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Effect of Inclusion of Date Press Cake on Texture, Color, Sensory, Microstructure, and Functional Properties of Date Jam

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Abstract: Date press cake (DPC) is a by-product of the date syrup industry with a high content of dietary fibers, minerals, and antioxidant compounds. Accordingly, the present study aimed to evaluate the inclusion of DPC on the color parameters, texture profile, sensory evaluation, microstructure properties, total phenolics, and antioxidant capacity of date jam. The DPC was included in the preparation of date jam in an increasing level of 0, 3, 6, 9, and 12% (*w/w*). The results revealed that increasing DPC levels significantly increased the hardness, cohesiveness, adhesiveness, and chewiness properties of date jam. The increase in DPC inclusion levels significantly decreased the L^* values and increased the a^* , b^* , and ΔE values of the jam. The DPC addition significantly increased the phenolics content and antioxidant capacity in a dose-dependent manner and the highest value reported in the jam contained 12% DPC by 40.02 and 11.50% compared to the control, respectively. The scanning electron microscopy results revealed that the addition of DPC up to 9% resulted in a jam surface with a denser network, homogeneous structure, and without cracks and pores, indicating improvement in the morphological properties. The sensory evaluation results showed that date jam prepared with 9% DPC had the highest overall acceptability score. This study revealed the potential use of DPC in date jam formulation up to 9% as a natural, functional, and low-cost ingredient to improve the jam's textural properties, antioxidant capacity, and overall acceptability.

Keywords: antioxidants; by-product upgrading; date press cake; jam; microstructure; sensorial properties



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1. Introduction

Jam, a delicious semi-solid food product with an intermediate moisture level, is prepared by cooking fruit pulp with sugar, water, acid, and a gelling agent until a gelatinous consistency is obtained [1,2]. High methoxyl pectin (HMP), the most popular gelling agent, is extensively used in the traditional jam industry [2]. Although HMP is an excellent gelling agent, it is not considered the best option for manufacturers due to its high cost. Therefore, it is of vital importance to find a suitable and economic alternative to HMP. Date palm (*Phoenix dactylifera* L.), one of the oldest and most important fruit crops, is mainly cultivated in arid and semiarid regions including northern Africa, the Arabian Peninsula, and Iran [3,4]. According to FAO statistics, the annual global production of date palm reached 9.45 million tons in 2020, and the top five producing countries were Egypt, Saudi Arabia, Iran, Algeria, and Iraq with annual production of 1.69, 1.54, 1.28, 1.15, and 0.73 million tons, respectively [5]. The date has gained great importance due to its unique properties, i.e., high nutritional value, great health benefits, and economic advantages in addition to its role in agroecosystems [6]. Ripe date fruits can be eaten fresh or in a processed form, e.g., juice, syrup (Dibs), paste, pickle, bar, butter, and jam [4]. To the best of our knowledge, very few studies have been conducted to develop date jam [3,7].

The by-products of the date palm industry, e.g., date press cake (DPC), a by-product of date fruit syrup (Dibs) extraction, can be used in the food industry as low-cost, value-added materials, as they are rich in sugars, minerals, dietary fiber, pectin, phenolic compounds, and antioxidants [8–11]. Generally, the incorporation of fruit by-products in the food industry may add value and decrease the amount of waste, which can be in harmony with the UN sustainable development objectives [11,12]. Recently, great attention has been focused on the upcycling of agro-industrial by-products in the food industry for the development of value-added products with high functionality. Such a trend would help in decreasing environmental pollution, upgrading low-value products, developing innovative functional foods, and therefore supporting the local and global economy [13,14].

Previously published studies discussed the use of natural and low-cost gelling agents in jam processing, e.g., sago starch [2], peach dietary fiber [15], date pit powder [16], cocoa bean husk extract [17], pomegranate peel powder [18], locust bean gum [19], mosambi (*Citrus limetta*) peel powder [20], and tomato pomace [21].

However, no studies have been carried out on the use of DPC as a valuable by-product in jam production. Accordingly, the current research aimed to evaluate the incorporation of DPC as a source of dietary fiber alternative to HMP on the sensorial and functional characteristics of date jam.

2. Materials and Methods

2.1. Materials

Date fruits (*Phoenix dactylifera* L.) of the Khalas type, in the Tamer stage (15.20% initial moisture content), were obtained from the local market, Al-Hofuf, Al-Ahsa, Saudi Arabia. Khalas date press cake (DPC) was obtained from the Al-Jazirah Dates Factory (Al-Hofuf, Al-Ahsa, Saudi Arabia) and dried at 48 °C in an electric tray dryer for 48 h. Then, the dried DPC was ground to pass through a 0.25-mm sieve (60 mesh) and kept in a glass jar for further use. Chemicals and reagents were obtained from Sigma-Aldrich Co., Steinheim, Germany. Commercial sucrose and glass jars were purchased from the local market. The proximate analysis of the powdered DPC (Table 1) was determined by the standard method of AOAC [22].

Table 1. Proximate composition of date press cake on a wet weight basis.

Item	%
Moisture	8.47 ± 0.11
Crude protein	5.13 ± 0.09
Crude fat	2.36 ± 0.06
Crude fiber	27.70 ± 0.15
Ash	2.25 ± 0.04
Carbohydrate	54.08 ± 0.23

Values are expressed as the means ± standard deviation.

2.2. Preparation of Date Jam

Date jam ingredients and formulations are presented in Table 2. Date jam was prepared based on the procedure described by Besbes et al. [3] with few modifications. Date fruits, free of microbial infection and insect infestation, were selected, pitted, and carefully washed. The obtained flesh was boiled in water (1:2; *w/w*) for 10 min to form a paste. Subsequently, about 350 g of sugar was added; then, the DPC was added in the proportions of 0, 3, 6, 9, and 12% (*w/w*). Jam formulations were cooked in an open kettle with manual agitation to the end cooking point at 65° Brix. Pectin was added as a gelling agent only to the control sample. Citric acid was added at the end of cooking to adjust the pH of jam samples to 4.0 ± 0.1. The total soluble solids (TSS) content of processed jam samples was determined using a hand-held refractometer (Model N-3E, Brix 58–90%, ATAGO®, Tokyo, Japan), while pH was determined using a digital pH meter (Model AD1030, ADWA®, Szeged,

Hungary) [23]. Finally, the samples were hot packed in 1-kg glass jars at 85 °C, cooled, and kept at room temperature for further analysis.

Table 2. Formulation of date jam treatments with gradient quantity of date press cake (DPC).

Date Jam Formulations	A (Control) 0% DPC 0.4% Pectin		B 3% DPC 0% Pectin		C 6% DPC 0% Pectin		D 9% DPC 0% Pectin		E 12% DPC 0% Pectin	
	g	%	g	%	g	%	g	%	g	%
	Date fruit (Tamr)	342	34.2	316	31.6	286	28.6	256	25.6	226
Sugar	350	35	350	35	350	35	350	35	350	35
Water added	600	60	600	60	600	60	600	60	600	60
DPC	0	0	30	3	60	6	90	9	120	12
Pectin	4	0.4	0	0	0	0	0	0	0	0
Citric acid	4	0.4	4	0.4	4	0.4	4	0.4	4	0.4
* Water lost	−300	−30	−300	−30	−300	−30	−300	−30	−300	−30
** Total	1000	100	1000	100	1000	100	1000	100	1000	100

* The water lost by evaporation during cooking. ** Trail batch of the preparations (1 kg of final product).

2.3. Textural Properties

Texture profile parameters [hardness (g), cohesiveness (%), adhesiveness (mJ), and chewiness (mJ)] of date jam samples were determined using a texture analyzer (Model CT3 10K, Brookfield, MA, USA) according to the method described previously [3]. Operation conditions were automatically controlled and the data were collected, processed, and displayed using ‘TexturePro’ CT software. A fixed amount of each sample was placed in a plastic container (about 50 mm in depth) to obtain a uniform thickness for all samples. A cylindrical probe (TA4/1000) with a diameter of 38 mm was used to read the force of compression. Samples were compressed to a depth of 20 mm at a speed of 1 mm/s and a trigger load of 5 g. All determinations were conducted at a controlled room temperature (25 °C).

2.4. Color Measurements

The color properties of processed date jam samples were determined using a color reader (Model CR-10, Konica Minolta, Japan). The results were expressed as L^* (0 = black, 100 = white), a^* (+60 = redness, −60 = greenness), and b^* (+60 = yellowness, −60 = blueness). In addition, the total color difference (ΔE) was calculated as follows:

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (1)$$

where ΔL^* , Δa^* , and Δb^* refer to the differences between the estimated color parameters of the processed jam samples and the standard (used as samples’ background). The L^* , a^* , and b^* values of the standard were 94.91, 0.06, and 2.29, respectively [8].

2.5. Extraction of Phenolic Compounds

Phenolic compounds were extracted from date jam samples according to the procedure described previously [1] with few modifications. A total of 10 g of jam samples were added to 40 mL of methanol–water (50:50, v/v), homogenized for 1 h at 60 °C using a magnetic stirrer (Model RCT basic, IKA®, Staufen, Germany), and centrifuged at 4000× g for 10 min. The obtained supernatant was recovered while the residue was further mixed with 40 mL of acetone–water (70:30, v/v), homogenized for 1 h at 60 °C, centrifuged, and the obtained supernatant was recovered. Finally, both extracts were combined and mixed with distilled water for a total volume of 100 mL to determine total phenolic content and antioxidant activity.

2.6. Total Phenolic Content

The total phenolic content (TPC) was determined using Folin–Ciocalteu’s reagent according to the method outlined by Corrêa et al. [1]. The absorbance was measured at 765 nm using a JENWAY spectrophotometer (Model 6405 UV/VIS, JENWAY®, Staffordshire, UK). The TPC was calculated as milligram of gallic acid equivalent (GAE) per gram sample.

2.7. Antioxidant Activity

The antioxidant activity of date jam samples was evaluated using the DPPH radical scavenging method as previously described [24]. The absorbance values were taken by spectrophotometer at 515 nm and the results were expressed as the percentage of DPPH scavenging activity.

2.8. Scanning Electron Microscopy

The morphological features of jam samples were examined according to the method described by Basu and Shivhare [25]. Samples were freeze-dried using a lyophilizer (Model 4KBTXL-75, VirTis SP Scientific, PA, USA). Small pieces of dried samples were then fixed on the specimen stubs with double-face carbon tape and sputter coated with a thin layer of gold using a fine coat ion sputter (Model JFC-1100, JEOL, Tokyo, Japan). Samples were examined and the images were captured at different magnification levels using a scanning electron microscope (Model JSM-IT200, JEOL, InTouchScope™, Tokyo, Japan).

2.9. Sensory Evaluation

The sensory properties of date jam samples were assessed based on the method described earlier [26]. Ten panelists of both sexes had been selected from the staff members of the Center of Research Excellence in Date Palm, King Faisal University, Saudi Arabia, to perform the test. The date jam was taken out of the fridge 2 h before serving. Samples were placed in three-coded plastic containers and presented to the panelists at room temperature (25 ± 1 °C) under normal light conditions. Spoons and drinking water (for oral rinsing after each sample testing) were also provided. The panelists were asked to evaluate the color, odor, taste, texture (mouthfeel), spreadability, and overall acceptability of date jam samples following the nine-point hedonic scale.

2.10. Statistical Analysis

The determinations of the current study were conducted in triplicate and expressed as the mean \pm standard deviation. Significant difference ($p < 0.05$) between means was evaluated using one-way analysis of variance (ANOVA). Duncan’s multiple range test was conducted using statistical software (SPSS Inc., Chicago, IL, USA) [8].

3. Results and Discussion

3.1. Textural Properties

The textural attributes [hardness (g), cohesiveness (%), adhesiveness (mJ), and chewiness (mJ)] of the date jam samples prepared with different amounts of DPC are shown in Table 3. Texture profile analysis is considered a simulation of the chewing operation in the mouth; accordingly, it could be used to predict the behavior of a food product in the mouth. Hardness, a parameter that indicates the food’s resistance to deformation, is the peak force developed after the first compression cycle. In sensory studies, it represents the required force to compress a food product between the molars [2,18]. Moreover, cohesiveness refers to the strength of the internal bonds of the jam matrix that make up the body of the product [27]. It represents how well the product withstands a second deformation relative to the first one [3]. As shown in Table 3, the hardness and cohesiveness values of the date jam samples significantly ($p < 0.05$) increased with the increase in the DPC inclusion levels. As DPC contains significant amounts of fiber and thickeners, particularly pectin [3,28,29], the increase in the hardness values could be interpreted by the increase in the number of junction zones; thus the gel network would become more rigid with

increasing DPC concentration [2]. Similar findings have been reported earlier [16,18,20]. These authors observed that the addition of date pit powder, pomegranate peel powder, and mosambi (*Citrus limetta*) peel powder increased the hardness and cohesiveness of strawberry, pomegranate, and papaya jams, respectively.

Table 3. Texture properties of date jam prepared with different amounts of powdered date press cake (A: 0% DPC; B: 3% DPC; C: 6% DPC; D: 9% DPC; E: 12% DPC).

Treatments	Hardness (g)	Cohesiveness (%)	Adhesiveness (mJ)	Chewiness (mJ)
A	19 ± 0.37 ^e	0.74 ± 0.05 ^d	0.83 ± 0.01 ^e	1.51 ± 0.07 ^e
B	35 ± 0.33 ^d	0.80 ± 0.04 ^c	1.45 ± 0.02 ^d	2.63 ± 0.06 ^d
C	63 ± 0.52 ^c	0.89 ± 0.06 ^b	3.16 ± 0.05 ^c	6.45 ± 0.08 ^c
D	116 ± 1.08 ^b	0.94 ± 0.02 ^a	5.73 ± 0.04 ^b	10.22 ± 0.11 ^b
E	226 ± 1.17 ^a	0.98 ± 0.03 ^a	10.22 ± 0.06 ^a	22.94 ± 0.12 ^a
Significancy	<i>p</i> value	0.0001	0.0001	0.0001
	linear	0.0001	0.0001	0.0001
	quadratic	0.0001	0.403	0.0001

Values are expressed as the means ± standard deviation; $n = 3$. Means in the same column with different superscript letters are significantly different ($p < 0.05$).

In addition, adhesiveness, an important texture parameter, estimates the work required to remove the attractive forces between the product and the surface of the probe used. In sensory analyses, it is defined as the force necessary to remove the material that adheres to the lips, palate, teeth, or tongue. Accordingly, it could be used to predict the degree of adhesion of the food in the mouth [3,18]. As mentioned in Table 3, the date jam samples exhibited a gradual increase ($p < 0.05$) in the adhesiveness values when the DPC concentration increased. The increase in the date jam adhesiveness could be due to the fact that DPC is a rich source of fiber and gelling agents. Moreover, the DPC revealed improved functional properties, e.g., high water-holding capacity, emulsifying, pseudoplasticity behavior, and gel formation [28]. Hence, it can be used to modify the textural properties of various food products including jam. Our results were consistent with those reported previously [16,18,30]. These studies reported that the inclusion of date pit powder and coconut pulp increased the adhesiveness of strawberry and pineapple jams, respectively.

Chewiness is defined as the force needed to masticate the product to a consistency suitable for swallowing. It is the product of firmness, cohesiveness, and springiness [3]. The chewiness values of the date jam samples significantly ($p < 0.05$) increased with the increase in the DPC incorporation level (Table 3). Such an increase in the chewiness values could be attributed to the sticky nature of DPC. The obtained values of chewiness in the current study were consistent with those reported for date, papaya, and pineapple jams [3,20,30]. A similar trend for the effect of the by-product addition on the jam chewiness was reported by Younis et al. [20]. They observed that the chewiness values of papaya jam increased with the increase in the mosambi (*Citrus limetta*) peel powder incorporation level.

3.2. Color Measurements

Color is one of the most important quality parameters that affect consumer choice. The color parameters of formulated date jam with different incorporation levels of DPC are presented in Table 4 and Figure 1. The jam containing DPC revealed lower L^* values, with higher a^* , b^* , and ΔE^* values than the control sample. As the DPC incorporation increased, L^* values decreased, a^* and b^* values increased ($p < 0.05$), and ΔE^* (the total color change) insignificantly increased ($p > 0.05$). The values of the color parameters obtained in the present study were close to those reported earlier for strawberry jam and edible films enriched with date by-products [8,16]. The increase in the values of the color parameters (a^* and b^*) in the current research could be attributed to the presence of natural red-brownish pigments in the DPC. In contrast, Igual et al. [31] stated that the addition of bamboo fiber may increase the reflectance, which in turn increases the lightness (L^*)

of grapefruit jam. It is worth noting that no colorants were added to the jam samples in this study. In fact, colorants are used to overcome the color problems that always occur during jam processing, as the heat usually converts the natural pigments, particularly red, into brown components [15]. Additionally, all of the developed jam samples showed a slightly dark color, which could be due to the non-enzymatic browning that was mainly caused by sugar caramelization and Maillard reactions [31]. The trends obtained for the effects of DPC incorporation on the color parameters of the date jam samples in the current research were consistent with other reports [8,16,18]. It was observed in these reports that a^* and b^* values increased while L^* values decreased with increasing concentrations of fruit by-products in the formulated jams and edible films.

Table 4. Color parameters of date jam prepared with different amounts of powdered date press cake (A: 0% DPC; B: 3% DPC; C: 6% DPC; D: 9% DPC; E: 12% DPC).

Treatments		L^*	a^*	b^*	ΔE
	A	28.39 ± 0.61^a	1.97 ± 0.06^e	2.67 ± 0.05^e	67.12 ± 0.65^b
	B	27.86 ± 0.37^{ab}	3.14 ± 0.08^d	2.84 ± 0.04^d	67.69 ± 0.82^{ab}
	C	27.42 ± 0.46^{bc}	3.36 ± 0.09^c	3.05 ± 0.06^c	68.14 ± 0.73^{ab}
	D	26.98 ± 0.52^{bc}	3.75 ± 0.07^b	3.38 ± 0.05^b	68.61 ± 0.84^{ab}
	E	26.57 ± 0.45^c	4.01 ± 0.09^a	3.63 ± 0.07^a	69.03 ± 0.91^a
Significancy	<i>p</i> value	0.008	0.0001	0.0001	0.005
	linear	0.0001	0.0001	0.0001	0.000
	quadratic	0.825	0.0001	0.040	0.795

Values are expressed as the means \pm standard deviation. Means in the same column with different superscript letters are significantly different ($p < 0.05$).

3.3. Total Phenolic Content

Polyphenols or TPC are a group of bioactive compounds present in plant tissues, particularly vegetables and fruits, as secondary metabolites [32]. Due to their antioxidant, anti-diabetes, and anti-inflammatory activities, polyphenols may protect against cancer, diabetes, and cardiovascular diseases [33]. The TPC of the developed date jam varied between 310.84 and 435.25 mg GAE/100 g (Figure 2). The TPC values of the date jam in the current study were close to those reported for hard date jam by Besbes et al. [3], but higher than those reported for raspberry and strawberry jam by Martinsen et al. [34], that are mainly due to the variations in the amounts and types of phenolic compounds among different fruits. Date jam containing DPC showed higher TPC values compared to the control. In general, it could be observed that the TPC values increased significantly ($p < 0.05$) with the increase in the DPC concentration. Jam containing 12% DPC had the highest TPC values, while the control had the lowest. Since DPC contains a significant amount of phenolic compounds [11], this could be responsible for the increase in the TPC values of the developed date jam. Additionally, Najib and Al-Yousef [35] reported that the dried DPC obtained from different date varieties contained 165–436 mg GAE/100 g. However, the high dietary fiber and phenolic content in developed date jam could have a positive effect on human health. The effect of DPC incorporation on the TPC of date jam in the current study was similar to the findings reported by Correa et al. [1] and Hernández-Hernández et al. [17], who found that the addition of concentrated grape juice and cocoa bean husk extract increased the TPC of guava and olive jam, respectively.

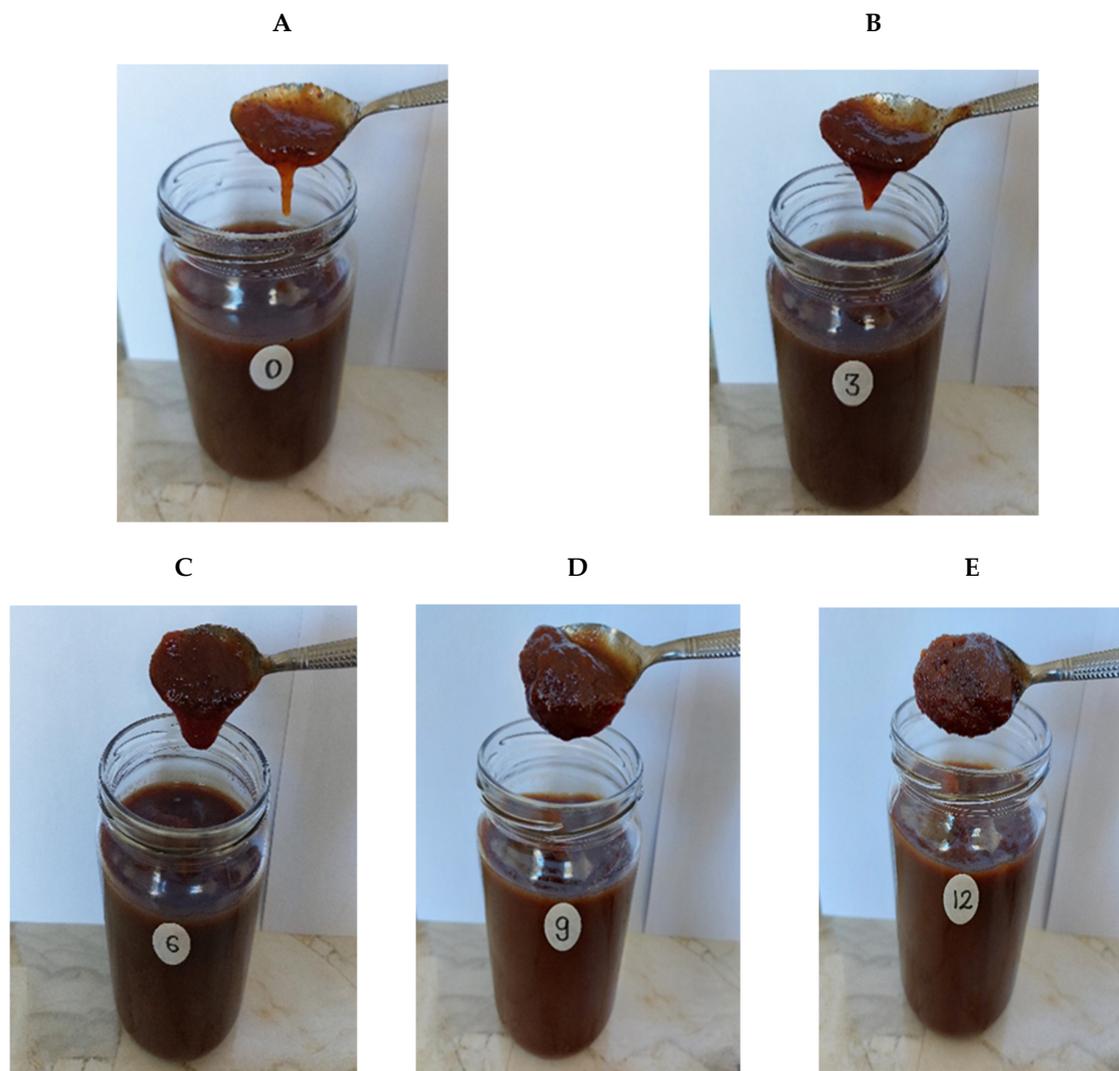


Figure 1. Date jam prepared with different amounts of powdered date press cake (A: 0% DPC; B: 3% DPC; C: 6% DPC; D: 9% DPC; E: 12% DPC).

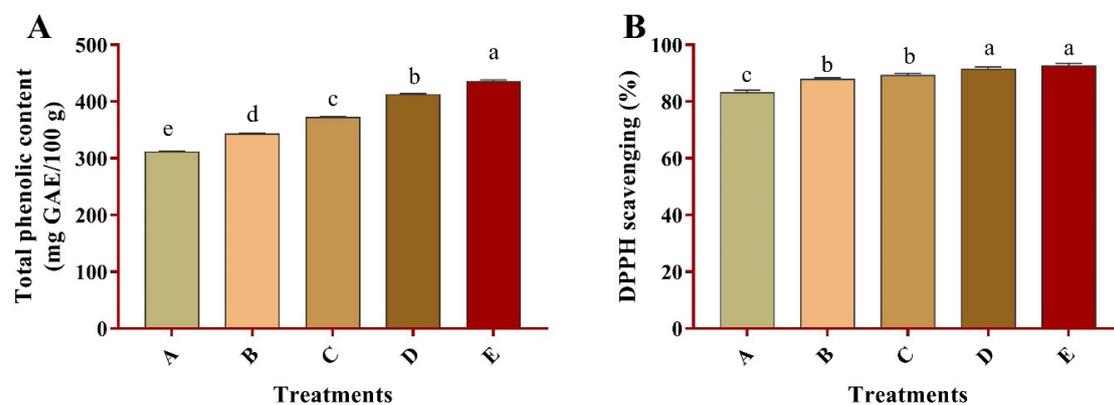


Figure 2. Total phenolic content (A), antioxidant activity (DPPH scavenging, (B)), of date jam prepared with different amounts of powdered date press cake. Values are expressed as the means \pm standard deviation. Columns bearing with different superscript letters are significantly different ($p < 0.05$). A: 0% DPC; B: 3% DPC; C: 6% DPC; D: 9% DPC; E: 12% DPC.

3.4. Antioxidant Activity

Figure 2 presents the antioxidant activity of formulated date jam with different incorporation levels of DPC. The antioxidant activity values of the date jam obtained in the present research were similar to those reported by Kopjar et al. [36] for strawberry jam, but higher than those reported by Correa et al. [1] and Aslam et al. [27] for guava- and jamun-based jam, respectively. The variations in the antioxidant activity may be related to the differences in the phenolics content, which could be attributed to the biological origin of the plant. Date jam containing 12% DPC showed the highest antioxidant activity, whereas the control sample showed the lowest. Generally, it was noted that the date jam revealed a gradual increase ($p < 0.05$) in the antioxidant activity with increasing DPC concentration. Such increase could be due to the fact that the DPC is a rich source of phenolic compounds, which in turn could be responsible for the increase in the antioxidant activity. A study conducted by Al-Farsi et al. [37] on the characteristics of dates and their by-products pointed out that DPC is a rich source of natural antioxidants (134–357 micromoles of Trolox equivalents per gram). Accordingly, such by-products could potentially be used as a functional food or functional food ingredient. Our findings of antioxidant activity in the present study were consistent with those reported by Correa et al. [1] and Hernández-Hernández et al. [17] for guava- and olive-based jams, respectively. These authors observed an increase in the antioxidant activity of the developed jams with increasing additions of concentrated juice and cocoa bean husk, respectively.

3.5. Microstructure of Date Jam

Scanning electron microscopy (SEM) was used to study the effect of DPC incorporation on the morphological properties of the developed jam. This approach provides a clear and detailed view of the microstructure of the examined product. The micrographs of the date jam treatments prepared with different incorporation levels of DPC are displayed in Figure 3. The control sample revealed a smooth surface with few convex areas, which could be related to the presence of insoluble particles developed during the jam preparation process (Figure 3A). The addition of DPC up to 9% revealed better morphological properties of the jam's surface compared to the control sample. The samples containing 3, 6, and 9% of DPC exhibited a denser network with homogeneous structure and without cracks and pores (Figure 3B–D). It is noteworthy that DPC is a rich source of fiber and gelling agents. These may increase in the number of junction zones, leading to the formation of a strong gel network that may improve the date jam structure.

However, few aggregates were observed in the micrographs of these samples, which was mainly due to the incorporation of DPC. In contrast, a further increase in DPC to 12% resulted in a dramatic change in the microstructure properties of the date jam. As shown in Figure 3E, heterogeneous areas appeared on the surface with more particles' aggregates leading to a rough structure. The higher concentrations of DPC increased the amount of insoluble fibers, resulting in the formation of more agglomerated particles with heterogeneous areas. This in turn decreased the mouthfeel sensory scores of the jam. The microstructure findings obtained by SEM were consistent with those determined by the sensory panel evaluation (Section 3.6). Similar microstructure findings were observed by Basu and Shivhare [26] and Massoud et al. [38] for mango, strawberry, apricot, and apple jam, respectively. These authors reported that the addition of gelling agents, such as xanthan, inulin, and pectin improved the microstructure properties of the developed jams.

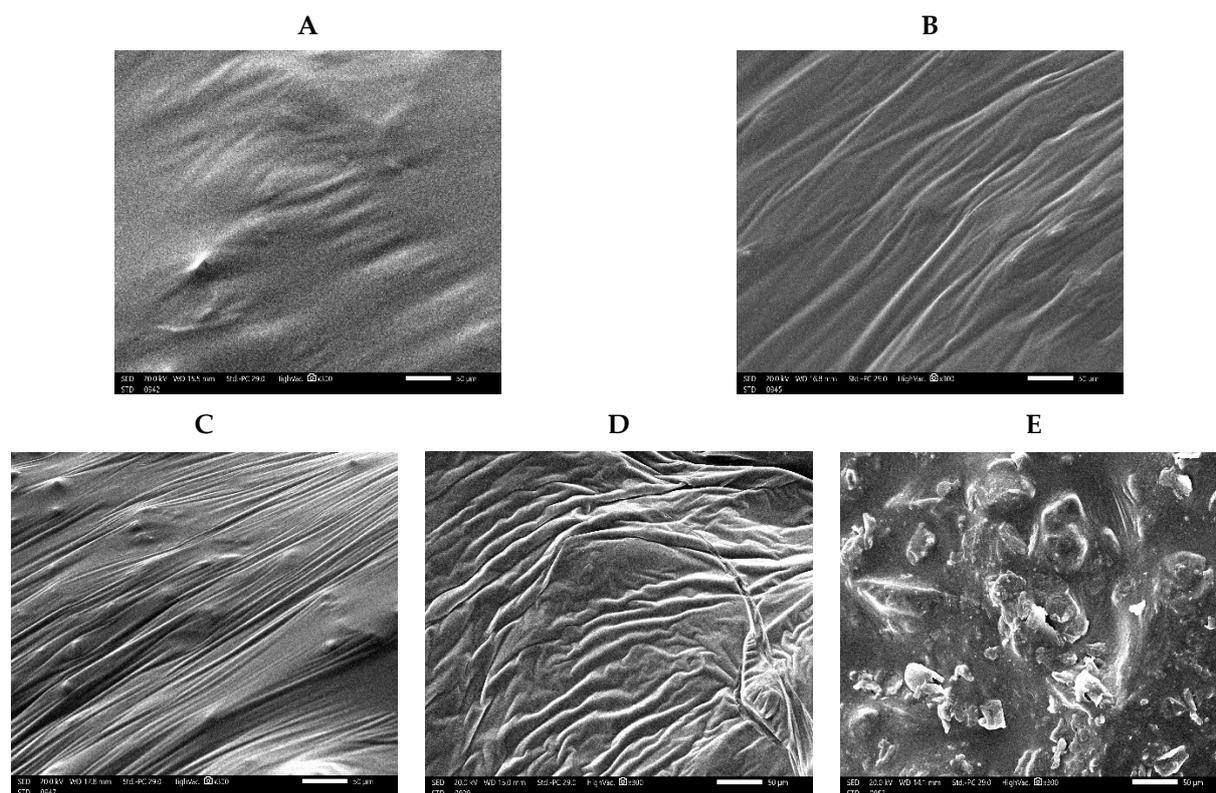


Figure 3. Scanning electron micrographs of date jam prepared with different amounts of powdered date press cake (A: 0% DPC; B: 3% DPC; C: 6% DPC; D: 9% DPC; E: 12% DPC).

3.6. Sensory Evaluation

Sensory evaluation of the date jam was conducted to assess consumer perception and acceptability. The scores of the sensory parameters [color, odor, taste, texture (mouthfeel), spreadability, and overall acceptability] of the formulated date jam with different concentrations of DPC are shown in Table 5. Regarding the color, it was observed that the addition of DPC slightly decreased the color scores of the date jam. Namely, the samples containing DPC were slightly darker than the control, which could be due to the natural red-brownish pigments present in the DPC. In addition, the sugars present in DPC may increase the caramelization and Maillard reactions leading to non-enzymatic browning. The results for color obtained by the sensory panel evaluation were consistent with the results presented in the color measurements section.

Table 5. Sensory properties of date jam prepared with different amounts of powdered date press cake (A: 0% DPC; B: 3% DPC; C: 6% DPC; D: 9% DPC; E: 12% DPC).

Treatments	Colour	Odour	Taste	Texture (Mouth Feel)	Spreadability	Overall Acceptability	
A	8.85 ± 0.21 ^a	7.52 ± 0.19 ^c	7.97 ± 0.23 ^a	7.31 ± 0.08 ^c	7.69 ± 0.14 ^d	7.87 ± 0.29 ^{bc}	
B	8.63 ± 0.14 ^{ab}	8.13 ± 0.16 ^b	8.24 ± 0.16 ^a	7.94 ± 0.13 ^b	8.09 ± 0.11 ^c	8.21 ± 0.25 ^b	
C	8.56 ± 0.16 ^{ab}	8.64 ± 0.22 ^a	8.60 ± 0.31 ^a	8.71 ± 0.24 ^a	8.47 ± 0.12 ^b	8.60 ± 0.19 ^a	
D	8.39 ± 0.18 ^{bc}	8.87 ± 0.28 ^a	8.76 ± 0.18 ^a	8.80 ± 0.17 ^a	8.75 ± 0.15 ^a	8.71 ± 0.14 ^a	
E	8.12 ± 0.17 ^c	7.36 ± 0.14 ^c	6.94 ± 0.09 ^b	6.59 ± 0.10 ^d	8.89 ± 0.19 ^a	7.58 ± 0.15 ^c	
Significancy	<i>p</i> value	0.005	0.0001	0.0001	0.0001	0.0001	0.0001
	linear	0.0001	0.286	0.002	0.067	0.0001	0.813
	quadratic	0.605	0.0001	0.0001	0.0001	0.075	0.0001

Values are expressed as the means ± standard deviation. Means in the same column with different superscript letters are significantly different ($p < 0.05$).

The odor and taste scores of the date jam samples increased gradually with the increase in DPC concentration up to 9% (Table 5). Singh et al. [39] reported that the favored aroma of jam enriched with fruit pulp could be developed due to the interaction between sucrose and organic acids. Moreover, the increase in reducing sugars and soluble solids content could be responsible for the increased taste scores [16]. On the contrary, a further increase in the DPC content to 12% resulted in decreased odor and taste scores. Indeed, the panelists observed a strong odor with a sour taste in the samples containing 12% DPC, which could be related to the higher content of organic acids at a higher incorporation level of DPC. Regarding the texture, the date jam incorporated with DPC up to 9% showed higher texture scores in terms of mouthfeel (Table 5). However, a further increase in the DPC content to 12% resulted in a dramatic decrease in the mouthfeel scores. It is worth noting that the date jam prepared with 12% DPC had more granular structure than the other samples due to the presence of more rough particles, which was consistent with the SEM results.

As shown in Table 5, the spreadability scores of the date jam samples significantly ($p < 0.05$) increased with the increase in the DPC concentration, which could be due to the richness of DPC in fiber and gelling agents, particularly pectin. Additionally, a previous study conducted by Belović et al. [21] on tomato pomace-based jam reported that the spreadability could be related to stickiness and adhesiveness. Generally, the jam containing 12% DPC revealed the highest spreadability scores, whereas the control showed the lowest. It could be noted that the findings of spreadability obtained by the sensory panel evaluation were in accordance with those determined by the texture analyzer (Section 3.1).

The overall acceptability scores of the date jam varied from 7.58 to 8.71. In general, the acceptability of the date jam improved with increasing DPC concentration up to 9%, whereas a further increase to 12% resulted in a decreased overall acceptability score (Table 5). Generally, the overall acceptability was rated highest (8.71) for the date jam prepared with 9% DPC. The effects of DPC concentration on the sensory properties of date jam in the present research were consistent with those reported in the literature [15,16,18,21]. Previous studies found that strawberry, pomegranate, and tomato jam enriched with different types of fruit by-products revealed acceptable sensory properties.

4. Conclusions

Date jam with different incorporation levels of DPC were successfully processed and characterized. The addition of DPC improved the texture properties, phenolics content, and antioxidant activity of the jam. The color attributes of the developed jam were slightly changed with the addition of DPC. The morphological characteristics and sensory properties of the jam were significantly improved with the incorporation of DPC up to 9%. In contrast, a further increase of DPC incorporation to 12% resulted in negative morphological characteristics and sensory properties. The present research reflects the potential use of DPC as a natural, functional, and low-cost ingredient in date jam manufacturing. Although the developed date jam exhibited improved physico-chemical and organoleptic properties, further studies on processing conditions and storage stability are needed.

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