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# Date flesh: Chemical composition and characteristics of the dietary fibre

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ABSTRACT

The date by-products of two date palm (*Phoenix dactylifera* L.) cultivars, Deglet-Nour and Allig, from the Degach region (Tunisia), were analysed for their main chemical composition. Studies were also conducted on the physicochemical properties (colour, water and oil-holding capacity and rheological behaviour) of dietary fibre (DF) extracted from date flesh. The following values (on a dry matter basis: DM) were obtained for fleshes of Deglet-Nour and Allig cultivars, respectively: sucrose 52.7% and 13.9%, glucose 13.7% and 29.9%, fructose 12.6% and 29.0%, total dietary fibre 14.4% and 18.4%, protein 2.1% and 3%, ash 2.5% and 2.52%. Insoluble DF, the major fraction of total DF, constituted 9.19–11.7% DM for Deglet-Nour and Allig, respectively. The elaboration of DF concentrates from date fleshes was characterised by an extraction yield of 67%. The chemical composition of these DF concentrates showed high total DF contents (between 88% and 92.4% DM) and low protein and ash contents (8.98–9.12% and 2.0–2.1% DM, respectively). The DF concentrates showed a high water-holding capacity (~15.5 g water/g sample) and oil-holding capacity (~9.7 g oil/g sample) and pseudoplasticity behaviour of their suspensions. Thus, date DF concentrates may not only be an excellent source of DF but an ingredient for the food industry.


## 1. Introduction

The date (*Phoenix dactylifera* L.) has been an important crop in arid and semiarid regions of the world. It has always played an important role in the economic and social lives of the people of these regions. The fruit is composed of a seed and fleshy pericarp which constitutes between 85% and 90% of date fruit weight (Hussein, Alhadrami, & Khalil, 1998). In Tunisia, the mean annual yield of date fruits is about 100,000 tonnes (Besbes, Blecker, Deroanne, Drira, & Attia, 2004). A great deal of dates (30,000 tonnes/year) is, however, lost during the sorting, the storage and the conditioning (Cheikh-Rouhou et al., 2006). This by-product is generally discarded, or used in animal feeding. The non-use of this by-product for human food constitutes a real economic loss since it is rich in bioactive compounds which can be extracted and used as value-added materials. Studies of new product development from date flesh are limited. The literature makes mention of certain technological transformations, e.g. the production of jams, frosts, juice and syrup of dates (Al-hooti, Sidhu, Al-otaibi, Al-ameeri, & Qabazard, 1996; Cheikh-Rouhou et al., 2006; Hobani 1998; Khatchadourian, Sawaya, Khalil, & Mashadi, 1983; Youssif, Abou Ali, & Bou Idreese, 1990; Youssif & Alghamdi, 1999; Youssif, Alghamdi, Hamad, & Mustafa, 1996). Fermentations have also been tried. They mainly aim at the production of biomass from the dates (Al obaidi & Berry 1982; Nacib et al., 1999) or the production of various metabolites, e.g. citric acid, oxytetracycline or ethanol (Abou zied, Abderrahman, & Baghlef, 1991; Abou zied & Baghlef, 1983; Abou zied & Khoja, 1993; Al obaidi & Berry 1982). Studies aiming at the extraction and characterisation of the different fractions of date are limited to oil, polyphenol and dietary fibre from date seeds (Al-Farsi & Lee, 2008; Besbes et al., 2005).

The chemical composition of the date shows that the flesh is an important source of sugar (~81–88%, mainly fructose, glucose and sucrose), dietary fibre (~5–8.5%) and small amounts of protein, fat, ash and polyphenol (Al-Farsi et al., 2007; Al-hooti, Jiuan, & Quabazard, 1995; Al-Shahib & Marshall 2002). Thus, dates provide a good source of rapid energy (sugars) and a good nutritional value, based on their dietary fibre (DF) contents. DF has important therapeutic implications (e.g. for diabetes, obesity) and exhibits a protective effect (Goni, Valdivieso, & Garcia-Alonso, 2000; Guillon & Champ, 2000; Hill, 1998; Roehrig, 1988). DF also shows some functional properties in the food industry, e.g. water-holding, oil-holding, emulsifying and/or gel formation. Indeed, DF can be incorporated in food products (dairy, soup, meat, bakery products and jam) to modify textural properties, avoid syneresis and stabilise high fat food and emulsions (Abdul-Hamid & Siew Luan, 2000; Mansour & Khalid, 1997; Montesinos-Herrero, Cottell, O'Riordan, & O'Sullivan, 2006; Paraskevopoulou, Boskou, & Kiosseoglou, 2005; Ramaswamy & Basak, 1992; Wang, Rosell, & Barber, 2002).

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The aim of this study is to determine the chemical composition of two important date cultivars grown in Tunisia (Deglet-Nour and Allig) and to extract the DF from the flesh, characterised by physical and chemical properties.

## 2. Materials and methods

### 2.1. Samples

Two varieties of date by-products, namely Deglet-Nour and Allig, collected at the "Tamr stage" (full ripeness) were procured from Déguech region (Tunisia). After removing the seeds, the date fleshes were rinsed with water, dried for 24 h at 40 °C, milled and preserved at −20 °C prior to analysis and extraction.

### 2.2. Dietary fibre extraction

Fig. 1 shows the extraction process from date flesh to produce DF concentrates. Hot water was used to extract DF from milled flesh (100 °C for 5 min). After solubilisation of the sugars (sucrose, glucose and fructose), DFs were recuperate by centrifugation (6500*g*, 10 min). The concentration of fibre was realised by a succession of five rinsings (water at 40 °C) and of five centrifugations until the residue was free of sugars. The residues obtained were freeze-dried to give the DF concentrates then stored at 3 °C for subsequent physicochemical analyses.

### 2.3. Methods

#### 2.3.1. Dry matter

This was determined by oven-drying at 105 °C to constant weight (AOAC, 1990).

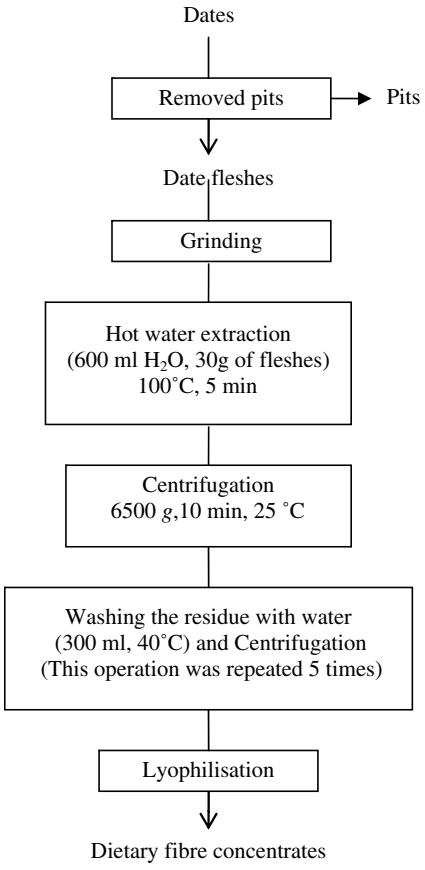


**Fig. 1.** Process of elaboration of date dietary fibre concentrates.

#### 2.3.2. Protein

Total nitrogen was determined by the Kjeldahl method, as described by Pearson (1970). Protein was calculated using the general factor (6.25).

#### 2.3.3. Ash and mineral content

Ash was determined by combustion of the sample in a muffle furnace at 550 °C for 8 h. The residue was dissolved in $HNO_3$ with 50 g/l of $LaCl_3$ (Larrauri, Rupérez, Borroto, & Saura-Calixto, 1996) and the mineral constituents (Ca, Mg, Na and K) were analysed separately, using an atomic absorption spectrophotometer (Hitachi Z6100, Tokyo, Japan). Phosphorus content (P) was determined by the phosphomolybdate method (AOAC, 1990).

#### 2.3.4. Sugars

Sugars were extracted with aqueous ethanol (800 ml/l) by shaking at 50 °C for 30 min (Bouabidi, Reyens, & Roussi, 1996). After centrifugation, the supernatant was collected and concentrated using a rotary evaporator at 40 °C. The sugar contents (sucrose, glucose and fructose) were determined, by HPLC, according to the method described by Bouabidi et al. (1996). After centrifugation (8000*g* for 5 min) and filtration using a millipore system (0.45 μm), 20 μl of the extract were injected onto the ionic column (polypore CA. 250 mm, thickness 4.6 mm). The temperature and the flow rate of the elution phase were maintained at 80 °C and 0.3 ml/min, respectively. The detection was done by a differential refractometer (Shimadzu.RID-10A). Sugars (sucrose, glucose and fructose) were identified by comparison of their retention times with a standard. They were quantified according to their percentage area, obtained by integration of the peaks.

#### 2.3.5. Dietary fibre

Insoluble and soluble dietary fibres (DF) were determined according to the AOAC enzymatic-gravimetric method of Prosky, Asp, Schweizer, De Vries, and Furda (1988). Briefly, the defatted samples were gelatinized with heat-stable alpha amylase (A-3306, Sigma Chemical Co., St. Louis, MO, USA) (100 °C, pH 6, 15 min) and then enzymatically digested with protease (P-5380, Sigma Chemical Co., St. Louis, MO) (60 °C, pH 7.5, 30 min), followed by incubation with amyloglucosidase (A-9268, Sigma Chemical Co., Poole, Dorset, UK) (60 °C, pH 4.5, 30 min) to remove protein and starch. Then, the samples were filtered, washed (with water, 95% ethanol and acetone), dried and weighed to determine insoluble fibre. Four volumes of 95% ethanol (preheated to 60 °C) were added to the filtrate and to the water washings. Then, the precipitates were filtered and washed with 78% ethanol, 95% ethanol and acetone. After that, the residues (soluble DF) were dried and weighed. The obtained values were corrected for ash and protein. Total DF was determined by summing insoluble DF and soluble DF.

#### 2.3.6. Non-starch polysaccharides (NSP) and Klason lignin

Total, insoluble and soluble non-starch polysaccharides (NSP) were determined according to the enzymatic-chemical method described by Englyst, Quigley, Hudson, and Cummings (1992). Two portions, A and B, of each defatted sample are required to obtain separate values for total, insoluble and soluble NSP. After enzymatic treatment with termamyl (Novo Industri, Copenhagen, Denmark), pancreatin (Paines and Bryne, Greenford, Middlesex) and pullulanase (Novo Nordisk, Farnham, Surrey, UK), portion A was treated with ethanol and acetone (precipitation and washing) for measurement of total NSP and portion B was treated with water, ethanol and acetone (extraction and washing) for measurement of insoluble NSP. Then, the total and insoluble (NSP) residues obtained were hydrolysed with sulphuric acid (12 M, 1 h, 35 °C) and then with 2 M sulphuric acid (100 °C, 1 h). Neutral sugars were identified and quantified by CPG after reduction and acetylation of

the sugars according to the method described by Englyst et al. (1992). Uronic acids (UA) were determined spectrometrically at 520 nm with galacturonic acid as a standard and 3,5-dimethylphenol as reagent (Englyst et al., 1992).

The residual material from insoluble NSP, recovered by filtration (sinter No 2), was washed with hot water (90 °C) until it was free of acid, then dried at 105 °C overnight and quantified as Klason lignin (KL).

### 2.3.7. Colour

The CIE Lab co-ordinates ($L^*$,$a^*$,$b^*$) were directly read in a glass cuvette with spectrophotocolorimeter Mini Scan XETM (HunterLab Inc., Reston, VA, USA). In this coordinate system, the $L^*$ value is a measure of lightness, ranging from 0 (black) to 100 (white); the $a^*$ value ranges from −100 (greenness) to +100 (redness) and the $b^*$ value ranges from −100 (blueness) to +100 (yellowness).

### 2.3.8. Rheological behaviour

The DF concentrates were reformulated with water at various concentrations (20, 30, 40 and 50 g/l) and homogenized with a mixer (Ultra-Turrax T25) at a speed of 8000 rpm during 2 min. The rheological behaviour of date DF suspensions was determined at 25 °C with a rheometer Stress Tech Reologica (Reologica Instruments AB, Lund, Suède) and using the system with coaxial measurement cylinders (25 mm/27 mm). The rotor speeds were in the range 10–1200 $s^{-1}$. To determine the rheological behaviour, the Herschel and Buckley model was used ($\tau = \tau_s + k\dot{\gamma}^n$).

### 2.3.9. Water-holding capacity

Water-holding capacity (WHC) was determined using the method described by MacConnell, Eastwood, and Mitchell (1974). Hundred milligrams of DF concentrates were added to 10 ml of distilled water in a 50 ml centrifuge tube and stirred overnight at 4 °C. Then the mixture was centrifuged at 14,000*g* for 20 min. The free water was decanted and absorbed water was then determined.

### 2.3.10. Oil-holding capacity

Oil-holding capacity (OHC) was measured using a method described by Caprez, Arrigoni, Amado, and Zeukom (1986). Hundred milligrams of DF concentrates were added to 10 ml of corn oil in a 50 ml centrifuge tube. The content was stirred then the tubes were centrifuged at 1500*g* for 30 min. The free oil was decanted and absorbed oil was determined.

## 3. Resultants and discussion

### 3.1. Chemical composition of date flesh

Table 1 presents the average compositions of date fleshes of the two studied cultivars. The date fleshes were characterised by the predominance of sugar. This mainly consisted of sucrose, fructose and glucose (Table 1). In the Deglet-Nour variety, sucrose is dominant, whereas the Allig variety is rich in fructose and in glucose in comparable proportions. This difference in sugar composition suggests the presence of relatively important invertase activity in the Allig variety, which would considerably reduce its content in sucrose (Fayadh & Al-showiman, 1990). The sugar contents are lower than in those commercial quality dates collected at the "Tamr stage" (full ripeness). In fact, Al-hooti, Jiuan, and Quabazard (1995) reported that sugars ranged between 81.6% and 88.4%. The sugar loss in the date by-products can be explained by non-enzymatic browning during storage (Maillard reaction) (Rinderknecht, 1959) and the rinsing operation of the date fleshes (Section 2.1). In fact, the dates contain the required reactants, sugars and amine groups, as found in protein molecules, to favour Maillard reaction during storage (Rinderknecht, 1959).

**Table 1**
Chemical compositions of date fleshes

| Component | Deglet-Nour | Allig |
|---|---|---|
| Dry matter (%) | 75.6 ± 0.05 | 73.1 ± 0.80 |
| *Sugars*[a] | 79.1 ± 0.80 | 72.8 ± 0.27 |
| Sucrose[a] | 52.7 ± 0.15 | 13.9 ± 0.13 |
| Glucose[a] | 13.7 ± 0.50 | 29.9 ± 0.20 |
| Fructose[a] | 12.6 ± 0.20 | 29.0 ± 0.48 |
| *Total dietary fibres*[a] | 14.4 ± 1.12 | 18.4 ± 0.45 |
| Insoluble dietary fibres[a] | 9.19 ± 0.93 | 11.7 ± 0.22 |
| Soluble dietary fibres[a] | 5.16 ± 0.24 | 6.68 ± 0.23 |
| *Ash*[a] | 2.50 ± 0.04 | 2.52 ± 0.01 |
| Potassium[b] | 863 ± 0.88 | 823 ± 13.10 |
| Phosphorus[b] | 101 ± 0.54 | 104 ± 0.24 |
| Magnesium[b] | 41.6 ± 0.29 | 44.1 ± 0.97 |
| Calcium[b] | 47.7 ± 0.22 | 63.0 ± 1.00 |
| Sodium[b] | 10.2 ± 0.33 | 10.1 ± 1.6 |
| Iron[b] | 2.50 ± 0.10 | 2.0 ± 0.21 |
| *Protein*[a] | 2.10 ± 0.10 | 3.02 ± 0.13 |

All the given values are means of three determinations ± standard deviation.
[a] In % dry matter.
[b] In mg/100 g dry matter.

The two studied varieties present low percentages of ash and proteins. The mineral composition shows that potassium was the predominant mineral, followed in descending order by phosphorus, magnesium, sodium and iron.

Regarding DF, date fleshes from the Allig cultivar contained higher amounts than did those of the Deglet-Nour (18.4% against 14.4%). Insoluble DF was the major fraction, ranging between 9.19% and 11.7%. These total DF contents are significantly higher than those of commercial quality dates collected at the "Tamr stage" (full ripeness). In fact, Al-hooti et al. (1995), Al-Shahib and Marshall (2002) and Al-farsi et al. (2007) reported lower amounts, ranging between 2% and 12.7%. Compared to other fruits (apple, orange, peach and grapes) which have DF contents ranging between 5.1% and 15% (Camire & Dougherty, 2003; Englyst & Hudson, 1996), date by-products could be considered as a good source of DF. Soluble DF contents in dates are relatively high compared to cereals and cereal derivatives which have a low soluble DF (0.4–4%) (Abdul-Hamid & Luan, 2000; Prosky et al., 1988).

The composition and amounts of sugars of the total, soluble and insoluble non-starch polysaccharides (NSP) of date fleshes are shown in Table 2. Neutral sugars, principally formed by cellulose and hemicelluloses, and uronic acids from pectic substances (Grigelmo-Miguel, Gorinstein & Martina-Belloso, 1999) were present in both the soluble and insoluble NSP. The two varieties had similar contents of total NSP (5.71–5.85%). They are constituted essentially of uronic acids (∼2%), glucose (∼2%), xylose (∼0.7%) and low amounts of galactose (∼0.35%), arabinose (∼0.32%) and rhamnose (∼0.075%). Insoluble NSP are essentially constituted of neutral sugars with high levels of glucose (∼1.5%) and xylose (∼0.68%) and a low content of uronic acids (between 0.14% and 0.21%). Soluble NSP consisted mainly of uronic acids. The Allig variety had a higher klason lignin content than had Deglet-Nour (2.90% against 2.07%).

According to Prosky et al. (1988), the NSP, lignin and resistant starch in the DF are determined by the AOAC method, whereas the Englyst method includes only NSP (Englyst, 1992). Table 2 shows that the enzymatic-chemical method described by Englyst et al. (1992) with the method for determination of Klason lignin (§ 2.3.6) gives DF values that are 1.85–2.11 times lower than those obtained with the AOAC method described by Prosky et al. (1988). The discrepancy, however, seems too large to be explained by the amounts of resistant starch only (Wolters, Verbeek, & Van Westerop, 1992). According to Wolters et al. (1992), this difference can

**Table 2**
Total, soluble and insoluble non-starch polysaccharides and Klason lignin in date flesh DF (% DM)

| | Total fraction | | Insoluble fraction | | Soluble fraction | |
|---|---|---|---|---|---|---|
| | Deglet-Nour | Allig | Deglet-Nour | Allig | Deglet-Nour | Allig |
| Rhamnose | 0.060 ± 0.001 | 0.070 ± 0.005 | 0.030 ± 0.0005 | 0.050 ± 0.002 | 0.030 ± 0005 | 0.020 ± 0.003 |
| Arabinose | 0.300 ± 0.010 | 0.350 ± 0.026 | 0.210 ± 0.030 | 0.300 ± 0.007 | 0.120 ± 0.003 | 0.045 ± 0.030 |
| Xylose | 0.760 ± 0.030 | 0.700 ± 0.012 | 0.680 ± 0.013 | 0.680 ± 0.005 | 0.080 ± 0.010 | 0.020 ± 0.005 |
| Mannose | 0.150 ± 0.001 | 0.170 ± 0.005 | 0.087 ± 0.004 | 0.120 ± 0.001 | 0.060 ± 0.004 | 0.050 ± 0.004 |
| Glucose | 2.00 ± 0.030 | 2.05 ± 0.080 | 1.57 ± 0.140 | 1.59 ± 0.040 | 0.410 ± 0.140 | 0.460 ± 0.040 |
| Galactose | 0.320 ± 0.001 | 0.390 ± 0.020 | 0.180 ± 0.004 | 0.270 ± 0.001 | 0.130 ± 0.004 | 0.12 ± 0.02 |
| Neutral sugars | 3.63 ± 0.030 | 3.75 ± 0.020 | 2.77 ± 0.140 | 3.02 ± 0.043 | 0.840 ± 0.140 | 0.730 ± 0.100 |
| Uronic acids | 2.04 ± 0.100 | 2.10 ± 0.090 | 0.210 ± 0.007 | 0.140 ± 0.010 | 1.80 ± 0.120 | 1.95 ± 0.080 |
| Polysaccharides[a] | 5.71 ± 0.200 | 5.85 ± 0.25 | 2.99 ± 0.200 | 3.16 ± 0.05 | 2.68 ± 0.300 | 2.68 ± 0.200 |
| Klason lignin | 2.07 ± 0.07 | 2.90 ± 0.10 | 2.07 ± 0.07 | 2.90 ± 0.10 | 0 | 0 |
| Total[b] | 7.75 ± 0.3 | 8.7 ± 0.3 | 5.06 ± 0.3 | 5.5 ± 0.1 | 2.68 ± 0.300 | 2.68 ± 0.200 |

All the given values are means of three determinations ± standard deviation.
DF: Dietary fibre.
[a] Neutral sugars + uronic acids.
[b] Polysaccharides + Klason lignin.

be explained by either overestimation of the amount of DF in the AOAC method (coprecipitation of oligosaccharides and Maillard reaction products) or underestimation of the amount of dietary fibre in the enzymatic-chemical method (loss of polysaccharides during hydrolysis or derivatization), or both.

Chemical composition of date flesh revealed that these by-products could be valuable. In order to justify the extraction of date flesh DF, it is necessary to study its functional properties.

### 3.2. Physical and chemical analysis of DF concentrates

#### 3.2.1. Chemical composition

Tables 3 and 4 present the composition and yields of the DF concentrates obtained, as indicated in Fig. 1. The DF concentrates show high DF contents ranging between 88% and 92% for Deglet-Nour and Allig, respectively.

**Table 3**
Chemical composition of Deglet-Nour and Allig DF concentrates (% DM)

| | Deglet-Nour | Allig |
|---|---|---|
| Total DF | 88.0 ± 1.56 | 92.4 ± 2.73 |
| Insoluble DF | 81.3 ± 0.85 | 84.7 ± 2.04 |
| Soluble DF | 6.70 ± 1.35 | 7. 69 ± 0.68 |
| Protein | 9.12 ± 0.45 | 8.98 ± 0.08 |
| Ash | 2.03 ± 0.03 | 2.1 ± 0.02 |
| Sugar (sucrose, glucose and fructose) | 0 | 0 |

All the given values are means of three determinations ± standard deviation.
DF: dietary fibre.

**Table 4**
Evaluation of different types of extract yields

| Yields (%) | Deglet-Nour | Allig |
|---|---|---|
| Dry matter | 11 ± 044 | 13.3 ± 0.34 |
| Total DF | 67.5 ± 1.59 | 67 ± 2.1 |
| Insoluble DF | 97.5 ± 5.25 | 96.1 ± 2.03 |
| Soluble DF | 14.3 ± 1.95 | 15.3 ± 0.4 |
| Total NSP | 63 ± 0.57 | 76 ± 1.1 |
| Insoluble NSP | 100 ± 1.8 | 95.6 ± 4 |
| Soluble NSP | 27.1 ± 1.44 | 35.5 ± 2.34 |
| Protein | 40.0 ± 3.48 | 38.3 ± 0.98 |

All the given values are means of three determinations ± standard deviation.
DF: dietary fibre.
NSP: non-starch polysaccharides.

These DF contents are close to levels measured for DF preparations from apple (Liberty cultivars) (89.8%), but notably higher than those of other fruit DF concentrates reported for grapefruit, lemon, orange, apple and mango (28–78.2%) (Figuerola, Hurtado, Estévez, Chiffelle, & Asenjo, 2005; Vergara-Valencia et al., 2007), grape skins (54.1–64.6%) (Bravo & Saura-Calixto, 1998; Saura-Calixto, 1998), citrus peel (57%) (Chau & Huang, 2003), or fibre from lime peels (66.7% and 70.4%) (Ubando, Navarro, & Valdivia, 2005) and mango peel (~71%) (Larrauri et al., 1996).

The extraction yield of total DF is 67% (DM). Thus, about 33% of DF was not recovered by the extraction method used. The extraction yield of soluble DF (~15%) confirms that the losses are essentially localized in the soluble fraction. Losses at the level of insoluble DF are indeed very minimal, since the yields are above 96%.

Date DF concentrates contain high proportions of insoluble DF (81.3–84.7%), similar to those reported in apple DF concentrates (Liberty cultivars) (81.6%) (Vergara-Valencia et al., 2007).

The DF concentrates were free of soluble sugars, showing the effect of the washing and yielding a final product with a low caloric value. Thus, 100% of the initially soluble sugars present in date fleshes were removed.

Despite application of the thermal treatment (100 °C, 5 min) and the use of water to extract DF, a soluble DF fraction (~7%) remains in the DF concentrates. This result suggests that these DF are intimately bound to the cell-wall.

The DF concentrates of the Allig variety show a dry matter yield higher than that of the Deglet-Nour variety (13.3% against 11%). This can be explained by the fact that the Allig variety has higher insoluble DF amounts than has the Deglet-Nour variety (Table 1).

The DF concentrates have relatively high contents of proteins (9%), with similar values to those reported by Grigelmo-Miguel and Martin-Belloso (1999) (8.1–10.1%) for orange DF concentrates. The extracted yields of protein were about 39%. This can be explained by the presence of a portion of protein that binds strongly to DF components (cell wall) (O'Neill & Selvendran, 1985; Redgwell & Selvendran, 1986) and another portion that is insoluble in water (initially insoluble and/or denatured (becomes insoluble) by hot water during extraction of DF).

The date DF concentrates have a low percentage of ash compared to the other fruit DF concentrates reported for grapefruit, lemon, orange and mango (2.71–3.91%) (Figuerola, Hurtado, Estévez, Chiffelle, & Asenjo, 2005).

The composition and the amounts of sugars of the total, soluble and insoluble NSP and Klason lignin of DF concentrates are shown in Table 5. The DF concentrates show high NSP contents (~31.5%)

**Table 5**
Total, soluble and insoluble non-starch polysaccharide and Klason lignin in date DF concentrates (% DM)

| | Total fraction | | Insoluble fraction | | Soluble fraction | |
|---|---|---|---|---|---|---|
| | Deglet-Nour | Allig | Deglet-Nour | Allig | Deglet-Nour | Allig |
| Rhamnose | 0.4 ± 0.14 | 0.4 ± 0.04 | 0.3 ± 0.1 | 0.24 ± 0.07 | 0.11 ± 0.02 | 0.14 ± 0.04 |
| Arabinose | 3.4 ± 0.15 | 3.6 ± 0.7 | 3.14 ± 0.2 | 2.5 ± 0.16 | 0.4 ± 0.11 | 1.1 ± 0.8 |
| Xylose | 10 ± 1.22 | 9.8 ± 0.5 | 9.17 ± 1.4 | 8.7 ± 0.2 | 0.88 ± 0.11 | 1.1 ± 0.4 |
| Mannose | 1.03 ± 0.07 | 1.12 ± 0.1 | 0.9 ± 0.12 | 1.0 ± 0.1 | 0.9 ± 0.12 | 0.14 ± 0.05 |
| Glucose | 11.3 ± 0.46 | 10.4 ± 1.6 | 9.4 ± 0.7 | 8.8 ± 1.05 | 9.4 ± 0.7 | 1.6 ± 0.08 |
| Galactose | 1.84 ± 0.06 | 2.0 ± 0.2 | 1.6 ± 0.33 | 1.32 ± 0.08 | 1.6 ± 0.33 | 0.69 ± 0.15 |
| Neutral sugars | 28 ± 2.2 | 27.5 ± 1.76 | 24.6 ± 1.23 | 22.6 ± 1.3 | 24.6 ± 1.23 | 4.82 ± 0.36 |
| Uronic acids | 4.17 ± 0.06 | 4.18 ± 0.04 | 1.4 ± 0.002 | 1.7 ± 0.02 | 1.4 ± 0.002 | 2.60 ± 0.02 |
| Polysaccharides[a] | 32.2 ± 2.27 | 31.7 ± 4.55 | 26.0 ± 1.75 | 24.2 ± 1.9 | 6.62 ± 0.8 | 7.42 ± 0.54 |
| Klason lignin | 8.00 ± 0.90 | 13.1 ± 0.03 | 8.00 ± 0.90 | 13.1 ± 0.03 | 0 | 0 |
| Total[b] | 40.2 ± 2.50 | 44.3 ± 4.50 | 33.9 ± 3.17 | 37.4 ± 1.90 | 6.62 ± 0.8 | 7.42 ± 0.54 |

All the given values are means of three determinations ± standard deviation.
DF: dietary fibre.
[a] Neutral sugars + uronic acids.
[b] Polysaccharides + Klason lignin.

**Table 6**
The CIE Lab values ($L^*$,$a^*$,$b^*$) of date flesh pastes and date DF concentrates

| Parameter | Pastes (Deglet) | DF concentrates (Deglet-Nour) | Pastes (Allig) | DF concentrates (Allig) |
|---|---|---|---|---|
| $L^*$ | 31.71 ± 0.57 | 65.25 ± 0.17 | 22.89 ± 0.45 | 61.92 ± 0.04 |
| $a^*$ | 14.68 ± 0.23 | 5.65 ± 0.06 | 11.48 ± 0.56 | 7.11 ± 0.03 |
| $b^*$ | 22.34 ± 0.12 | 16.28 ± 0.05 | 10.42 ± 0.22 | 14.85 ± 0.03 |

All the given values are means of three determinations ± standard deviation.

with different extractions yields of 63% and 76% for Deglet-Nour and Allig, respectively. Insoluble NSP was essentially constituted of neutral sugars with high levels of glucose (8.8–9.4%) and xylose (8.7–9.17%) and a low content of uronic acids. The soluble NSP had low percentages of different neutral sugars and uronic acids.

### 3.2.2. Physical analyse of DF concentrates

*3.2.2.1. Colour.* Table 6 presents the CIE Lab values ($L^*$,$a^*$,$b^*$) of date flesh pastes and DF concentrates. Regarding the raw materials, the two varieties show significant differences in the colour. Indeed, Deglet-Nour is characterised by higher $L^*$, $a^*$ and $b^*$ than is Allig. These numbers suggest that Deglet-Nour is lighter, more yellow and redder than is Allig. Al-hooti, Sidhu, and Qabazard (1996) studied other varieties from the United Arab Emirates (Bushibal, Gash, Gaafar, Gash Habash, Lulu and Shahla varieties) and reported that the values of $L^*$ ranged between 17.47 and 23.05, indicating that Deglet-Nour was the most light. The values of $a^*$ and $b^*$ reported by these authors are, nevertheless, significantly lower than those of Deglet-Nour and Allig. These differences can be explained by the variability of cultivars and mainly by a very hot climate, characterising countries of the Gulf and, therefore, a more intense browning (Maillard reactions).

The date DF concentrates (Table 6), showed comparable colours, although the corresponding raw materials had different hues. Indeed, $L^*$ passes from 31.74 (flesh pastes) to 65.25 (DF concentrate) and from 22.89 (flesh pastes) to 61.92 (DF concentrates) for Deglet-Nour and Allig varieties, respectively, indicating that DF concentrates become relatively lighter. This could be due, on the one hand, to the wash operations during the extraction and concentration of DF and, on the other hand, to the solubility of pigments responsible for the dark units of colour. As shown in Table 6, DF concentrates are coloured; consequently, the use of this material could affect the colour of the final product.

*3.2.2.2. Rheological measurements.* Fig. 2 shows that the DF concentrates, reconstituted with water at different concentrations (between 20 and 50 g/l) present a non-Newtonian behaviour, which is more marked when the concentration of DF is raised (Fig. 2). The experimental results shows that the rheological behaviour of DF concentrate suspensions (20–50 g/l) is pseudoplastic and is fitted by the power-law model whose the rheological equation is the one described by Herschel and Buckley ($\tau = \tau_s + k\dot{\gamma}^n$). This flow behaviour was also observed in peach DF concentrates (Grigelmo-Miguel, Ibarz-Ribas, & Martin-Belloso, 1999) and fruit juice concentrates (Hobani, 1998; Vitali & Rao, 1984). The degree of the pseudoplastic behaviour can be measured by the flow behaviour index ($n$). All the date DF suspensions exhibit pseudoplastic behaviour ($n < 1$). This index decreases, indeed, when the pseudoplasticity increases and with DF concentration (Table 7). The threshold of drainage ($\tau_s$) corresponds to the necessary constraint to overcome the cohesion between the various components of DF

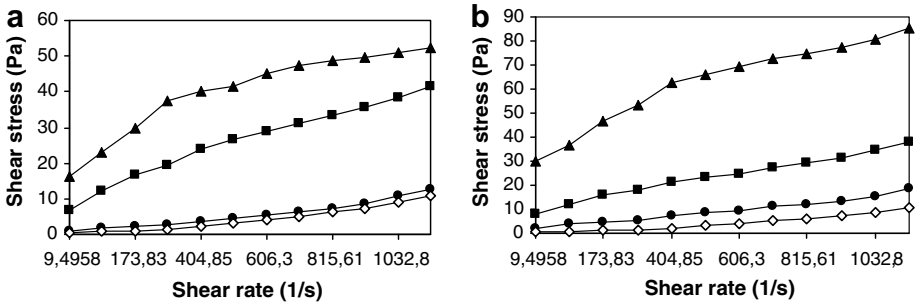


**Fig. 2.** Rheological behaviour of DF suspensions at different concentrations: (◇) 20 g/l, (●) 30 g/l, (■) 40 g/l and (▲) 50 g/l – (a) Deglet-Nour and (b) Allig.

**Table 7**
The flow behaviour index ($n$) at different concentrations of date dietary fibre suspensions (Herschel and Buckley model)

| | Date dietary fibre suspensions (g/l) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 20 | | 30 | | 40 | | 50 | |
| | Deglet | Allig | Deglet | Allig | Deglet | Allig | Deglet | Allig |
| The flow behaviour index ($n$) | 0.326 | 0.319 | 0.252 | 0.198 | 0.163 | 0.160 | 0.130 | 0.091 |
| $r^2$ | 0.960 | 0.950 | 0.987 | 0.961 | 0.873 | 0.987 | 0.830 | 0.894 |

$r^2$: Determination coefficient.

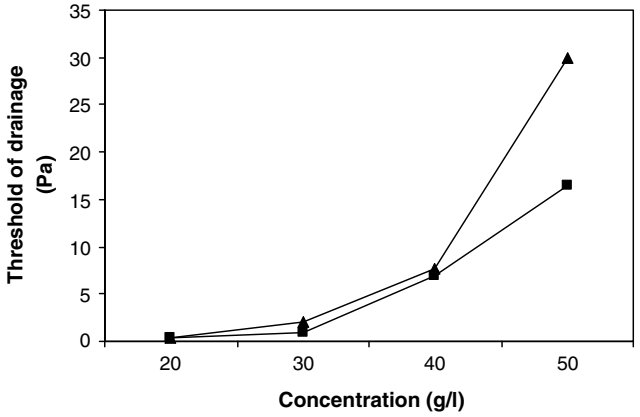


**Fig. 3.** Effect of concentration on the threshold of drainage (shear stress, Pa): (▲) Allig and (■) Deglet-Nour.

**Table 8**
Water- and oil-holding capacities (WHC and OHC) of date DF concentrates

| | WHC (g water/g sample) | OHC (g oil/g sample) |
|---|---|---|
| Deglet DF concentrate | 15.45 ± 0.6 | 9.6 ± 1.0 |
| Allig DF concentrate | 15.90 ± 0.7 | 9.9 ± 0.3 |

All the given values are means of three determinations ± standard deviation.

(cellulose, hemicelluloses, pectin and lignin) and, on the other hand, between these components and the water. This threshold becomes more pronounced with the concentration. It passes from 0.4 Pa to 16 Pa and 30 Pa for Deglet-Nour and Allig, respectively when the concentration of DF suspensions passes, respectively, from 20 g/l to 50 g/l (Fig. 3). Thus, Allig DF concentrates appear to be more cohesive. DF concentrates from Deglet-Nour and Allig could be used as functional ingredients to modify viscosity and texture of formulated products.

*3.2.2.3. Water- and oil-holding capacities.* DF concentrates show a high WHC (~15.5 g water/g sample) (Table 8). These values were higher than those reported in other fruit fibre concentrates, such as mango DF (11 g of water/g sample) (Vergara-Valencia et al., 2007), peach and orange DF (7.3–12.1 g water/g sample) (Grigelmo-Miguel, Gorinstien, et al., 1999; Grigelmo-Miguel and Martin-Belloso, 1999). The high WHC of date DF concentrate suggested that this material can be used as a functional ingredient in food to avoid syneresis of formulated products.

DF concentrates are also characterised by a high OHC (~9.7 g oil/g sample), superior to some agricultural by-products and DF concentrates cited by Abdul-Hamid and Luan (2000), Grigelmo-Miguel and Martin-Belloso (1999), Grigelmo-Miguel, Gorinstien, et al. (1999), and Vergara-Valencia et al. (2007) for orange, peach and mango DF concentrates and rice bran (0.86–4.54 g oil/g sample). The high OHC of DF concentrates suggested that this material could be used as an ingredient to stabilise foods with a high percentage of fat and emulsion.

## 4. Conclusion

Considering sugar (sucrose, glucose and fructose) and DF contents of date flesh, we conclude that they could be recovered and used for added value.

DF concentrates extracted from Deglet-Nour and Allig fleshes showed high contents of total DF (between 88% and 92%) with an extraction yield of 67%. The study of the physical properties showed that the DF concentrates could be used as functional ingredients in food to avoid syneresis, to stabilise products with a high percentage of fat and emulsion and to modify the texture and the viscosity of formulated products by virtue of their high WHC and OHC and their rheological properties. These results must be strengthened by essays of addition of these DF concentrates in foods and dietetic formulations.

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