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Tunisian date (*Phoenix dactylifera* L.) by-products: Characterization and potential effects on sensory, textural and antioxidant properties of dairy desserts

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ABSTRACT

Three Tunisian date varieties, Deglet Nour, Kentichi and Allig, served to produce syrups and powders, which were then examined for their physico-chemical composition and antioxidant properties. Different proportions of these sweetening-like agents were incorporated to produce nine different formulations of dairy desserts, with lower amount of added sugars to avoid any artificial flavoring or coloring agents. Sensory and color evaluation data revealed that incorporating Deglet Nour and Kentichi syrup offers the most desirable formulation. Furthermore, syrup polysaccharides and fibers contribute to better maintain the final product texture. In addition, date by-products create a good source of natural thickening agents, involved in enhancing apparent viscosity and spontaneous exudation. Thanks to their high content in phenolic compounds, date by-products considerably improve antioxidant activities of the formulated desserts. Therefore, they could be valued as natural ingredients in the formulation of novel dairy products with high nutritional-properties.

1. Introduction

Date palm (*Phoenix dactylifera* L.) is one of the oldest trees in the Arabian Peninsula that is generally cultivated in the arid and semi-arid regions. This fruit tree has played an important role in the day-to-day people life for the last 7000 years. Moreover, date fruits provide a wide range of essential nutrients, and represent a very good source of carbohydrates, salts and minerals, in addition to their richness with dietary fibers, vitamins, fatty acids, amino acids and proteins (Chandrasekaran & Bahkali, 2013). This high nutritive quality makes date fruits widely used in the processing industries all over the world. Tunisia is one of the date producing countries, with around 99,587 tons per year (FAOSTAT, 2013). Unfortunately, about 30% of the total production is continuously lost during the technological transformations (Masmoudi et al., 2008).

Huge amounts of wastes generated from dates have a potential use in syrup and dried dates production with several economic advantages. Owing to their composition, low quality dates can be used for the preparation of some high value-added products. Indeed, date syrup, the main and general by-product of dates contains various bioactive compounds (phenolic compounds), gifted with several biological activities including anti-oxidation (Lachman, Orsák, Hejtmánková, & Kovářová, 2010). Thus, it is used in the preparation of foodstuffs such as sweets, snacks, jams, butters and confectionery and bakery products, and even in healthy foods. Furthermore, date syrup can be used as a sweetening and flavoring agent in dairy foods like fermented milk products. In addition, recent findings showed that dates constitute a good source of antioxidants due to the highest polyphenols concentrations, especially found in the dried fruits (Lachman et al., 2010).

Epidemiological studies have reported that an increased consumption of fruits has been recommended as a key factor for a healthy diet to prevent of chronic diseases by reducing the mortality risks with an average of 6% for each daily additional serving (Wang et al., 2014). For instance, dates and their constituents showed an important role in the protection from several diseases thanks to their numerous biological activities including, antioxidant, antimicrobial, anti-diabetic, anti-inflammatory, antitumor, anti-mutagenic, hepatic and renal protection properties (Saddiq & Bawazir, 2010). This is attributed to the fact that these fruits may provide an optimal mixture of phytochemicals such as dietary

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fibers, phenolics, natural antioxidants and other bioactive molecules.

Hence, the idea of incorporating these bioactive compounds in the formulation of dairy desserts, on the one hand, for a better use of industrial date by-products wastes, and on the other hand, to make health-promoting products with high nutritive value. Unfortunately, the formulation of such foods may affect the final product quality, especially texture, aroma and flavor (González-Tomás, Bayarri, Taylor, & Costell, 2008). In fact, because of the integration of a complex multisensory process in a flavor perception, involving almost all of the senses, particularly taste and smell through odors generated in the olfactory pathway, flavor is widely believed in the general acceptability evaluation of new products.

Thus, the aim of the present investigation was to produce syrups and powders from three Tunisian date varieties, Deglet Nour, Kentichi and Allig, served as additives to prepare new dairy dessert formulations. Thereafter, the physico-chemical composition, antioxidant and techno-functional properties of the correspondent date by-products, as well as textural, rheological and nutritive effect of the obtained dairy desserts were evaluated.

2. Materials and methods

2.1. Materials

Three low grade dates, namely Deglet Nour, Allig, and Kentichi, were obtained from RIDAT's Tunisian Company, Gabes city, in the beginning of the 2013 harvest season. A mature fruit without any physical damage, insect's injuries nor fungal infection, were selected and used for all experiments. Defatted milk, milk fat, modified starch, sugar, maltodextrin and carrageenan (E407) were of food grade.

2.2. Extraction of date syrup

Syrup was prepared in triplicate from each date variety as the method described by Abbès et al. (2011), with slight modification. Briefly, 500 g from each date variety was mixed with 1500 ml of water. Then, the mixture was placed in water bath at 100 °C for 15 min. The resulted juice was filtered and then centrifuged at 3000*g* during 15 min. To prepare date syrup, juice was concentrated at 100 °C using hotplate to 80 Brix, and then kept in refrigerated storage at room temperature until analysis and application.

2.3. Date powder preparation

Date (500 g) obtained from each date variety was dried at 50 °C, until constancy of the mass (20 h), then mashed in a commercial food grinder (Type D56, Moulinex, Seb Group, France). The dried mashed dates were finally stored at room temperature 25 °C before being analyzed and added to the dairy dessert mix.

2.4. Proximate analysis

2.4.1. pH and water activity (a_w) determination

The pH was measured using a pH-meter (Metrohm, 744 pH meter) equipped with a glass probe for penetration. Moisture, protein, fat and ash contents were determined according to AOAC (2000) methods. Protein concentration was calculated using the conversion factor of 6.25. Water activity (a_w) was determined using Novasina Thermoconstanter SPRINT equipment (TH-500, Switzerland) at 25 °C. The equipment was previously calibrated, according to the calibration procedure of the equipment manufacturer, using the following salts: $MgCl_2$, NaCl, $BaCl_2$ and $K_2Cr_2O_7$.

2.4.2. Physico-chemical analysis

The total soluble sugars were determined using Perez, Olias, Espada, Olias, and Sanz (1997) method with slight modifications. 5 g of each sample was homogenized with 5 ml of aqueous ethanol (95%). The solid phase was washed with another volume of 95% aqueous ethanol (10 ml) which was already combined with the homogenate. After centrifugation (9418g, 20 min, 4 °C), the pellet was resuspended in 5 ml of aqueous ethanol (80%) and centrifuged again, as indicated above. The two supernatants were combined and then evaporated to a minimal volume in a water bath (30 °C) under a fan. The samples were diluted to a final volume of 10 ml with distilled water and used for the determination of soluble sugars by the method described by Dubois, Gilles, Hamilton, Rebers, and Smith (1956).

The reducing sugars were measured by the dinitrosalicylic acid method using D-glucose as a standard. Sucrose content was estimated by calculating the difference between the total soluble sugars and the reducing sugars.

Soluble solids content (Degree Brix) was determined using an Abbe Refractometer (Iymen Optic system). Titrable acidity and dietary fibers were carried out using 934.06 and 991.43 methods, respectively (AOAC, 2000). Total phenolic compounds were determined by Folin–Ciocalteu procedure (Al-Farsi et al., 2007), and results were expressed as milligrams of gallic acid equivalent (mg GAE) per 100 g of dry weight matter.

2.5. Particle size distribution

The samples particle size distributions were determined at room temperature with a laser diffraction particle size analyzer equipped with an accessory Hydro 2000S (A) small volume automated wet dispersion accessory (Malvern Mastersizer 2000 particle size analyzer; Malvern Instruments Ltd., Worcestershire, UK) (Keshtkaran, Mohammadifar, Asadi, Nejad, & Balaghi, 2013).

2.6. Water holding capacity of date powder

The water holding capacity (WHC) of dried date powder was determined according to Okezie and Bello (1988) method, with slight modifications. The sample (1 g) was dispersed in 50 ml of distilled water and mixed for 2 min. The mixture was kept at room temperature for 30 min, and then centrifuged for 30 min at 5000*g*. The two supernatants were filtered with Whatman No. 1 filter paper and the recovered volume was measured. The difference between initial volume of distilled water added to the dried sample and the volume of the supernatant was determined, and results were reported as milliliters of water absorbed per gram of dried date.

2.7. Dairy dessert formulation

The dairy dessert formulation (g/100 g dairy dessert) consisted on defatted milk (72%), milk fat (5%), modified starch (6%), sugar (14%), maltodextrin (2%) and carrageenan E407 (1%). Cold milk (30%) was firstly added to the ingredients (except of maltodextrin and carraghenan) and gently homogenized for 5 min in a commercial food processor (Moulinex, Paris, France) at a medium speed. After that, maltodextrin, carrageenan and heated milk (42% at 60 °C) were added and mixed during 2–3 min. The mixture was then heated at 72 °C for 30 s using a thermo-stated bath (Haake, Kalsruhe, Germany). The temperature was measured by a type-T (copper-constantan) thermocouple inserted into the center of the dairy dessert.

In our study, syrups and powders from date by-products, from three different varieties of Tunisian dates (Allig, Kentichi and Deglet Nour), have been used as sweetening agents in the formulation of dairy desserts. Thus, sugar and maltodextrin (16%) were replaced by date syrup (S) and dried date powder (P) from each variety, with different ratios (P/S). Nine samples were produced according to three different formulations. The first one (F1) was enriched in P with the proportion of (P/S = 2); F2 contained an equal weight mixture of these two compounds, while the last one (F3) was more enriched in S than P (P/S = 0.5). Dairy dessert formulations were cooled immediately and then stored at 4 °C until analysis.

2.8. Dairy dessert properties

2.8.1. Sensory evaluation

The sensory properties were determined according to Murray, Delahunty, and Baxter (2001) method. Sixty panelists were asked to evaluate texture, taste, color, flavor and overall acceptability of the final products using a five-point hedonic scale, ranging from 5 (extremely liked) to 1 (extremely disliked), for each sensory attribute. Different formulations of dairy desserts were distributed in white polystyrene cups and presented to the panelists with codes in a random order. Experiments were conducted in an appropriate designed and lit room; water was served for the purpose of cleaning the mouth between samples.

2.8.2. Color evaluation

Color measurements of different dairy dessert formulations were carried out using a Color Flex spectrocolorimeter (Hunter Associates Laboratory, Inc., Reston, VA, USA). The instrument was standardized using standard white plates. An average value was determined by taking observations from ten different cut surface points of the same sample, and the CieLab coordinates of lightness (L^*), redness (a^*) and yellowness (b^*) were recorded.

2.8.3. Instrumental texture analysis

The texture analysis of the different dairy dessert formulations was achieved on the samples, previously stored at least for 24 h at 4 °C, using a texture analyzer (Lloyd Instruments, Ltd., West Sussex, UK). Dairy dessert samples, 4 cm high × 4 cm diameter, were placed in a cylindrical cell and a cylindrical probe (12 mm in diameter). Then, samples were compressed to 50% of their original thickness in a double cycle with a rate of 40 mm/min. The texture profile parameters, namely firmness (N), elasticity (mm), and cohesiveness were computed from the resulting force–deformation curves.

2.8.4. Syneresis measurement and viscosity

Syneresis measurement was determined according to the method of Charoenrein, Tatirat, and Muadklay (2008). Briefly, 50 g of the dairy dessert were placed in centrifuge tubes and centrifuged at 1000*g* for 15 min. The cylindrical plastic tube with cover was removed from the centrifuge tube. The percentage of syneresis was then calculated as the ratio of the weight of the liquid separated from the dairy dessert to the total weight of the sample before centrifugation, multiplied by 100. The data were reported as the average of five measurements.

The rheological behavior was analyzed with a rotational viscometer Haake Rotovisco RV2 (Karlsruhe, Germany) with a thermostatic system. All data were obtained with a sensor MV IP (medium viscosity rotor) of concentric cylinders with profiled surfaces. This sensor system is appropriate for the substances that tend to slip on cup and rotor surfaces. Rheological properties were measured at 20 °C. Transient shear stress curves (σ vs. time) were obtained at constant shear rates (D) ranging from 32 to 512 s^{-1}. The equilibrium value of the shear stress ($\sigma\infty$) was measured at 180 s at each shear rate to estimate the parameters of the power law model. Apparent viscosities were evaluated at $D = 32\ s^{-1}$. Each run was performed in triplicate.

2.9. Evaluation of antioxidant properties

DPPH radical-scavenging activity was determined as described by Bersuder, Hole, and Smith (1998). Ferric reducing antioxidant power (FRAP) of dairy dessert samples was determined according to the method of Yildirim, Mavi, and Kara (2001). The presented values are the mean of triplicate measures.

2.10. Statistical analysis

All analytical determinations were performed at least in triplicate. Values were expressed as the mean ± standard deviation (SD). Duncan's test and one-way analysis of variance (ANOVA) were used to compare results with significant differences using SPSS software, 17.0 (Statistical Package for the Social Sciences, The Predictive Analytics Company, Chicago, IL, USA). A difference was considered statistically significant at $P \leqslant 0.05$.

3. Results and discussion

3.1. Date syrup characterization

The proximate composition of date syrup is presented in Table 1. Results demonstrated that pH values of Deglet Nour-S, Allig-S and Kentichi-S were slightly acids, estimated at about 4.6, 4.5, and 4.1, respectively. In addition, all date syrups were characterized by low water activity values (0.45–0.48), which might contribute to a long-term conservation and an excellent protection against all bacterial and fungal alterations. Furthermore, the highest levels of titrable and citric acid acidity found in Allig-S may improve the protective effect of Allig by-products.

Moreover, our results showed that sugars were the most predominant components in all prepared date syrups. Their richness in reducing sugars could contribute to the reduction of syrup crystallization phenomenon and provide a good source of rapid energy

Table 1
Chemical composition of date syrup (S) and powder (P) of three Tunisian varieties of date by-products.

	Deglet Nour	Kentichi	Allig
Date syrup (S)			
pH	4.60 ± 0.01[a]	4.10 ± 0.02[c]	4.50 ± 0.01[b]
a_w	0.46 ± 0.01[b]	0.45 ± 0.05[c]	0.48 ± 0.10[a]
Total sugars (%)	80.97 ± 2.15[a]	81.78 ± 2.36[b]	85.47 ± 1.67[b]
Titrable acidity*	3.10 ± 0.20[b]	3.56 ± 0.10[b]	4.50 ± 0.30[a]
Acidity (as citric acid)**	0.96 ± 0.05[b]	0.90 ± 0.12[b]	1.13 ± 0.11[a]
Phenolic compounds***	442.1 ± 0.68[a]	402.3 ± 1.31[b]	397.50 ± 1.20[c]
Date powder (P)			
Dry weight (%)	81.00 ± 0.01[b]	84.04 ± 0.01[a]	78.50 ± 0.02[c]
Particle size distribution	>0.4 mm (95.07%) [0.4; 0.16] (4.38%)	>0.4 mm (79.65%) [0.4; 0.16] (18.10%)	>0.4 mm (80.48%) [0.4; 0.16] (12.35%)
Water activity (a_w)	0.51 ± 0.01[b]	0.53 ± 0.04[a]	0.47 ± 0.02[c]
Dietary fibers*	9.53 ± 0.04[b]	10.70 ± 0.80[b]	16.70 ± 0.60[a]
Water holding capacity (WHC)	6.50 ± 0.05[b]	6.89 ± 0.08[c]	9.35 ± 0.87[a]
Radical scavenging (%)	87.25 ± 1.30[a]	82.49 ± 0.10[b]	69.78 ± 0.58[c]

Results followed by different letters, within the row, are significantly different at $P \leqslant 0.05$.
%: g/100 g on a dry weight basis.
* NaOH 0.1 eq/kg on a wet weight basis.
** g of citric acid/100 g on a wet weight basis.
*** mg of gallic acid equivalent (GAE)/100 g on a dry weight basis.

(Abbès et al., 2011). In addition, reducing sugars and proteins interaction, during the Maillard reaction (a well-known non-enzymatic browning reaction), could produce colored or colorless reaction products, which can play an important role in the oxidation prevention (Yilmaz & Toledo, 2005). Thus, they could be incorporated in functional foods (Al-Mamary, Al-Habori, & Al-Zubairi, 2011).

On another hand, syrups were also found to be good sources of total phenolics. In fact, among the tested varieties, significant differences ($P \leqslant 0.05$) in total phenolic contents were observed. Deglet Nour-S had the highest level (442 mg of GAE/100 g), followed by Kentichi-S (401 mg of GAE/100 g) and finally Allig (397 mg of GAE/100 g). Therefore, date syrups contain, besides the nutritional components, various biological active compounds (phenolic compounds) qualified by their potential antioxidant activities (Abbès et al., 2011; Lachman et al., 2010), which justify their incorporation in the dairy dessert formulations.

3.2. Characterization of dried date

The characteristics of the dried date powders (P) of the three tested varieties are shown in Table 1. The results showed that the dry weight contents were greater than those of non dried date by-products, and varied from 78.50% to 84.04%. The particle size analysis of powders showed significant differences in diameter particle distribution, and the major particle size range was greater than 0.4 mm. In the case of Kentichi, 18.10% of total particles ranged between 0.16 and 0.4 mm.

Food industries emphasize the importance of higher water holding capacity (WHC) due to its positive correlation in minimizing the water release improving the textural stability during storage time. WHC of the dried powders is shown in Table 1. Allig-P exhibited higher WHC than Kentichi-P and Deglet Nour-P. This high water retention ability is mainly attributed to the presence of large amounts of insoluble fiber in dates. In fact, the fiber level in Allig-P (16.70%) was significantly higher ($P \leqslant 0.05$) than that of the Kentichi-P (10.70%), followed by Deglet Nour-P (9.30%). These values are significantly lower compared to those found by Elleuch et al. (2008).

In addition, the most considerable radical scavenging effects of date powders were seen in Deglet Nour followed by Kentichi powders (87.25% and 82.49%, respectively), whereas, Allig-P exhibited the lowest activities (69.78%). In fact, anti-DPPH activity varied in the same way as phenolic compounds content in date by-products. Therefore, because of the high scavenging activity of Deglet Nour and Kentichi powders, they might be incorporated in dessert formulations in order to fabricate new products with high nutritional values.

3.3. Preparation of dairy desserts formulations

Syrups (S) and powders (P) from date fruits, from three different varieties of Tunisian dates (Allig, Kentichi and Deglet Nour) have been used as sweetening additives in the formulation of dairy desserts. Nine samples were produced according to three different formulations. The first one (F1) was enriched in P with the proportion of (P/S > 1); F2 contained an equal weight mixture of these two compounds, while the last one (F3) was more enriched in S than P (P/S < 1). The resulting products are then characterized with distinct sensory profiles, textural assessments and viscosity, which were compared to a standard dairy dessert used as a reference.

3.3.1. Dairy desserts physico-chemical characteristics

Table 2 illustrates water activity (a_w), pH, total solids and protein contents of the different formulations. Determining a_w parameter is essential to evaluate food safety, including microbiological quality. Indeed, the presence of huge available water quantities in the components is the principal factor inducing the development of bacteria, yeast and mold, which affects safety and food quality. Data demonstrated that dairy desserts added with Allig by-products were characterized by the lowest a_w compared to the other formulations. This result could be explained by the greater richness of the Allig variety in fibers than other ones. In fact, the presence of such components increased water retention in the corresponding product. Furthermore, among the three date varieties, the highest a_w levels shown in F3 might be due to the high proportion of syrup in these formulations.

Regarding the pH values of the dairy desserts whether enriched with date by-products or not, it is clearly indicated that the nine formulations prepared with S and P presented more acidic pH values than the standard one. This decrease, estimated at 0.13, may be due to the acid nature of powder and syrup dates added to the formulations. Similar data were reported by Espírito-Santo, Perego, Converti, and Oliveira (2012) who observed an important decrease in the pH of yogurt samples added with the fibers of passion and orange fruits, respectively.

Moreover, the variation of soluble solids content (SSC) in F1, F2 and F3 formulations was proportional to the P content in the correspondent product. Besides, the maximal values of SSC were observed in dairy products prepared from Kentichi and Deglet Nour varieties, due to the high level of dried matters in their powders. In addition, among the investigated varieties of dates, the incorporation of various proportions of powder/syrup from Allig by-products gives the most protein enriched formulations, especially in F1 (P/S > 1). This result might be due to the highest protein content observed in this variety compared to the others.

Our results agree with those reached by Amellal (2008) who observed the enrichment of yogurts, added with date's powder of different Algerian varieties, in dry and protein contents.

3.3.2. Sensory evaluation of dairy desserts after the incorporation of date by-products

To determine sensory profile of dairy desserts, the color, flavor, taste, texture and overall acceptability (OA) were studied using hedonic test (Fig. 1). There is no significant difference ($P > 0.05$) among tasters. Our results indicated that control and tested products have shown detectable differences in their sensory parameters.

Whatever the date variety used for dairy dessert preparation, the formulations F3 relative to Kentichi and Deglet Nour varieties were the most appreciated by consumers in terms of taste, flavor and texture. Interestingly, color and OA of F3 prepared with Kentichi syrup were the best scored. However, the majority of consumers have not enjoyed the intense astringency tasted in F1, which might be due to the high content of P. Similarly, this taste was detected when comparing formulations F3 within the different varieties. Hence, the increase in the quantity of syrup leads to reduce the astringent appearance in the final product. These results are in agreement with those found by Abbès et al. (2011), indicating that products prepared with Kentichi-S were the most appreciated by consumers, in terms of overall appearance, when compared to those made with syrups from other varieties of dates.

On the other hand, when comparing the three date varieties in formulation F3, Kentichi by-product has been considered as the best one in most of the cases. Thus, relying on the present results and regarding the OA scores, it could be concluding that F3, based on the Kentichi variety, is considered as the most appreciated product by the consumers.

3.3.3. Color measurement of dairy dessert samples

Due to the considerable influence of product colors on consumer acceptance, samples colors were measured. The L^*, a^* and

Table 2
Physical properties, protein content and color parameters of dairy desserts prepared with different concentrations of P and S from three Tunisian varieties of date by-products.

	Deglet Nour			Kentichi			Allig		
	F1	F2	F3	F1	F2	F3	F1	F2	F3
pH	6.36 ± 0.10	6.46 ± 0.01	6.40 ± 0.05	6.36 ± 0.04	6.36 ± 0.10	6.43 ± 0.01	6.36 ± 0.02	6.37 ± 0.04	6.29 ± 0.06
a_w	0.90 ± 0.10	0.91 ± 0.00	0.92 ± 0.12	0.92 ± 0.10	0.92 ± 0.01	0.92 ± 0.03	0.86 ± 0.01	0.87 ± 0.02	0.90 ± 0.01
SSC	29.47 ± 0.2	28.75 ± 0.12	28.25 ± 0.16	30.03 ± 0.11	29.38 ± 0.01	28.67 ± 0.14	28.88 ± 0.11	28.78 ± 0.12	23.37 ± 0.16
Protein (%)	4.37 ± 0.6	4.59 ± 0.05	4.81 ± 0.12	4.37 ± 0.44	3.9 ± 0.61	4.7 ± 1.2	6.56 ± 0.08	5.90 ± 0.21	5.02 ± 0.10
L^*	85.42	64.84	67.84	67.03	63.97	62.57	62.81	60.56	59.55
a^*	−2.24	7.66	8.10	9.19	10.81	12.18	12.49	10.54	11.61
b^*	14.81	16.59	16.83	15.72	16.01	15.34	13.95	17.42	17.45

SSC: soluble solids content (°Brix); %: g/100 g on dry wet basis. L^* represents lightness, a^* represents redness, b^* represents yellowness.

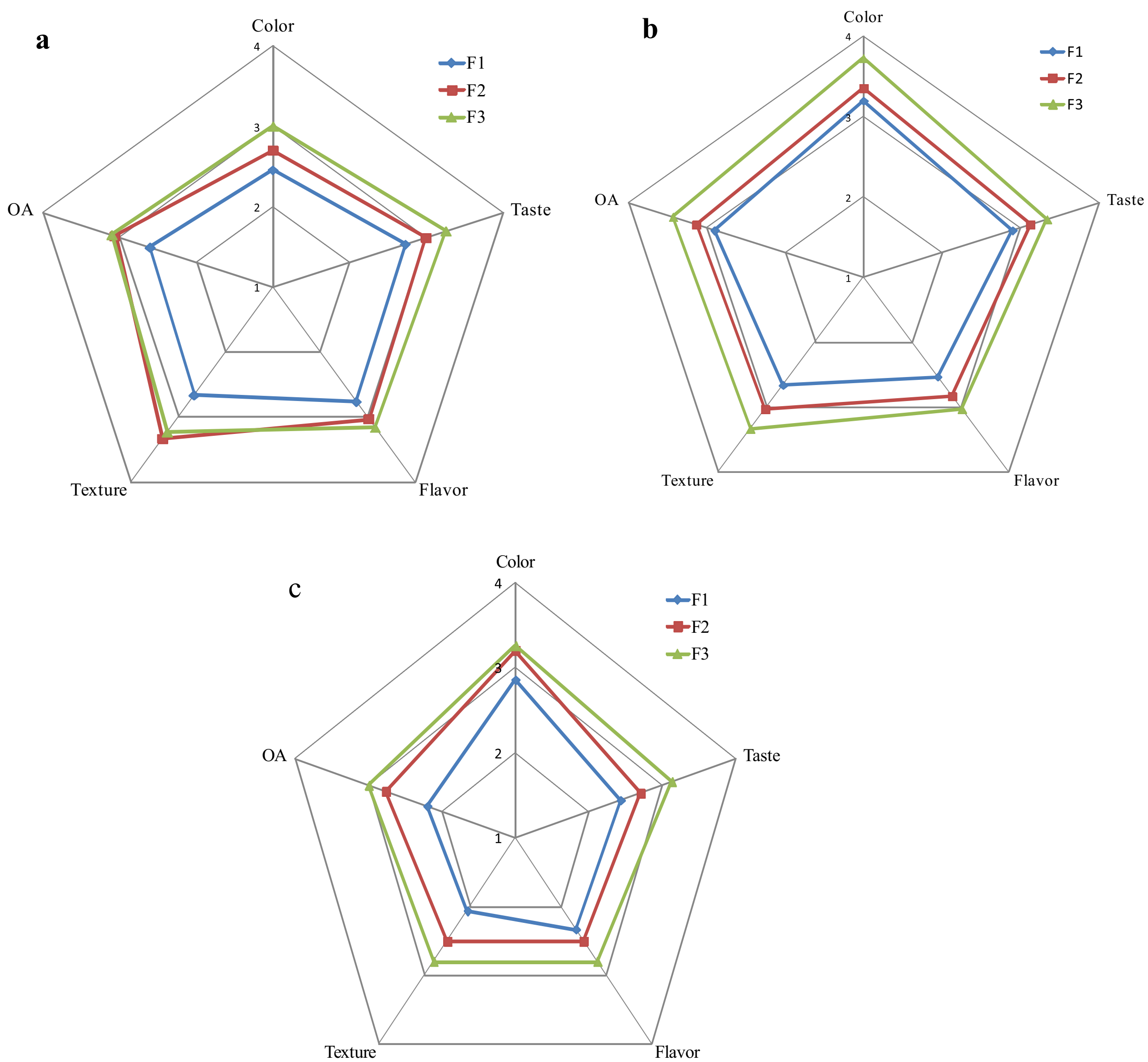

Fig. 1. Sensory average scores of dairy desserts with different concentrations of P and S relative to three Tunisian varieties by-products, (a) Deglet Nour, (b) Kentichi and (c) Allig.

b^* color data, resulting from natural colors of date by-products, are summarized in Table 2. These results indicate that color values were more affected by the date variety than the P/S ratio. In fact, when examining each variety individually, only a^* results were significantly affected by the formulation type, and was intensified within the syrup concentrations.

In contrast, color parameters were significantly different within the by-product origin. The L^* attributes show that dairy desserts formulated using Deglet Nour by-products had the highest lightness values followed by those related to Kentichi and Allig. In fact, the greater content of polysaccharides in Deglet Nour products may increase the interaction with milk proteins as was observed by light scattering (Arancibia, Costell, & Bayarri, 2011). The darkness observed in dessert samples prepared with Allig by-products might be due to the natural black color of Allig fruit itself. Nevertheless, samples prepared with Deglet Nour syrups and powders were characterized by the lowest a^* values. These reduced redness could be explained by the richness of Deglet Nour-S in polysaccharides. Indeed, the lower the soluble sugar concentrations is, the more the polysaccharide level increases, and in their turn, samples tend to be greener (Keshtkaran et al., 2013). Concerning b^* results, which represent the yellowness, they were slightly modified by the variety used. So, based on L^*, a^* and b^* values, it could be concluded that Deglet Nour and Kentichi by-products gave more lightness and less redness to the dairy desserts than those of Allig variety. The present results are similar to those found by Amellal studies (2008), which tested the effect of date powder addition, obtained from three different varieties, Mech Degla, Degla Beida and Frezza (dried Deglet Nour), on yogurt colors.

3.3.4. Effect of P and S addition on textural properties

Textural modification is one of the most common forms of intervention for dysphagia, and is widely considered important for promoting safe and efficient swallowing (Steele et al., 2015). It is a key criteria used to determine organoleptic quality of food products. Indeed, textural parameters, including firmness, cohesiveness, elasticity and adhesion strength, strongly correlated with sensory attributes and provide more information than the traditional food evaluation (Steele et al., 2015). Table 3 shows the textural evaluation results of samples, with different P and S concentrations, in terms of cohesiveness, firmness and elasticity.

It was found that the maximal cohesiveness values were attributed to F1 for all the date varieties. Since cohesiveness represents a measure of the degree of difficulty in breaking down the internal structure (Sanderson, 1990), the present relatively high values recorded in F1 might be probably due to the date powder richness with fibers that play the role of texturing compounds. However, samples prepared according to F2 and F3, whatever the date variety, received the lowest scores because of the reduced powder concentrations in these formulations.

Moreover, regardless the by-product variety, results showed that there is no significant difference between F2 and F3 firmness values ($P > 0.05$), while F1 exhibited the greater firmness attributes. This data might be explained by the high powder content (high SSC) in the F1 products (Tamime and Robison, 1985). Furthermore, this increase in firmness showed a synergetic effect between insoluble fiber and other components of dessert. These results suggested the ability of pectins to increase the firmness of dairy dessert (Bouaziz, Rassaoui, & Besbes, 2014).

Thickness is related to the resistance of the aliment structure to the force applied by teeth during mastication, that's why F1 products were generally unappreciated by consumers. Otherwise, the dessert samples prepared using Kentichi and Allig by-products were softer than that of Deglet Nour, for both F2 and F3 formulations. This could be explained by the presence of low energy bonds involved in textural maintaining, resulting from lower polysaccharide contents in Kentichi and Allig syrups interacting with dairy dessert proteins (Shaker, Jumah, & Abdu-Jdayil, 2000). A great amount of research focused on the non-covalent interactions between milk proteins and polysaccharides fruits in order to improve the final product properties (McClements, 2005; Tijssen, Canabady-Rochelle, & Mellema, 2007). In addition, the perception of F1 rubberiness in the mouth, evaluated with the elasticity parameter, indicates that there is a positive correlation between hardness and date powder content in the product.

Hence, the present results proved the beneficial effect of the date syrup addition on the textural properties of the dairy dessert samples. In fact, cohesiveness, thickness and elasticity have been considerably improved compared to the samples with high powder content. In the same context, it was shown that using date S to make some products such as halwa-ardeh, low-fat frozen yogurt dessert, and low caloric cakes resulted in a successful replacing sugar agent coupled to the improvement of the techno-functional properties of the formulated product (Milani & Koocheki, 2011).

3.3.5. Effect of P and S on viscosity

3.3.5.1. Apparent viscosity. The apparent viscosity is considered as an instrumental index of the oral thickness for food products. It significantly influences the consumer acceptance and purchase intention, being then an important factor that should be controlled during food processing. Generally, dairy desserts with gel-like behavior have a Newtonian shear-thinning flow which depends on time and viscoelastic properties (Bayarri & Costell, 2009; Bayarri, Dolz, & Hernández, 2009). Fig. 2 shows the apparent viscosity values of the different formulations prepared with syrups and powdered dates. On the one hand, it was found that F1 ($P/S > 1$) had the highest viscosity levels ($P \leqslant 0.05$), whatever the variety of the date used, compared to F2 and F3 samples. In addition, the desserts made with Deglet Nour by-products, in all the formulations, exhibited the highest viscosity values. In fact, the increasing contents of P and SSC in F1 formulations, especially in Deglet Nour powder, played the role of texturing agents, and then induced significant rise in apparent viscosity of the dessert samples. In the same context, Vignola (2002) has reported that texturing additives incorporated as ingredients in fruit yogurt may improve viscosity and textural appearance of the resulting product by increasing the SSC.

Table 3
Textural parameters, total phenolic content and antioxidant potency of dairy desserts prepared with different concentrations of P and S relatives to three Tunisian varieties by-products, compared to a control dessert (without date).

		Phenolic compounds*	Scavenging activity (%)	Reducing power**	Cohesiveness	Firmness (N)	Elasticity (mm)
Standard		35.10 ± 0.20^{d}	9.40 ± 0.80^{d}	0.07 ± 0.00^{d}	–	–	–
Deglet Nour	F1	0.93 ± 0.01^{aA}	59.23 ± 1.36^{bA}	1.82 ± 0.02^{bA}	0.93 ± 0.01^{aA}	29.57 ± 0.20^{aA}	18.20 ± 1.10^{aA}
	F2	0.76 ± 0.03^{bA}	51.65 ± 2.65^{cA}	1.19 ± 0.01^{cA}	0.76 ± 0.03^{bA}	20.39 ± 0.67^{bA}	14.90 ± 1.00^{bA}
	F3	0.57 ± 0.10^{cA}	69.36 ± 1.10^{aA}	1.91 ± 0.01^{aA}	0.57 ± 0.10^{cA}	20.39 ± 0.91^{bA}	13.10 ± 0.61^{cA}
Kentichi	F1	0.94 ± 0.07^{aA}	41.41 ± 1.32^{bB}	1.84 ± 0.06^{aA}	0.94 ± 0.07^{aC}	21.41 ± 1.40^{aB}	18.40 ± 0.67^{aA}
	F2	0.56 ± 0.12^{bB}	43.65 ± 1.02^{aB}	1.31 ± 0.24^{bA}	0.56 ± 0.12^{bB}	12.24 ± 1.30^{bC}	13.21 ± 2.40^{bA}
	F3	0.38 ± 0.03^{cB}	43.95 ± 5.36^{aB}	1.01 ± 0.31^{cB}	0.38 ± 0.03^{cB}	12.24 ± 1.90^{bC}	10.12 ± 3.10^{cB}
Allig	F1	0.74 ± 0.17^{aB}	19.69 ± 2.95^{cC}	1.03 ± 0.09^{bB}	0.74 ± 0.17^{aB}	19.37 ± 1.10^{aC}	19.70 ± 0.92^{aA}
	F2	0.41 ± 0.06^{bC}	26.59 ± 1.36^{bC}	1.04 ± 0.11^{bA}	0.41 ± 0.06^{bC}	16.32 ± 0.47^{bB}	14.40 ± 1.10^{bA}
	F3	0.39 ± 0.02^{cB}	30.02 ± 1.20^{aC}	1.35 ± 0.06^{aB}	0.39 ± 0.02^{cB}	16.32 ± 0.95^{bB}	13.50 ± 0.60^{bA}

Results followed by different letters, within the same variety, are significantly different at $P \leqslant 0.05$. Results followed by different capital letters, within the same formulation, are significantly different at $P \leqslant 0.05$.
* mg of gallic acid equivalent (GAE)/100 g on dry weight basis.
** OD at 700 nm.

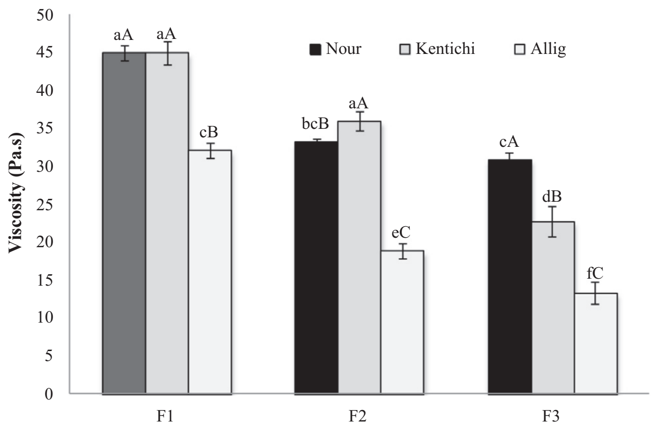

Fig. 2. Viscosity of dairy desserts prepared with different concentrations of P and S relative to three Tunisian varieties of date by-products. Results followed by different letters, within the row, are significantly different at $P \leqslant 0.05$. Results followed by different capital letters, within the same formulation, are significantly different at $P \leqslant 0.05$.

On the other hand, the incorporation of Allig by-products in dairy dessert formulations hadn't improved the samples viscosity, which still significantly ($P \leqslant 0.05$) lower than that of Kentichi and Deglet Nour. In fact, their apparent viscosity values didn't exceed 33 Pa s even in F1 formulations.

3.3.5.2. Syneresis of dairy desserts. Syneresis, or water loss, is a critical parameter used to evaluate the stability of the dairy products during storage (Lucey, 2002), which remains a challenge in processed foods. Thus, the spontaneous whey expulsion from different samples of dairy desserts was determined and the results are reported in Fig. 3. Findings illustrate that, except for F1 products, all the other samples showed a partial water release during the storage period. This might be due to the presence of high fiber concentrations in date P, which increase SSC in the formulated desserts. It has been reported that dates and their by-products serve as good sources of fiber compared with syrups (Al-Farsi et al., 2007). These physical stabilizers have an important function as natural bio-thickening agents and are capable to improve the texture of the fermented products by enhancing water retention, and then syneresis limitation (Amellal, 2008). Staffolo, Bertola, Martino, and Bevilacqua (2004) showed that there is no observed syneresis in yoghurt samples enriched with wheat, bamboo fiber and inulin apple during 21 days of storage. Nevertheless, increasing S level in dairy desserts is proportional to the released water quantities that could be explained by the fibers loss during syrup extraction.

Moreover, the date variety considerably influences syneresis level of dairy desserts. In fact, Allig by-products showed the minimum water release results. This could be explained by the increased WHC, together with the high fibers content, of Allig-P.

3.3.6. Antioxidant properties

Nowadays, much interest has been focused on health-promoting foods, enriched with bioactive compounds, generally, derived from plants thanks to their safety and effectiveness in the prevention and/or treatment of human diseases. In fact, the antioxidant activity of plant extracts derived from their richness in numerous free radical scavenging agents. So, in order to evaluate date by-products contribution to the antioxidant properties of the resulting dairy desserts, phenolic compounds rate, DPPH-radical scavenging activity and reducing power have been determined (Table 2). Compared to the standard dessert (without dates), date by-products incorporation significantly improve the phenolic compounds

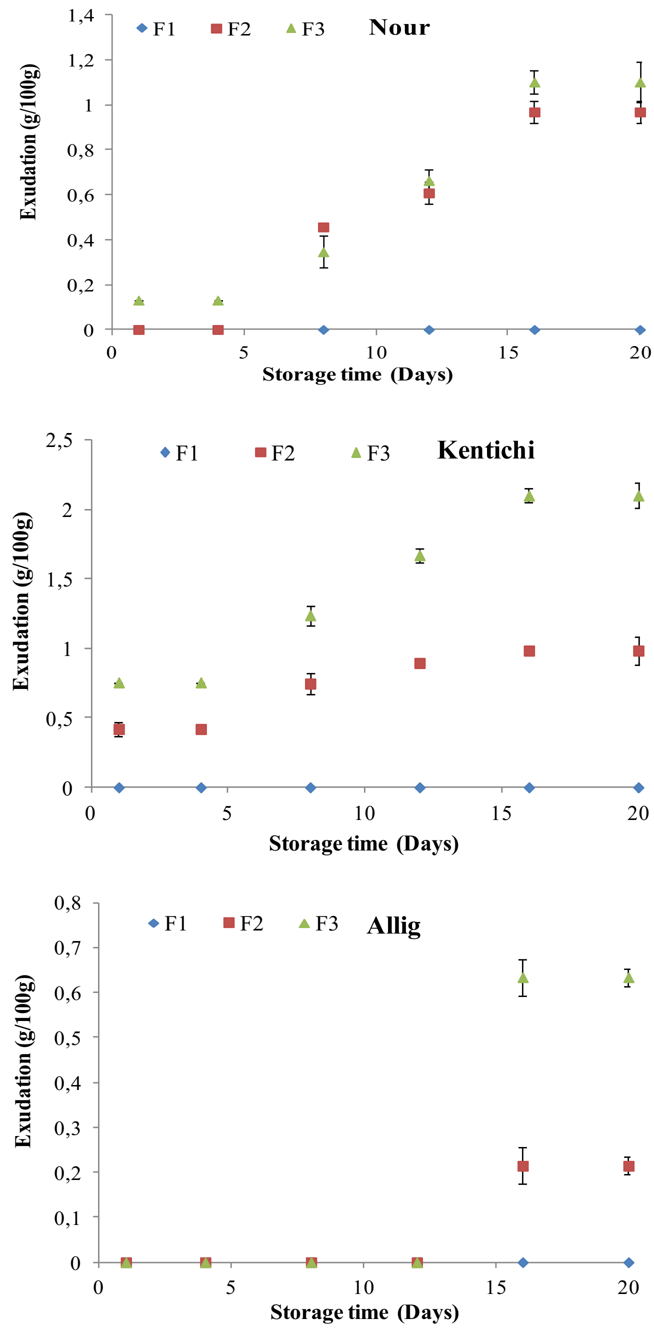

Fig. 3. Syneresis of dairy desserts prepared with different concentrations of P and S relative to three Tunisian varieties of date by-products.

levels ($P \leqslant 0.05$), besides the enhancement of anti-DPPH and the reducing power activities. Our results indicate that the dairy desserts prepared with Deglet Nour and Kentichi by-products were the richest desserts in phenolic compounds. These results agree with total phenolic contents of the three date varieties determined previously. Furthermore, a positive linear correlation between the total antioxidant activity, determined by FRAP and anti-DPPH methods, and phenolic contents was clearly observed. In fact, the samples prepared with Deglet Nour by-products exhibited the highest antioxidant activities, whatever the P/S ratio.

Interestingly, samples made according to F1 method were the richest products in phenolic compounds. Contrariwise, the most potent free radical scavenging activity and reducing power effect have been obtained among F3 dessert samples. This observed contradictory data could be explained by phenolic compounds-casein interactions in dairy products, resulting in reducing antioxidant efficiency in F1 products. From these data, it might be concluded that the incorporation of the date by-products in dessert formulations might be an efficient alternative to fabricate new products, with novel characteristics and could be qualified as functional foods.

4. Conclusion

Date syrups and powders, from three different Tunisian varieties, proved their efficient use as innovative and attractive additives in dairy dessert processing. In addition to their sweetening effect, date by-products serve as a good source of natural coloring and flavoring agents. Moreover, date by-products, especially Kentichi and Deglet Nour, rich in fibers and polysaccharides, play a physical stabilizer role involved in the textural product maintaining by improving mouth feel and enhancing apparent viscosity and syneresis. Moreover, they serve as a good source of phenolic compounds, known by their potent antioxidant effects. Taking into account the sensory, textural and techno-functional results, it could be concluded that the dairy dessert prepared according to F3 formulation (DP/DS < 1) based on the Kentichi variety is the most appreciated product by consumers. Therefore, these by-products might be used as benefit natural ingredients in functional foods making, in response to the actual consumers demand. Further researches are planned to quantify and identify the bioactive compounds in date by-products.

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