claimed to prevent many metabolic or digestive diseases. It is usually defined as the part of the diet which is resistant to human digestive enzymes. Dietary fibers (DF) diets are associated with the prevention of some diseases such as constipation, colonic cancer, diverticular disease, coronary heart disease, cardiovascular disease, atherosclerosis, diabetes and obesity (Grigelmo-Miguel et al., 1999; Al-Farsi et al., 2007). DF are not only desirable for their nutritional properties, but also for their functional and technological properties. So, the functional properties of DF from different fruits should be studied in order to obtain the individual characteristics of each one (Figuerola et al., 2005). However, studies of functional properties of DF from date fruits are limited (Elleuch et al., 2008).

To date, limited data is available regarding compositional and functional characteristics of date by-products grown in Tunisia. The date by-products are safe for human consumption and may possess high value components that may be used in value-added applications, including their use as functional foods and ingredients in nutraceuticals, pharmaceuticals and medicine (Al-Farsi et al., 2007; Besbes et al., 2009).

The purpose of this work is to study the chemical composition of dates from 11 cultivars grown in Tunisia, to set up a simple extraction process of date fiber concentrates and to evaluate their chemical composition and functional properties, which in the end could promote the use of dates and their corresponding fibers in food formulations.

MATERIALS AND METHODS

Samples

Date palm fruits were obtained from the national Institute of Arid Zone (Tozeur, Tunisia). Eleven date-cultivars, subject of this research, were collected at the "Tamr stage" (full ripeness) which is characterized by dry dates allowing easy preservation. These were stored at –20°C. After denutting, the date fleshes were soaked in water, washed and then air-dried. Date fleshes of each variety were separately milled and then stored at -20°C until analysis and extraction.

Fiber extraction and preservation

Fibers were extracted from date flesh previously maintained in hot water at 70°C (100 g/600 ml) for 15 min. The mixture was then filtrated with a thin cloth of 0.318 mm of pore size in order to separate the insoluble residue. These operations of filtration and extraction were repeated 7 times until a paste exempted from simple sugars was obtained. Fiber extracts were dried at 100°C in the oven; then milled in a grinder (7000 rpm, 1 min) and preserved at 4°C (Figure 1).

Evaluation of extract yields

The yield of date fiber concentrates is the mathematical expression of the quantity of the product obtained starting from the initial quantity of dates. The yield was expressed in three manners:

Dry matter yield

Dry matter yield is defined as the output in dry weight expressed as the percentage of dry matter recovered from date flesh.

Total dietary fiber yield

Total dietary fiber yield is defined as the weight of fibers (g) recovered in date fiber concentrate and expressed as the percentage compared with the quantity of fibers contained in 100 g of date flesh.

Protein yield

Protein yield is defined as the protein content in date fiber concentrates and expressed as the percentage compared with the initial content in date flesh.

Proximate composition analysis

Dry matter

Dry matter was determined by a halogen dryer "HB43 Halogen" (Mettler Toledo, Switzerland).

Protein content

Total protein content was determined by the Kjeldahl method, using the general conversion factor 6.25 (El-Shurafa et al., 1982).

Ash and mineral content

To remove carbon, about 2 g (powdered) of sample, in a porcelain container, was ignited and incinerated in the muffle furnace at about 550°C for 8 h. The total ash was expressed in percentage of dry weight. Mineral constituents (Ca, Na, K, Mg and Fe) were analyzed separately, using an atomic absorption spectrophotometer (Hitachi Z6100, Japan) (AOAC, 1990). Samples were prepared for analyses as described by Besbes et al. (2004).

Fat content

Fat was determined according to the AFNOR norm NF V 03-713 (AFNOR, 1986). Lipid extraction was carried out with hexane after chlorydric acid hydrolysis.

Carbohydrate content

Sugars were extracted with ethanol solution (96%) by shaking at 60°C for 30 min. Total soluble carbohydrates were assessed by the phenol- sulphuric method (Dubois et al., 1956).

Sugars

Sample was boiled with aqueous ethanol (80%, 1:20 w/v, 1 h, thrice), centrifuged and the pooled extracts were deionized by passing through Duolite A 368 Type S (H^+) and BioRex 70 de Biorad (OH^-) resins and concentrated by flash evaporation. Sugars in the deionized extracts were analyzed by high performance liquid chromatography (HPLC). Quantitative sugar analysis was done on a Eurospher-100 NH_2 column (250 × 4.6 mm) in a Shimadzu HPLC system consisting of a LC-10 AD pump, RI detector and a Shimadzu CTO-10 AS column oven. The mobile phase consisted of acetonitrile-water (75:25, v/v). An isocratic elution at a flow rate of 0.8 ml min^{-1} was used at 40°C.

Dietary fiber

Total dietary fiber was calculated using the expression:

Total dietary fiber = 100 - (protein + fat+ Total Sugars + ash).

For date flesh, total non-starch polysaccharides (NSP) were determined according to the modified method of Englyst et al. (1992). To 0.5 g of date flesh, 10 ml of distilled water was added and the mixture was boiled at 100°C for 10 min. 40 ml of absolute ethanol was added and the mixture was agitated by repeated inversion and left in ice water for 30 min. Then, the mixture was centrifuged at 1500 g for 10 min and the obtained supernatant was removed by aspiration. 50 ml of 85% ethanol was added to the residue, mixed and centrifuged at 1500 g for 10 min. This stage was repeated using 50 ml of absolute ethanol. 50 ml of acetone was added to the residue and mixed. The obtained suspension was centrifuged and the supernatant was removed. Finally, the residue was dried at ambient temperature during 24 h to remove any trace of acetone.

Functional properties

Water activity

Water activity (a_w) was measured at 25°C using a NOVASINA a_w Sprint TH-500 apparatus (Novasina, pfäffikon, Switzerland).

pH

The pH was measured at 20°C using a MP 744 pH meter (Metrohm, Switzerland).

Water holding capacity (WHC)

WHC of DFC was determined according to the method of Mac Connell et al. (1974). About 100 mg DFC were added to 10 ml of distilled water in a 50 ml centrifuge tube and stirred overnight at 4°C. The mixture was then centrifuged at 14000 g for 20 min. The supernatant was carefully eliminated. WHC was expressed in grams of water fixed by gram of the sample.

Oil holding capacity (OHC)

OHC of DFC was measured by adding 15 ml of corn oil to the concentrate of date fibers in a 50 ml centrifuge tube. The content was stirred then the tubes were centrifuged at 1600 g for 25 min. OHC was expressed in grams of oils held by one gram in a sample (Lin et al., 1974).

Statistical analysis

Results were expressed as mean values ± standard error of the

Table 1. Chemical composition (g/100 g dry weight basis) of date flesh from eleven studied cultivars.

Date variety	Dry matter (%)	Protein	Fat	Total sugars	Ash	*Total dietary fiber	NSP
Alligh	82.94 ± 0.70[d]	1.22 ± 0.03[ab]	0.56 ± 0.19[a]	84.59 ± 0.18[b]	2.18 ± 0.22[ab]	11.45 ± 0.62[a]	9.66±0.71[ab]
Deglet Nour	86.42 ± 0.75[e]	1.71 ± 0.08[abc]	0.40 ± 0.11[a]	88.02 ± 0.60[c]	1.78 ± 0.10[ab]	8.09 ± 0.89[a]	7.47±0.63[a]
Bajo	86.88 ± 0.59[e]	1.28 ± 0.08[ab]	0.11 ± 0.04[a]	79.93 ± 0.31[a]	1.73 ± 0.04[ab]	16.95 ± 0.47[b]	14.97±0.41[d]
Boufeggous	88.70 ± 0.68[e]	1.51 ± 0.16[abc]	0.14 ± 0.00[a]	86.72 ± 0.95[bc]	1.58 ± 0.05[a]	10.05 ± 1.16[a]	8.91±0.74[ab]
Goundi	90.57 ± 0.37[f]	2.85 ± 0.20[c]	0.35 ± 0.21[a]	84.79 ± 0.91[b]	1.85 ± 0.03[ab]	10.16 ± 1.35[a]	9.28±0.58[ab]
Ikhouat	87.97 ± 0.40[e]	0.66 ± 0.03[a]	0.07 ± 0.00[a]	78.86 ± 0.33[a]	2.59 ± 0.52[bc]	17.82 ± 0.88[b]	14.92±0.41[d]
Kenta	88.22 ± 0.79[e]	0.90 ± 0.02[ab]	0.06 ± 0.01[a]	85.11 ± 0.46[b]	1.75 ± 0.02[ab]	12.18 ± 0.51[a]	11.12±0.39[bc]
Kentichi	87.29 ± 0.18[e]	0.46 ± 0.01[a]	0.11 ± 0.04[a]	77.44 ± 0.26[a]	1.74 ± 0.05[ab]	20.25 ± 0.36[b]	12.48±0.84[bcd]
Lagou	73.10 ± 0.60[b]	1.83 ± 0.05[abc]	0.25 ± 0.00[a]	77.31 ± 0.15[a]	2.08 ± 0.02[ab]	18.53 ± 0.22[b]	13.55±0.32[cd]
Touzerzaillet	70.66 ± 0.38[a]	1.49 ± 0.05[ab]	0.57 ± 0.04[a]	78.58 ± 0.77[a]	2.11 ± 0.19[ab]	17.25 ± 1.05[b]	12.19±0.56[bcd]
Tranja	87.85 ± 0.55[e]	2.42 ± 0.85[bc]	0.14 ± 0.07[a]	83.95 ± 0.35[b]	2.23 ± 0.09[ab]	11.26 ± 1.36[a]	9.89±0.18[ab]

Results are expressed as mean values of three determinations ± SD; * Total dietary fiber = 100 - (protein + fat+ total sugars + ash); Means within the same column with different letters are significantly different (p < 0.01).

three separate determinations. Data were subjected to the analysis of variance to study the differences between group means. Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) (version 13). ANOVAs were followed by post hoc comparisons (Newman-Keuls test). Differences at p < 0.01 were considered to be significant.

RESULTS AND DISCUSSION

Proximate composition of date flesh

Table 1 presents the average composition of *P. dactylifera* L. date flesh of the eleven studied cultivars. Moisture contents of date flesh samples of the different cultivars at the “tamr stage” ranged between 9.43 and 29.34 g/100 g. Goundi had the highest dry matter content whereas Touzerzaillet had the lowest. There were no significant differences (p > 0.01) in moisture of date flesh samples between Deglet Nour, Bajo, Boufeggous, Ikhouat, Kenta, Kentichi and Tranja.

Protein content ranged from 0.46 g/100 g (dry matter basis) in Kentichi cultivar to 2.85 g/100 g (dry matter basis) in Goundi cultivar. Results showed a relatively low content of protein. In fact, Al-Hooti et al. (1995) reported that dates were not considered as a good source of protein. Goundi presented the highest protein content (2.85 g/100 g dry matter) followed by Tranja (2.42 g/100 g dry matter). No significant differences in protein content were observed in three groups of dates cultivars: group 1: (Deglet Nour, Boufeggous and Lagou), group 2: (Alligh, Bajo and Touzerzaillet), group 3: (Ikhouat and Kentichi). This later group presented the lowest protein contents.

Date flesh samples of the different cultivars presented very low fat contents (0.06 g/100 g dry matter in Kenta to 0.57 g/100 g dry matter in Touzerzaillet), with no significant variations (p > 0.01).

Ash content ranged from 1.58 g/100 g (dry matter basis) in Boufeggous to 2.59 g/100 g (dry matter basis) in Ikhouat. No significant differences in ash content were observed between Alligh, Deglet Nour, Bajo, Goundi, Kenta, Kentichi, Lagou, Touzerzaillet and Tranja.

Total carbohydrate content of date flesh samples ranged from 77.31 g/100 g (dry matter basis) in Lagou to 88.02 g/100 g (dry matter basis) in Deglet Nour. It is well known that dates are important sources of sugars. The total sugar of date by-products was similar to that reported by Al-Hooti et al. (1995) (81.6 - 88.4%); Elleuch et al. (2008) (72.80 - 79.10%) and Besbes et al. (2009) (78.30 - 87.55%). There were no significant differences in total sugar contents between Alligh, Deglet Nour, Boufeggous, Goundi, Kenta and Tranja and between Bajo, Ikhouat, Kentichi, Lagou and Touzerzaillet.

The major sugars found in the date flesh samples were fructose, glucose and sucrose (Table 2). Sucrose was the major sugar in Deglet Nour (51.14 g/100 g dry matter), Bajo (38.64 g/100 g dry matter) and Kentichi (37.35 g/100 g dry matter), whereas the other cultivars were essentially formed by reducing sugars (glucose and fructose). The richness of these varieties in reducing sugars suggests the existence of a more pronounced invertase activity, which would considerably reduce its content in sucrose (Elleuch et al., 2008; Besbes et al., 2009).

The sugar contents were lower than in those commercial dates with high sensory quality. In fact, Elleuch et al. (2008) reported that sugar loss in date by-products could be explained by non-enzymatic browning during storage (Maillard reaction) and rinsing operation of date flesh samples.

Statistical analysis did not show significant differences (P > 0.01) in fructose content between Goundi, Kenta and Tranja, between Ikhouat, Lagou and Touzerzaillet and between Bajo and Kentichi. There were no significant differences (P > 0.01) in glucose content between Deglet Nour, Bajo and Kentichi; between Boufeggous, Goundi, kenta and Tranja and between Ikhouat, Lagou and Touzerzaillet. No significant differences (P > 0.01) were observed in sucrose content between Boufeggous, Goundi, Ikhouat, Kenta, Lagou, Touzerzaillet and Tranja and

Table 2. Sugar content of date flesh from eleven studied cultivars (g/100 g dry weight basis).

	Free sugars		
	Fructose	Glucose	Sucrose
Alligh	32.70 ± 0.45[c]	39.40 ± 0.43[c]	12.25 ± 0.70[c]
Deglet Nour	16.54 ± 0.34[a]	19.85 ± 0.60[a]	51.14 ± 0.19[e]
Bajo	18.35 ± 0.24[b]	22.02 ± 0.29[b]	38.64 ± 0.52[d]
Boufeggous	41.17 ± 0.24[f]	44.41 ± 0.09[e]	1.14 ± 0.04[ab]
Goundi	36.69 ± 0.02[e]	44.03 ± 0.03[e]	3.29 ± 0.04[b]
Ikhouat	34.45 ± 0.48[d]	41.34 ± 0.58[d]	2.22 ± 0.10[ab]
Kenta	37.32 ± 0.08[e]	44.79 ± 0.11[e]	2.89 ± 0.18[ab]
Kentichi	18.36 ± 0.36[b]	21.02 ± 0.02[ab]	37.35 ± 0.35[d]
Lagou	34.11 ± 0.05[d]	40.93 ± 0.06[d]	1.97 ± 0.11[ab]
Touzerzaillet	35.10 ± 0.05[d]	42.15 ± 0.05[d]	0.63 ± 0.03[a]
Tranja	37.24 ± 0.36[e]	44.68 ± 0.42[e]	1.07 ± 0.76[ab]

Results are expressed as mean values of three determinations ± SD;
Means within the same column with different letters are significantly different ($p < 0.01$).

between Bajo and Kentichi.

Total dietary fiber contents varied significantly between 8.09 g/100 g (dry matter basis) in Deglet Nour and 20.25 g/100 g (dry matter basis) in Kentichi. However, no significant differences were found in Alligh, Deglet Nour, Boufeggous, Goundi, Kenta and Tranja and in Bajo, Ikhouat, Kentichi, Lagou and Touzerzaillet. Besbes et al. (2009) reported much lower values in their study of the fiber contents (8.70 g/100 g dry matter for Alligh and 18.83 g/100 g dry matter for Kentichi) except for Deglet Nour variety that presented a similar result. This could be explained by various factors such as climatic or growing conditions, season, geographic origin and use of different analytical methods. Al-Shahib and Marshall (2002) surveyed the total dietary fiber contents of 13 date varieties from various countries and found that the percentage of total dietary fiber was in the range of 6.4 - 11.5 g/100 g fresh weight, depending on variety and degree of ripeness. The dietary fiber contents of a number of fresh fruits, namely apples, apricots, berries, grapes, oranges, peaches and plums, were reported by Marlett et al. (1994). The obtained values ranged from 1.0 g/100 g for grapes to 4.4 g/100 g for raspberries. In addition, the contents of dietary fiber in dried apricots, prunes, figs and raisins were 7.7, 8.0, 12.2 and 5.1 g/100 g, respectively (Al-Farsi et al., 2007). Thus, dates and their by-products could be considered as a valuable source of dietary fiber compared with most fresh and dried fruits. Although no recommended dietary allowances (RDA) was set, most health/nutrition professionals agree on the benefits of increased consumption of dietary fiber of 25 - 35 g/day (Al-Farsi et al., 2007).

The NSP contents of date fleshes are shown in Table 1. The obtained values ranged from 7.47 to 14.97 g/100 g (dry matter basis), respectively, for Deglet Nour and Bajo. These values were lower than those of total DF cited previously. This difference can be explained by the underestimation of the amount of DF in the Englyst method which includes only Non-starch polysaccharide and not other fiber such as lignin.

The good nutritional value of date flesh samples is also based on their DF content, which made them suitable for preparation of fiber-based foods and dietary supplements. Chemical composition of date flesh samples revealed that this by-product could potentially be considered as a functional food or functional food ingredient.

Mineral composition of date flesh

Date fruit contained significant amount of minerals (Table 3). Potassium concentration was the highest (404.19 - 774.71 mg/100 g dry matter), followed in descending order by magnesium (30.32 - 89.17 mg/100 g dry matter), calcium (11.1 - 36.61 mg/100 g dry matter), sodium (5.27 - 25.14 mg/100 g dry matter basis) and iron (1.06 - 2.3 mg/100 g dry matter). This order had being reported by Devshony et al. (1992) and Al-Hooti et al. (1998).

The mineral composition showed that all studied cultivars were relatively low in sodium but rich in potassium. This low sodium : potassium ratio made the date a desirable food for persons suffering from hypertension (Al-Hooti et al., 1995, 2002).

The majority of the analyzed minerals had no significant variations between date's varieties ($P > 0.01$). However, significant differences ($P < 0.01$) were found in magnesium content between Alligh and Bajo and in sodium content between Lagou and the other varieties. Thus, the variations observed in magnesium and sodium contents of dates could be explained by various factors such as variety, soil type and amount of fertilizer.

Table 3. Mineral composition of date flesh from eleven studied cultivars (mg/100 g dry weight basis).

Date variety	Potassium	Calcium	Sodium	Magnesium	Iron
Alligh	430.69 ± 16.78[a]	11.10 ± 0.49[a]	5.27 ± 0.53[a]	30.32 ± 1.51[a]	1.06 ± 0.03[a]
Deglet Nour	774.71 ± 17.74[a]	25.05 ± 6.82[a]	5.79 ± 0.31[a]	50.26 ± 9.42[ab]	1.33 ± 0.23[a]
Bajo	533.42 ± 17.69[a]	18.65 ± 0.81[a]	8.84 ± 0.41[a]	89.17 ± 1.60[b]	1.41 ± 0.18[a]
Boufeggous	447.46 ± 64.51[a]	22.31 ± 5.66[a]	8.87 ± 0.68[a]	56.05 ± 7.11[ab]	2.30 ± 0.90[a]
Goundi	641.02 ± 10.3[a]	20.82 ± 1.08[a]	11.77 ± 0.53[a]	62.30 ± 0.20[ab]	1.30 ± 0.18[a]
Ikhouat	575.11 ± 16.44[a]	20.66 ± 4.13[a]	8.71 ± 3.26[a]	61.15 ± 4.97[ab]	1.31 ± 0.19[a]
Kenta	404.19 ± 87.84[a]	26.71 ± 13.19[a]	7.04 ± 1.91[a]	47.57 ± 15.6[ab]	1.73 ± 0.26[a]
Kentichi	476.36 ± 15.33[a]	36.52 ± 3.35[a]	8.12 ± 0.82[a]	57.43 ± 5.69[ab]	1.89 ± 0.10[a]
Lagou	537.62 ± 7.97[a]	14.82 ± 0.16[a]	25.14 ± 6.51[b]	58.26 ± 1.71[ab]	1.18 ± 0.02[a]
Touzerzaillet	544.28 ± 2.21[a]	14.98 ± 0.01[a]	13.87 ± 0.80[a]	48.27 ± 1.62[ab]	1.30 ± 0.07[a]
Tranja	670.93 ± 27.10[a]	19.78 ± 0.07[a]	14.66 ± 3.74[a]	57.65 ± 11.34[ab]	1.86 ± 0.12[a]

Results are expressed as mean values of three determinations ± SD; Means within the same column with different letters are significantly different ($p < 0.01$).

Table 4. pH and water activity of date flesh from eleven studied cultivars.

Date variety	pH	Water activity
Alligh	5.55 ± 0.02[d]	0.65 ± 0.01[bc]
Deglet Nour	5.45 ± 0.02[c]	0.67 ± 0.01[c]
Bajo	5.56 ± 0.02[d]	0.64 ± 0.01[bc]
Boufeggous	5.58 ± 0.01[de]	0.64 ± 0.01[bc]
Goundi	5.58 ± 0.01[de]	0.67 ± 0.01[c]
Ikhouat	5.67 ± 0.01[e]	0.64 ± 0.01[bc]
Kenta	5.33 ± 0.05[b]	0.60 ± 0.01[a]
Kentichi	5.43 ± 0.03[bc]	0.64 ± 0.01[bc]
Lagou	5.43 ± 0.02[bc]	0.70 ± 0.01[d]
Touzerzaillet	5.36 ± 0.07[bc]	0.60 ± 0.01[a]
Tranja	5.19 ± 0.02[a]	0.63 ± 0.01[b]

Results are expressed as mean values of three determinations ± SD; Means within the same column with different letters are significantly different ($p < 0.01$).

pH and water activity

The pH values of the date flesh samples ranged from 5.19 for Tranja to 5.67 for Ikhouat (Table 4). The pH value of fruits is one of the important attributes which affected their processing and storage quality. Statistical analysis showed that Tranja had the lowest pH value, whereas Ikhouat had the highest pH value.

The water activity (a_w) of date by-products ranged from 0.6 for Kenta variety to 0.7 for Lagou variety. However, dates could be infected by yeasts if they are badly stocked, that is, at a relatively high temperature and at a high relative humidity (Besbes et al., 2009). Sablani et al. (2005) pointed out that the concept of a_w was used to assess the storage stability of food products.

Physico-chemical characteristics of date fruits revealed that this by-product could be valuable. In order to justify the extraction of date flesh fibers, it is necessary to study their composition and functional properties.

Evaluation of extract yields of date fiber concentrates (DFC)

Table 5 presents different types of extract yields of the obtained DFC, indicated in Figure 1. The DFC of the Touzerzaillet variety show significantly the highest dry matter yield versus that of the Deglet Nour variety (9.95% against 5.66%). This could be explained by the fact that the Touzerzaillet variety had higher DF amounts than the Deglet Nour variety (Table 1).

The extracted yield of total DF was in the range of 37.16 - 74.97% (dry matter), with no significant variations among date's varieties ($p > 0.01$). Thus, about 25.03 - 62.84% of DF was not recovered by the extraction method used.

The extraction yield of protein varied significantly between 12.05% for Goundi variety and 55.51% for Ikhouat variety. This can be explained by the presence of a protein fraction that binds strongly to DF components

Table 5. Evaluation of extract yields (%) of date fiber concentrates from eleven studied cultivars.

Date variety	Dry matter yield	Total DF yield	Protein yield
Alligh	8.03 ± 0.02^{e}	60.60 ± 3.28^{a}	20.58 ± 0.02^{abc}
Deglet Nour	5.66 ± 0.01^{a}	64.11 ± 7.05^{a}	15.59 ± 0.38^{ab}
Bajo	9.25 ± 0.03^{i}	48.94 ± 1.36^{a}	35.01 ± 1.61^{d}
Boufeggous	8.13 ± 0.01^{f}	74.97 ± 8.65^{a}	30.05 ± 2.06^{bcd}
Goundi	7.72 ± 0.01^{d}	72.42 ± 9.62^{a}	12.05 ± 0.75^{a}
Ikhouat	7.35 ± 0.01^{c}	37.16 ± 1.41^{a}	55.51 ±2.02^{e}
Kenta	5.95 ± 0.00^{b}	45.27 ± 1.90^{a}	33.76 ± 0.17^{cd}
Kentichi	8.70 ± 0.03^{h}	38.85 ± 0.69^{a}	67.04 ± 0.78^{f}
Lagou	9.26 ± 0.02^{i}	38.51 ± 0.46^{a}	17.32 ± 0.32^{ab}
Touzerzaillet	9.95 ± 0.02^{j}	42.31 ± 2.58^{a}	17.88 ± 0.41^{ab}
Tranja	8.40 ± 0.01^{g}	68.01 ± 8.22^{a}	21.14 ± 7.18^{abc}

Results are expressed as mean values of three determinations ± SD; DF = dietary fiber; means within the same column with different letters are significantly different ($p < 0.01$).

Table 6. Chemical composition of date fiber concentrates (g/100 g dry weight basis) from eleven studied cultivars.

Fiber concentrate	Dry matter (%)	Protein	Lipid	Ash	*Total dietary fiber
Alligh	96.25 ± 0.19^{bc}	3.68 ± 0.04^{a}	0.58 ± 0.01^{abc}	2.20 ± 0.05^{cd}	93.54 ± 0.10^{c}
Deglet Nour	95.45 ± 0.18^{ab}	5.21 ± 0.37^{def}	0.79 ± 0.08^{cde}	3.29 ± 0.04^{h}	90.71 ± 0.49^{a}
Bajo	96.92 ± 0.31^{c}	5.39 ± 0.09^{efg}	0.35 ± 0.06^{a}	2.53 ± 0.01^{f}	91.73 ± 0.16^{ab}
Boufeggous	96.98 ± 0.13^{c}	6.06 ± 0.23^{g}	0.67 ± 0.05^{bcd}	1.93 ± 0.01^{b}	91.34 ± 0.29^{ab}
Goundi	96.73 ± 0.12^{c}	4.73 ± 0.04^{cde}	0.96 ± 0.01^{de}	2.29 ± 0.06^{de}	92.02 ± 0.11^{b}
Ikhouat	96.59 ± 0.06^{c}	5.47 ± 0.05^{efg}	0.54 ± 0.08^{abc}	1.65 ± 0.03^{a}	92.34 ± 0.16^{b}
Kenta	95.36 ± 0.04^{ab}	5.52 ± 0.15^{efg}	0.48 ± 0.01^{ab}	1.97 ± 0.03^{b}	92.03 ± 0.19^{b}
Kentichi	96.57 ± 0.29^{c}	3.92 ± 0.04^{ab}	0.54 ± 0.04^{abc}	1.78 ± 0.01^{ab}	93.76 ± 0.09^{c}
Lagou	94.86 ± 0.19^{a}	4.44 ± 0.04^{abc}	1.08 ± 0.05^{e}	2.16 ± 0.03^{c}	92.32 ± 0.12^{b}
Touzerzaillet	96.69 ± 0.19^{c}	3.66 ± 0.04^{a}	0.54 ± 0.01^{abc}	1.88 ± 0.03^{b}	93.92 ± 0.08^{c}
Tranja	97.78 ± 0.09^{d}	5.97 ± 0.08^{g}	0.91 ± 0.05^{de}	1.68 ± 0.02^{a}	91.44 ± 0.15^{ab}

Results are expressed as mean values of three determinations ± SD; *Total dietary fiber = 100 - (protein + lipid + ash); Means within the same column with different letters are significantly different ($p < 0.01$).

(cell-wall) (O'Neill and Selvendran, 1985; Redgwell and Selvendran, 1986) and another fraction that is insoluble in hot water during extraction of DF.

Proximate composition of date fiber concentrates (DFC)

Table 6 shows the chemical composition of DFC (g per 100 g dry weight) from eleven varieties of date palm *P. dactylifera* L. Moisture content which ranged between 2.22 and 5.14 g/100 g for Tranja and Lagou varieties, respectively (Table 6). Statistically, the moisture content did not show significant differences ($P > 0.01$) between Bajo, Boufeggous, Goundi, Ikhouat, Kentichi and Touzerzaillet and between Deglet Nour and Kenta.

Protein content ranged from 3.66 g/100 g (dry matter basis) for Touzerzaillet to 6.06 g/100 g (dry matter basis) for Boufeggous. Statistical analysis did not show significant differences between Alligh and Touzerzaillet and between Bajo, Ikhouat and Kenta and between Boufeggous and Tranja.

Lipid content ranged between 0.35 g/100 g (dry matter basis) for Bajo and 1.08 g/100 g (dry matter basis) for Lagou. There were no significant differences between Alligh, Ikhouat, Kentichi and Touzerzaillet and between Goundi and Tranja.

Ash content of DFC remained between 1.65 g/100 g (dry matter basis) for Ikhouat and 3.29 g/100 g (dry matter basis) for Deglet Nour. Statistical analysis did not show significant differences ($P > 0.01$) between Boufeggous, Kenta and Touzerzaillet and between

Table 7. Mineral composition of date fiber concentrates (mg/100 g dry weight basis) from eleven studied cultivars.

Fiber concentrate	Potassium	Calcium	Sodium	Magnesium	Iron
Alligh	40.94 ± 0.01^{abc}	10.59 ± 0.45^{ab}	12.39 ± 1.65^{a}	122.59 ± 4.54^{ab}	6.69 ± 0.26^{a}
Deglet Nour	28.98 ± 6.75^{abc}	15.63 ± 2.52^{ab}	9.44 ± 1.22^{a}	138.32 ± 7.82^{abc}	11.27 ± 2.6^{ab}
Bajo	20.26 ± 1.76^{ab}	8.03 ± 0.30^{ab}	7.56 ± 0.54^{a}	161.24 ± 0.27^{c}	8.80 ± 0.14^{ab}
Boufeggous	13.52 ± 0.45^{a}	9.12 ± 0.47^{ab}	8.26 ± 0.03^{a}	131.55 ± 3.24^{abc}	9.03 ± 0.18^{ab}
Goundi	20.53 ± 0.10^{ab}	17.38 ± 0.59^{b}	7.63 ± 0.56^{a}	136.27 ± 0.30^{abc}	11.00 ± 1.18^{ab}
Ikhouat	34.44 ± 8.93^{abc}	6.80 ± 1.54^{a}	6.70 ± 0.74^{a}	103.49 ± 1.54^{a}	8.78 ± 0.18^{ab}
Kenta	30.96 ± 0.48^{abc}	10.64 ± 1.70^{ab}	7.57 ± 0.07^{a}	144.31 ± 0.95^{bc}	15.01 ± 0.07^{ab}
Kentichi	21.14 ± 8.7^{ab}	17.43 ± 3.45^{b}	6.43 ± 1.72^{a}	119.43 ± 17.27^{ab}	9.36 ± 0.92^{ab}
Lagou	32.44 ± 3.17^{abc}	11.18 ± 1.59^{ab}	6.63 ± 0.40^{a}	122.82 ± 0.96^{ab}	24.3 ± 7.84^{b}
Touzerzaillet	56.89 ± 4.91^{c}	7.36 ± 0.19^{a}	8.80 ± 0.64^{a}	99.67 ± 5.84^{a}	10.10 ± 0.04^{ab}
Tranja	34.11 ± 0.2^{abc}	8.88 ± 0.68^{ab}	8.78 ± 0.08^{a}	119.02 ± 3.26^{ab}	11.13 ± 0.14^{ab}

Results are expressed as mean values of three determinations ± SD; means within the same column with different letters are significantly different ($p < 0.01$).

Ikhouat and Tranja. These results suggested that DFC could be used as an ingredient in food products.

Total dietary fiber content of DFC ranged from 90.71 g/100 g (dry matter basis) for Deglet Nour to 93.92 g/100 g (dry matter basis) for Touzerzaillet. There were no significant differences ($P > 0.01$) between Deglet Nour, Bajo, Boufeggous, Goundi, Ikhouat, Kenta, Lagou and Tranja and between Alligh, Kentichi and Touzerzaillet.

DFC may be used in value-added product formulation. In fact, DFC will not be only appreciated for their nutritional properties but also for their functional and technological properties.

Mineral composition of date fiber concentrates (DFC)

Minerals were classified into two major groups: the macro-elements and the micro-elements (trace elements). The amounts of potassium and magnesium in DFC were high, while sodium, calcium and iron were low (Table 7). Magnesium (99.67 - 161.24 mg/100 g) was the most abundant element in DFC from the eleven varieties, followed by potassium, sodium, calcium and iron (Table 7). The biological roles of a number of trace elements have been reported. Iron is an essential element for both plants and animals (Valkovic, 1978). This element serves as prosthetic group of some enzymes (Emaga et al., 2007). The potassium content did not show significant differences ($P > 0.01$) between Alligh, Deglet Nour, Ikhouat, Kenta, Lagou and Tranja and between Bajo, Goundi and Kentichi. The calcium content did not show significant differences between Alligh, Deglet Nour, Bajo, Boufeggous, Kenta, Lagou and Tranja and between Goundi and Kentichi and between Ikhouat and Touzerzaillet. The sodium content did not show significant differences ($P > 0.01$) among varieties. The magnesium content did not show significant differences ($P > 0.01$) between Deglet Nour, Boufeggous and Goundi and between Alligh, Kentichi, Lagou and Tranja and between Ikhouat and Touzerzaillet. The iron content of DFC showed significant differences ($P < 0.01$) between Alligh and Lagou.

Water and oil holding capacities of date fiber concentrates (DFC)

As shown in Figure 2, water holding capacity (WHC) of DFC ranged between 3.97 and 6.20 g/g dry fiber; the highest values were found in Alligh varieties. The high WHC of Alligh fiber concentrate showed that this material could be used as a functional ingredient to avoid syneresis, modify texture and viscosity and reduce calories of food formulations (Lario et al., 2004).

The oil holding capacity (OHC) depended on surface properties, overall charge density, thickness and hydrophobic nature of the fiber particle (López et al., 1996; Femenia et al., 1997). The OHC ranged between 1.11 g oil/g dry fiber for Bajo and 1.80 g oil/g dry fiber for Alligh. The values of OHC obtained in this study were similar to those found for fibers from grape fruit, apple, orange and lemon (Figuerola et al., 2005). The OHC of DFC suggested that this material could be used as an ingredient to stabilize some food formulations with a high content of fat (Grigelmo-Miguel and Martin-Belloso, 1999).

Considering protein, fat, sugar and mineral of date flesh, it could be concluded that they could be used in value-added applications. This by-product of date processing industries could be regarded as an excellent source of food ingredients with interesting technological functionality such as dietary fiber.

In this preliminary study, an attempt was made to set up a simple process to extract DFC. Chemical composition of DFC showed high contents of total dietary fiber

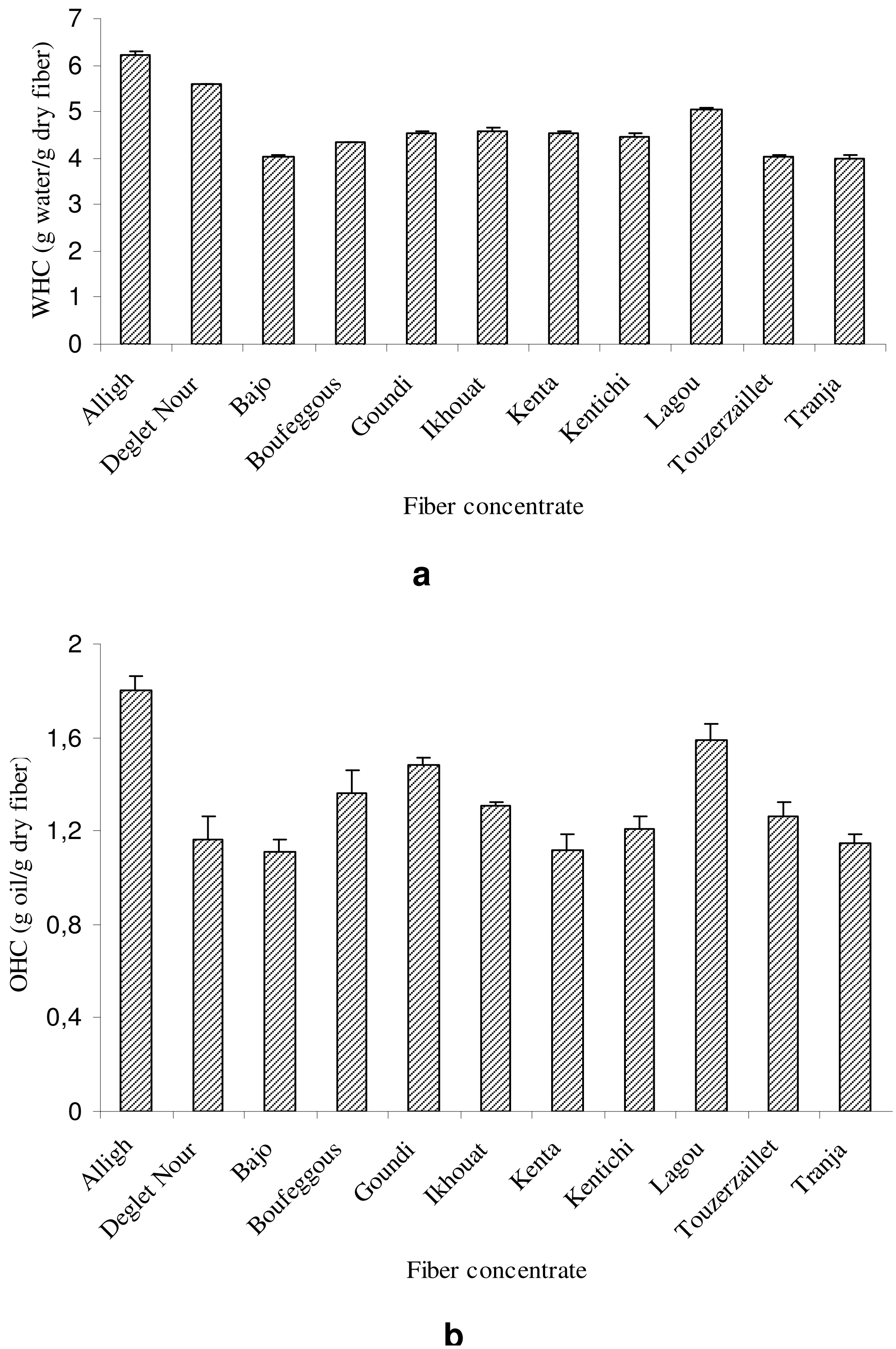

Figure 2. Water holding capacity (a) and oil holding capacity (b) of date fiber concentrates from eleven studied cultivars.

(between 90.71 and 93.92%). DFC showed a relatively high WHC and OHC. These results suggested that DFC could be used as an ingredient in food and dietetic formulations.

REFERENCES

Al-Farsi M, Alasalvar C, Al-Abid M, Al-Shoaily K, Al-Amry M, Al-Rawahy F (2007). Compositional and functional characteristics of dates, syrups, and their by-products. Food Chem. 104: 943-947.

AFNOR (1986). Norme AFNOR NF V 03-713- Céréales et produits céréaliers : Détermination de la teneur en matières grasses totales. AFNOR (eds), Paris. 39: 155.

Al-Hooti S, Jiuan S, Qabazard H (1995). Studies on the physico-chemical characteristics of date fruits of five UAE cultivars at different stages of maturity. Arab Gulf J. Sci. Res. 13: 553-569.

Al-Hooti S, Sidhu JS, Qabazard H (1998). Chemical composition of seeds date fruit cultivars of United Arab Emirates. J. Food Sci. Technol. 35: 44-46.

Al-Hooti SN, Sidhu JS, Al-Saqer JM, Al-Othman A (2002). Chemical composition and quality of date syrup as affected by pectinase/cellulase enzyme treatment. Food Chem. 79: 215-220.

Al-Shahib W, Marshall RJ (2002). Dietary fibre content of dates from 13 varieties of date palm *Phoenix dactylifera* L. Int. J. Food Sci. Technol. 37: 719-721.

AOAC (1990). Official Method of Analysis. AOAC Int., Washington, DC: Association of Official Analytical Chemists.

Besbes S, Blecker C, Deroanne C, Drira NE, Attia H (2004). Date seeds: chemical composition and characteristic profiles of the lipid fraction. Food chem. 84: 577-584.

Besbes S, Drira L, Blecker C, Deroanne C, Attia H (2009). Adding value to hard date (*Phoenix dactylifera* L.): Compositional, functional and sensory characteristics of date jam. Food Chem. 112: 406-411.

Devshony S, Ete Shola A, Shani A (1992). Characterisation and some potential application of date palm (*Phoenix dactylifera* L.) seeds and seeds oil. J. Am. Oil Chem. Soc. 69: 595-597.

Dubois M, Giles KA, Hamilton FK, Rebers PA, Smith F (1956). Colorimetric method for determination of sugars and related substances. Anal. Chem. 28: 350-356.

Elleuch M, Besbes S, Roiseux O, Blecker C, Deroanne C, Attia H (2008). Date flesh: Chemical composition and characteristics of the dietary fibre. Food Chem. 111: 676-682.

El-Shurafa MY, Ahmed HS, Abou-Naji SE (1982). Organic and inorganic constituent of dates palm pit (seeds). J. Date Palm, 2: 275-284.

Emaga TH, Andrianaivo RH, Wathelet B, Tchango JT, Paquot M (2007). Effects of the stage of maturation and varieties on the chemical composition of banana and plantain peels. Food Chem. 103: 590-600.

Englyst HN, Quigley ME, Hudson GJ, Cummings JH (1992). Determination of dietary fibre as non-starch polysaccharides by gas-liquid chromatography. Anal. 117: 1707-1714.

FAOSTAT (2006). All databases. Agricultural data. Agricultural production indices

Home page. ‹ http://www.faostat.fao.org ›.

Femenia A, Lefebvre C, Thebaudin Y, Robertson J, Bourgeois C (1997). Physical and sensory properties of model foods supplemented with cauliflower fiber. J. Food Sci. 62: 635-639.

Figuerola F, Hurtado ML, Estévez AM, Chiffelle I, Asenjo F (2005). Fibre concentrates from apple pomace and citrus peel as potential fibre sources for food enrichment. Food Chem. 91: 395-401.

Grigelmo-Miguel N, Gorinstein S, Martin-Belloso O (1999). Characterisation of peach dietary fibre concentrate as a food ingredient. Food chem. 65: 175-181.

Grigelmo-Miguel N, Martin-Belloso O (1999). Characterisation of dietary fiber from orange juice extraction. Food Res. Int. 31: 355-361.

Lario Y, Sendra E, García-Pérez J, Fuentes C, Sayas-Barberá E, Fernández-López J, Pérez-Alvarez JA (2004). Preparation of high dietary fiber powder from lemon juice by-products. Innov. Food Sci. Emerg. Technol. 5: 113-117. Lin MJY, Humbert ES, Sousulki FW (1974). Certain functional properties of sunflower meal product. J. Food Sci. 39: 368-370.

López G, Ros G, Rincón F, Periago MJ, Martínez MC, Ortuño J (1996). Relationship between physical and hydratation properties of soluble and insoluble fiber of artichoke. J. Agr. Food Chem. 44: 2773-2778.

Mac Connell AA, Eastwood A, Mitchell WD (1974). Physical characterization of vegetable foodstuffs that could influence bowel function. J. Sci. Food Agr. 25: 1457-1464.

Marlett JA, Hosig KB, Vollendorf NW, Shinnick FL, Haack VS, Story JA (1994). Mechanism of serum cholesterol reduction by oat bran. Hepatology, 20: 1450-1457.

O'Neill MA, Selvendran RR (1985). Hemicellulosic complexes from the cell walls of runner beans (*Phaseolus coccineus*). Biochem. J. 227: 475-481.

Redgwell R, Selvendran RR (1986). Structural features of cell-wall polysaccharides of onion (*Allium cepa*). Carbohyd. Res. 157: 183-199.

Sablani SS, Kasapis S, Rahman MS (2005). Evaluating water activity and glass transition concepts for food stability. J. Food Eng. 78: 266-271.

Valkovic V (1978). Trace elements in petroleum. Tulsa, ok: Petroleum publishing Co, pp: 25-32.