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Effect of substituted gelling agents from pomegranate peel on colour, textural and sensory properties of pomegranate jam

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ABSTRACT

A series of pomegranate jams were prepared from a Tunisian ecotype (Tounsi) with different amounts of sugar (10, 20 and 30%) and low-methoxylated pectin (0.2, 0.7 and 1.2%). The most appreciated formulation was that contaning 30% sugars and 0.2% pectin. Then, commercial pectin was substituted by other gelling agents (pomegranate peel powders dried at 50 °C vs lyophilized, pectin and fibre extracted from pomegranate peel) for the preparation of pomegranate peel-based jams. The elaborated jams were evaluated for physichochemical, colour, texture and sensory characteristics. Results revealed that the jam (JPP2) elaborated with 0.2% pectin extracted from pomegranate peel exhibited similar overall acceptability to that prepared with commercial pectin. However, it was more acceptable than other pomegranate peel-based jams, which was related to a better appreciation of sweetness and colour. According to the colour and texture measurements, this sample (JPP2) was more reddish and less firm than other samples.

1. Introduction

Cooking jams is one of the oldest food preserving processes allowing fruit consumption in the off-season. According to the European Union Council Directive, 2004, jams are mixtures of sugars, pulp and/or puree of one or more fruits and water brought to a suitable gelled consistency (Holzwarth, Korhummel, Siekmann, Carle, & Kammerer, 2013). Addition of gelling agent is important to ensure that the jam product has a reasonable thick consistency and is firm enough to hold the fruit puree-sugar in position. Pectin is primarily used in food industry as a gelling agent for jams, jellies, and other foods (El-Nawawi & Heinkel, 1997). Pectins are classified into two broad classes – low methoxyl (LM) pectin with a degree of methylation (DM) less than 50%, and high methoxyl (HM) pectin with a DM more than 50%. It was reported that different pectins and their concentrations affect colour and texture of jam (Kopjar et al., 2009). Nevertheless, other alternative gelling agents could be used in the elaboration of new formulations of jam. The development of new products contributes to the diversification of the market possibilities, especially if they are attractive, practical and have a long shelf life. However, jams incorporated with alternative gelling agent should have textural and sensory attributes that are similar to the traditional jam product.

Many studies are available on the elaboration of jams with an alternative gelling agent such as sago starch and carboxymethyl cellulose (Javanmard, Chin, Mirhosseini, & Endan, 2012); however, there are no available studies devoted to the effect of using pomegranate peel as gelling agent.

Pomegranate (*Punica granatum* L.) is increasingly consumed in recent years as various products such as juices, jams and jellies. In pomegranate juice industry, 1 ton of fresh fruit generates 669 kg by-product containing 78% peel and 22% seeds (Qu et al., 2009). This large amount of pomegranate peel generated could have industrial applications and be used as ingredient in food formulations due to its richness in LM pectin and fibre (Abid, Cheikhrouhou, & Renard, et al., 2017). Low methoxyl (LM) pectins are often used in low-sugar products due to their gel-forming properties without or with a small amount of sugar and in the presence of Ca^{2+}. For fibre contribution, Grigelmo-Miguel and Martin-Belloso (1999) reported that this fraction could aid the gel formation and texture stability of the product by avoiding syneresis which occurs in many food products with a gel structure, including jams and yoghurt.

To the best of our knowledge, many studies are available on the sensory and textural characteristics of fruit jams (Basu & Shivhare, 2010; Basu, Shivhare, Singh, & Beniwal, 2011; Fu & Rao, 2001), however only few studies were focused on the study of pomegranate jam (Melgarejo, Martínez, Hernández, Martinez, & Legua, 2011), and besides there are no available studies which focused on the effect of substitution of gelling agents by pomegranate peel

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in jams. Therefore, the objective of the present study was to develop pomegranate jam product incorporated with pomegranate peel powder, rich in pectin and fibre, and to study the effect of substitution of commercial pectin by that extracted from pomegranate peel on jam characteristics.

2. Materials and methods

2.1. Plant material

Pomegranates from ecotype "Tounsi" (To) were used in this study. Pomegranate fruits were collected from an oasis at Gabes region (southeast of Tunisia) at mature stage. Fruits were manually peeled and edible parts (arils with seeds) were ground using a manual food mill (PR-0020, hole size 3 mm, China) to obtain pomegranate puree and kept at −20 °C until jam preparation.

The collected peels were ground into small pieces (particles' size were 1–3 mm) and stored at −12 °C for further physicochemical characterization. Peels were dried by two methods (oven drying at 50 °C until constant weight and freeze-drying), ground using Moulinex-the genuine Type LM240 and milled through 0.5 and 1.25 mm sieves. Final oven-dried powders with sizes between 0.5 and 1.25 mm were retained for pectin extraction. Both oven and freeze-dried powders with particles size <0.5 mm were used as gelling agents in pomegranate jams.

2.2. Physichochemical analysis of pomegranates from ecotype Tounsi

Twenty pomegranates, randomly chosen, were weighted on a balance of accuracy of 0.001 g (Mettler Toledo-PG503-S DeltaRange) then the peels were manually separated from the fruits, and the percentage of edible parts and peels per fruit were measured. Using a digital caliper (±0.01 mm), the length, the width and the height of 100 arils, randomly chosen from different pomegranates, were measured.

Proximate composition (dry matter, fat, ash and protein content) was determined according to the method described by the Association of Official Analytical Chemists (AOAC, 1997). Dry matter was determined by drying samples at 105 ± 3 °C to constant weights (AOAC, 1997). The total ash was determined by calcination in muffle furnace at 550 °C until constant weight was obtained (AOAC, 1997). The total nitrogen concentration was obtained using Kjeldahl method (AOAC, 1997), and the protein concentration was estimated using a nitrogen conversion factor of 6.25. Fat content was determined by Soxhlet extraction with hexane at boiling point of the solvent (AOAC, 1997). Total fibre content was determined according to the AOAC enzymatic-gravimetric method of Prosky, Asp, Schweizer, De Vries, and Fruda (1988). The total sugar content was determined by the phenol-sulphuric acid method of Dubois, Gilles, Hamilton, Rebers, and Smith (1956) after extraction with ethanol solution 96% (v: v). The insoluble sugars content was determined by the same method after hydrolyse of the insoluble fraction with chloridric acid (30%) at 60 °C for 2 h. The total sugars content is the sum of soluble and insoluble sugar. Pectin content was determined by the colorimetric method described by Englyst, Quigley, and Hudson (1994).

2.3. Pectin extraction

Pectins were extracted from pomegranate peel of Tounsi ecotype as described previously by Abid, Cheikhrouhou, & Renard, et al. (2017). The extraction conditions were optimized in a previous work (80 min, 86 °C and 20 mmol/L nitric acid) (Abid et al., 2016). The obtained pectin was dried at 45 °C to a constant weight and stored at room temperature for further jams' preparation. This extraction was repeated 12 times to collect the quantity of pectin needed to jams' preparation. The degree of methoxylation (DM) of pectin extracted (37%) was determined in a previous work (Abid, Cheikhrouhou, & Renard, et al. (2017)).

2.4. Fibre extraction

Fibres were extracted from fresh pomegranate peel (Tounsi) previously ground. The sample was maintained in hot water (85 °C) at the ratio of 4 :1 (v/w) for 5 min, then he mixture was filtrated with a thin cloth in order to separate the insoluble residue. The concentration of fibre was realised by a succession of two rinsings (water at 40 °C–10 min) in order to exempt the residue from simple sugars. Fibre extracts were dried at 50 °C to a constant weight then milled. Final powders with sizes <0.5 mm were retained for further incorporation in jam.

2.5. Preparation of jams

Pomegranate puree was mixed with half the quantity of sugar and stirred at room temperature until dissolution of sugar. Then, pH was adjusted to 3 with citric acid 10% (w/v) and the mixture was heated. When the temperature reached 77–82 °C, the rest of sugar, previously mixed with pectin, was added and stirred (Smith, 2003). Then, calcium was added (0.1%) and the mixture was heated until boiling. Pomegranate jams were cooked until the final product contained 65% of soluble solids (determined by refractometer (Bellinghan, & Stanley Ltd., Tunbridge Wells, United Kingdom) at 20 °C). Hot jams were poured into glass jars with screw caps and stored at 4 °C until use.

Nine pomegranate jam formulations (A, B, C, D, E, F, G, H, I) were prepared with different amounts of fruits, sugars and pectins. The commercial pectin used (Unipectine AYS 407c) was low methoxylated (degree of methoxylation = 26–32%). The conditions and coding of prepared jams are represented in Table 1.

After characterization of these nine samples (colour, texture and sensory evaluation), the sugar and pectin contents of the best selected jam, scoring the highest average acceptability, were fixed for the preparation of jams incorporated with pomegranate peel (JPP) (Table 2). It is important to note that the best selected jam was prepared once again in the same conditions of JPP jams and was coded J1.

Jams (JPP) were prepared by substituting the commercial pectin (of J1) by that extracted from peel (in JPP2), by enriching with fibre (3%) (in JPP3) and by incorporating the dry and the lyophilized peel powders (in JPP4/JPP6 and JPP5/JPP7, respectively). Taking into account the content of peel in pectin and fibre, the required quantities of peels were added i) in JPP4 and JPP5 to reach a final pectin concentration as it was fixed in the best selected jam (J1) and ii) in JPP6 and JPP7 to reach a final fibre concentration of 3%.

Table 1
Conditions and designation of different jam's formulations.

Sample	Added sugar (%)	Added commercial pectin (%)
A	30	0.2
B		0.7
C		1.2
D	20	0.2
E		0.7
F		1.2
G	10	0.2
H		0.7
I		1.2

Table 2
Jams preparation with different gelling agents.

Jam	Gelling agent
J1	0.2% commercial pectin commercial (Unipectine AYS 407c)
JPP2	0.2% pectin extracted from pomegranate peel (PPP)
JPP3	0.2% (PPP) + 3% fibre extracted from pomegranate peel
JPP4	Dry pomegranate peel powder (0.2% pectin)
JPP5	Lyophilized pomegranate peel powder (0.2% pectin)
JPP6	Dry pomegranate peel powder (3% fibre)
JPP7	Lyophilized pomegranate peel powder (3% fibre)

2.6. Analysis of jams

2.6.1. Physichochemical properties

The pH was measured at 20 °C using a Metrohom 744 pH meter (Metrohm, Herisau, Switzerland). The water activity was measured by a NOVASINA a_w Sprint TH-500 apparatus (Novasina, Pfaffikon, Switzerland). The measurement was performed at 25 °C. The dry matter was determined as described in section 2.3.

2.6.2. Colour measurement

CIE-$L^*a^*b^*$ colour coordinates (10° observer and D65 illuminant) were obtained using tintometer (Lovibond, PFX195, UK). The L^*, a^*, and b^* values indicate lightness/darkness, greenness/redness, and yellowness/blueness, respectively (Renuka, Prakash, & Prapulla, 2010).

2.6.3. Texture analysis

Texture properties of pomegranate jams were determined by TPA (Texture profile analysis) test. A Texture Analyzer (Analysis LLOYD instruments, Fareham, UK) interfaced to a personal computer (Windows-based Software NEXYGEN PLOT) was used to measure the force-time curve for a two-cycle compression. Jams were poured into plastic food containers to have 40 mm height. A cylindrical probe (19 mm diameter) was used to compress the sample to a 20 mm depth with a displacement spped of 40 mm/min and a trigger detection force of 0.005 kg. All instrumental texture analyses were conducted at room temperature.

2.6.4. Sensory evaluation

Pomegranate jams were served at room temperature under normal light conditions within 50 ml cups with three-digit randomized codes. Hedonic evaluation was carried out by an untrained panel (30 subjects) of both sexes from the students and the staff members of the National School of Engineer (Sfax, Tunisia). Colour, odour, sweetness, acidity, texture and overall acceptability of pomegranate jams were evaluated by the five-point hedonic scale, from 0 (very disliked) to 5 (very liked). Each panellist tested approximately the same amount of each sample and mineral water was provided to the assessors to rinse their mouths. As a first step, the nine samples were evaluated at the same time and by the same consumers (jam consumers).

The pomegranate peel-based jams, which were prepared in a next step, were evaluated also by the same consumers. All pomegranate jams were evaluated 48 h after preparation.

2.7. Statistical analysis

Experiments were conducted in triplicate and the differences between treatment means were determined by Duncan's procedure at $p < 0.05$ using the SPSS statistics 19. The expressed values are means ± standard deviation of triplicate measurements.

3. Results and discussion

3.1. Physicochemical properties of pomegranate peel and edible part

The physical characteristics of Tounsi ecotype are described in Table 3. The fruit weight, the peel and the edible part contents were 456.43 g, 196.21 g and 246.74 g, respectively. The fruit weight of the studied ecotype was higher than that of pomegranates grown in Iran, varying within the range of 164.89 g and 375.76 g (Sarkhosh, Zamani, Fatahi, & Ranjbar, 2009). Shulman, Fainbertein, and Lavee (1984) reported that the variation of fruit weight depend on the cultivar and the ecological conditions. The edible part content, constituting 54.06% of the whole fruit, was comparable to that of Jabal cultivar grown in the Sultanate of Oman ranging between 216.69 and 267.09 g (Al-Said, Opara, & Al-Yahyai, 2009).

The study of Tounsi arils' characteristics showed that the length (11.7 mm) was comparable to that of Sefri ecotype (11.6 mm) and superior to that of Bouaâdime ecotype (10.9 mm) grown both in Morocco. However, the width of Tounsi arils was superior to that of these two ecotypes (Sefri and Bouaâdime) (8.4 mm vs 7.8 and 6.4 mm, respectively) (Martínez et al., 2012).

The chemical characteristics of pomegranate puree and peel are displayed in Table 3. Contrary to the peel which was devoid of fat, pomegranate puree contained about 2.1% of fat. The pomegranate puree presented a total soluble solids of 15.45 °Brix which was in accordance with Ozgen, Durgac, Serc, and Kaya (2008) for turkish cultivars (14.7–19.0 °Brix). Pomegranate puree was characterized by its richness in sugar (67.5%). This content was higher than that of pomegranate grown in Dar es Salaam-Tanzania (48.9%) (Hellen, Christina, & Othman, 2014). Nevertheless, pomegranate puree had a relatively low total fibre and pectin contents (11.21 and 3.47%, respectively) compared to the peel (33.93 and 6.63%, respectively). It can be noticed from our results that chemical characteristics varied markedly among pomegranate parts.

3.2. Characteristics of the prepared jams with different formulations

3.2.1. Physichochemical characteristics

Table 4 presents the physichochemical characteristics of pomegranate jams prepared with commercial pectin. pH values ranged

Table 3
Some physichochemical properties of pomegranate (Tounsi).

Physical properties	Fruit weight (g)		456.43 ± 47.34
	Edible part (%)		54.06 ± 6.09
	Peel (%)		42.99 ± 6.51
	Length of arils (mm)		11.70 ± 0.72
	Width of arils (mm)		8.40 ± 0.66
	Height of arils (mm)		7.17 ± 0.67
Chemical properties (g/100 g DW)	Dry matter	Peel	27.32 ± 0.79^b
		Puree	16.15 ± 0.03^a
	Ash	Peel	4.52 ± 0.75^b
		Puree	0.47 ± 0.12^a
	Protein	Peel	5.84 ± 0.38^b
		Puree	3.37 ± 0.07^a
	Fat	Peel	ND ^{a}
		Puree	2.13 ± 0.12^b
	Total sugar	Peel	34.83 ± 0.79^a
		Puree	67.50 ± 3.41^b
	Total fibre	Peel	33.93 ± 0.66^b
		Puree	11.21 ± 0.31^a
	pectin	Peel	6.45 ± 0.23^b
		Puree	3.47 ± 0.27^a
	°Brix	Puree	15.45 ± 0.05

Significant differences between peel and puree for each component are indicated by different letters ($P < 0.05$); DW: dry weight; ND: not detected.

Table 4
Physicochemical characteristics of pomegranate jams.

Jam sample	pH	aw	DM	L^*	a^*	b^*
A	3.11 ± 0.05^{c}	0.797 ± 0.00^{b}	59.40 ± 0.90^{e}	51.61 ± 2.21^{b}	11.34 ± 1.64^{b}	2.32 ± 1.08^{a}
B	2.97 ± 0.01^{c}	0.783 ± 0.00^{a}	57.70 ± 0.80^{d}	50.18 ± 0.20^{b}	12.08 ± 0.12^{b}	4.06 ± 0.22^{b}
C	3.08 ± 0.05^{b}	0.791 ± 0.00^{bc}	58.05 ± 0.35^{d}	48.6 ± 1.28^{b}	14.57 ± 0.26^{c}	3.75 ± 0.12^{b}
D	2.88 ± 0.01^{a}	0.786 ± 0.00^{ab}	58.00 ± 1.10^{d}	47.56 ± 0.22^{b}	12.06 ± 0.06^{b}	3.92 ± 0.13^{b}
E	$3.06e \pm 0.01^{e}$	0.796 ± 0.00^{cd}	53.60 ± 0.80^{c}	$45.\ 34 \pm 1.8^{a}$	9.36 ± 0.27^{a}	2.30 ± 0.05^{a}
F	3.00 ± 0.05^{b}	0.836 ± 0.00^{e}	51.10 ± 0.80^{b}	45.29 ± 0.63^{a}	12.07 ± 0.18^{b}	4.97 ± 0.41^{c}
G	2.97 ± 0.05^{b}	0.836 ± 0.00^{e}	49.70 ± 0.30^{a}	44.51 ± 0.80^{a}	9.85 ± 0.02^{a}	4.10 ± 0.22^{b}
H	2.99 ± 0.00^{b}	0.822 ± 0.00^{e}	51.15 ± 0.35^{b}	44.48 ± 3.50^{a}	9.08 ± 0.02^{a}	3.64 ± 0.52^{b}
I	2.99 ± 0.00^{b}	0.809 ± 0.00^{e}	53.20 ± 0.30^{c}	44.36 ± 1.40^{a}	9.81 ± 0.57^{a}	3.99 ± 0.56^{b}
J1	2.89 ± 0.01^{D}	0.786 ± 0.00^{C}	61.55 ± 0.01^{B}	44.38 ± 0.29^{G}	14.40 ± 0.14^{F}	2.1 ± 0.09^{E}
JPP2	2.83 ± 0.01^{C}	0.771 ± 0.00^{B}	64.31 ± 0.03^{CD}	38.97 ± 0.18^{E}	13.13 ± 0.06^{E}	0.95 ± 0.06^{C}
JPP3	2.82 ± 0.01^{C}	0.803 ± 0.03^{D}	60.3 ± 0.41^{AB}	43.49 ± 0.02^{F}	10.62 ± 0.01^{D}	1.34 ± 0.01^{D}
JPP4	2.70 ± 0.01^{A}	0.769 ± 0.01^{B}	66.50 ± 0.02^{E}	33.02 ± 0.09^{B}	8.23 ± 0.22^{AB}	-0.41 ± 0.29^{AB}
JPP5	2.7 ± 0.01^{A}	0.761 ± 0.00^{A}	63.60 ± 0.06^{C}	36.69 ± 1.15^{D}	8.48 ± 0.03^{C}	-0.53 ± 0.03^{A}
JPP6	2.79 ± 0.01^{B}	0.736 ± 0.01^{A}	65.25 ± 0.15^{DE}	31.82 ± 0.27^{A}	8.15 ± 0.01^{A}	-0.55 ± 0.04^{A}
JPP7	2.79 ± 0.00^{B}	0.816 ± 0.03^{E}	59.80 ± 1.30^{A}	35.23 ± 1.98^{C}	8.35 ± 0.01^{BC}	-0.23 ± 0.02^{B}

Means of jams (A, B, C, D, E, F, G, H, I) in each column followed by different lower case letters are significantly different ($P < 0.05$); ±, standard deviation.
Means of pomegranate peel-based jams (J1, JPP2, JPP3, JPP4, JPP5, JPP6, JPP7) in each column followed by different capital letters are significantly different ($P < 0.05$); ±, standard deviation.

between 2.88 and 3.11. This parameter was beforehand fixed to 3 by addition of the citric acid to the formulation. Acidity of the fruit or its pH value is one of the most important factors in jam process which should be monitored and controlled. Indeed, acidity is an imperative fact influencing pectin gelation, texture and overall quality of fruit jams. (Garrido, Lozano, & Genovese, 2015)

Jams had water activity (aw) values ranging between 0.783 and 0.836, making them safe from the development of the majority of bacteria since their aw is lower than 0.86 (El-Gerssifi, 1998). The aw of jams prepared with 90% fruits (G, H, I) was higher than that of other samples due to their low sugar content.

The dry matter of formulated jams ranged between 49.7 and 59.4%. This content is considered high with regard to the raw material, which is due to the loss in water during the cooking process. The dry matter contents were higher for jams with 70% of fruits than those with 90% of fruits. It is important to note that the high dry matter is directly related to the conservation of the product in storage and to a longer jam's shelf life.

3.2.2. Colour

One of the most important parameters to which consumers are sensitive when selecting foods is the colour. The tristimulus colour system CIELab was used to record the colour parameters of jam samples. The units within the L^*, a^*, b^* system give equal perception of the colour difference to a human observer. The average L^*, a^*, b^* values of jam samples prepared with different amounts of fruits, sugar and commercial pectins are presented in Table 4.

3.2.2.1. Effect of pectin concentration. Table 4 showed that the increase in pectin concentration from 0.2% to 1.2%, in jams with 70% fruits (A, B and C), increased the a^* value from 11.34 to 14.57. Phimpharian et al. (2011) similarly reported that an increase in pectin concentration, increased the a^* value in fruit products. The a^* value represents the changes in the redness and is mainly governed by the anthocyanins (Emerton, 2008). This could be explained by the fact that in some cases pectin acts as co-pigment (Lewis, Walker, & Lancaster, 1995), thus increasing the jam red colour (a^* values). On the other hand, the increase in pectin concentration from 0.2% à 1.2%, in jams with 80 and 90% fruits (D, E, F, G, H and I), did not significantly affect the a^* value. This means that pectin act differently depending on the quantity of anthocyanins in pomegranate. These findings are supported by those of Kopjar et al. (2009) who reported that different pectins and their concentrations definitively affect colour of products.

3.2.2.2. Effect of fruit concentration. As shown in Table 4, increasing proportions of fruits in the jam formulation (from 70 to 90%), decreased L^* value. Indeed, the jams prepared with 90% fruits were darker. This was attributed to non-enzymatic (Maillard) browning during the concentration process, since higher fruits concentrations implicated longer cooking times (Garrido et al., 2015).

In addition to its effect on L^*, increasing proportions of fruits decreased a^* value. The obtained jams (with higher amount of fruit) were less reddish which could be due to decomposition of the anthocyanins during cooking. Anthocyanins are reported to have an important role in the colour quality of many fruits, however, they are quite unstable during processing and storage. Indeed, during heating, degradation and polymerisation usually lead to their discoloration (Kopjar et al., 2009).

3.2.3. Texture

Texture profile analysis (TPA), consisting of compressing a food sample twice, can be considered as an imitation of the mastication operation. Texture parameters, namely firmness, cohesiveness, adhesiveness and elasticity, of pomegranate jams are shown in Table 5.

Firmness is defined as the force required to achieve a given deformation. In sensory analyses, firmness is the force required to compress a food between molars in the first bite (Garrido et al., 2015). As shown in Table 5, the firmness values of pomegranate jam samples are directly proportional to the pectin concentration. As a matter of fact, increasing pectin concentration from 0.2% to 1.2%, the firmness of jams containing 70, 80 and 90% fruits increased from 0.420 to 1.922 N, from 0.697 to 2.688 N and from 0.836 to 4.001 N, respectively. The firmness effect of pectin may be explained by the increase in the number of junction zones with pectin concentration. As a result, the number of the elasticity active polymeric chains in the pectin structure would increase (Basu & Shivhare, 2010; Fu & Rao, 2001), thus the gel network would become more rigid.

It can also be observed how an increase in fruits concentration produced an increase in the firmness. This was attributed to the increased contribution of native pectin from the fruits.

Cohesiveness represents the strength of the internal bonds making up the body of the product. It is expected to be inversely proportional to the rate at which the material fractures under mechanical action (Garrido et al., 2015). As shown in Table 5, the effect of increasing pectin concentration decreased cohesiveness from 0.380 to 0.092, from 0.363 to 0.120 and from 0.333 to 0.202

Table 5
Texture properties of pomegranate jams.

Jam sample	Firmness	Cohesiveness	Adhesiveness	Elasticity
A	0.420	0.380	0.159	9.159
B	1.017	0.269	0.274	7.441
C	1.922	0.092	0.177	2.574
D	0.697	0.363	0.253	7.676
E	2.023	0.137	0.277	3.508
F	2.688	0.120	0.322	2.630
G	0.836	0.333	0.278	6.911
H	2.612	0.158	0.412	6.521
I	4.001	0.202	0.807	5.349
J1	0.418	0.381	0.158	8.889
JPP2	0.340	0.633	0.216	8.949
JPP3	1.084	0.397	0.431	6.366
JPP4	0.609	0.396	0.242	6.362
JPP5	0.6862	0.421	0.289	8.180
JPP6	1.034	0.228	0.236	5.580
JPP7	0.513	0.502	0.257	9.681

for jams prepared with 70, 80 and 90% fruits, respectively. This means that jams fractured more easily (they were more brittle) with increasing pectin concentration.

Adhesiveness represents the work required to pull the compressive probe away from the sample. In sensory analyses, it represents the work necessary to overcome the attractive forces between the surface of the food and the surface of the material with which the food comes into contact (Garrido et al., 2015). Table 5 showed that added pectin concentration had a positive effect on adhesiveness of pomegranate jam samples, which means that at higher pectin concentration in the formulation, the more adhesive were the jams.

Elasticity is related to the height that the food recovers during the time that elapses between the end and the first bite and the start of the second bite (Garrido et al., 2015). The elasticity of jam samples decreased with increasing pectin concentration in all samples, however this effect was more pronounced for jam samples with lower level of fruits. Indeed, with increasing pectin concentration, the elasticity of jam prepared with 70% fruit decreased from 9.159 to 2.574 mm.

3.2.4. Sensory evaluation

Table 6 shows that the colour of jams prepared with 70 and 80% fruits was more appreciated by consumers than that with 90%. According to the results of colour measurements (Table 4), these samples are more reddish than other samples, with high values of a^*. This could be attributed to the lower amount of fruits implicating a shorter cooking time, and so a preservation of the red colour of pomegranate fruit.

Average scores of overall acceptability, reported in Table 6, ranged from 1.20 to 3.90 in the 5-point Hedonic scale. Jams A and B, preparing with 70% fruits and containing 0.2 and 0.7% pectin, respectively, were the preferred samples. Indeed, samples A and B which scored the highest average acceptability (3.90 and 3.57, respectively), exhibited more appreciated texture and sweetness than those of other samples. A high and a low contents of sucrose and pectin, respectively, could contribute so to these sensations. While comparing the results of texture by sensory evaluation (Table 6) to those of the TPA test (Table 5), we observed that higher elasticity was related to a better appreciation by consumers.

In the following part, the fruit and pectin percentages (70% and 0.2%, respectively) of sample (A) (scoring the highest average acceptability with the lowest pectin content) were retained for the elaboration of pomegranate peel-based jams.

3.3. Characteristics of the jams incorporated with pomegranate peel

3.3.1. Physichochemical characteristics

Table 4 shows the values of pH, water activity and dry matter of the formulated pomegranate jams. The range of pH was between 2.7 and 2.89. Comparing JPP2 and JPP3, it can be noticed that the addition of fibre to pomegranate jam did not influence the pH of the final poduct. However, jams JPP4, JPP5, JPP6 and JPP7 incorporated with pomegranate peel powders, were more acidic than

Table 6
Sensory properties of pomegranate jams.

Jam sample	Color	Odor	Sweetness	Acidity	Texture	Overall acceptability
A	3.37 ± 0.93^{bc}	2.00 ± 1.51^{a}	3.63 ± 1.30^{e}	1.93 ± 1.31^{a}	3.63 ± 1.52^{b}	3.90 ± 1.18^{e}
B	3.50 ± 0.94^{c}	2.27 ± 1.1^{ab}	3.00 ± 1.20^{De}	2.33 ± 1.21^{ab}	3.33 ± 1.58^{b}	3.57 ± 1.17^{de}
C	3.37 ± 1.35^{bc}	2.07 ± 1.53^{a}	2.83 ± 1.34^{cD}	2.37 ± 1.10^{ab}	2.57 ± 1.38^{a}	3.07 ± 1.26^{cd}
D	2.90 ± 0.96^{bc}	2.40 ± 1.1^{abc}	2.27 ± 1.44^{bc}	3.43 ± 1.17^{c}	2.50 ± 1.41^{a}	2.60 ± 1.35^{bc}
E	2.67 ± 0.80^{b}	2.80 ± 0.92^{bc}	2.20 ± 1.27^{bc}	3.47 ± 1.17^{c}	2.43 ± 1.14^{a}	2.13 ± 1.20^{b}
F	2.90 ± 1.16^{bc}	2.50 ± 1.22^{abc}	2.20 ± 1.45^{bc}	2.67 ± 1.32^{b}	2.17 ± 1.39^{a}	2.23 ± 1.19^{b}
G	1.53 ± 1.93^{a}	3.03 ± 1.38^{c}	1.63 ± 1.10^{ab}	3.87 ± 1.17^{c}	2.33 ± 1.47^{a}	1.20 ± 0.92^{a}
H	1.43 ± 1.72^{a}	2.87 ± 1.25^{bc}	1.33 ± 1.18^{a}	3.57 ± 1.25^{c}	2.30 ± 1.44^{a}	1.27 ± 1.08^{a}
I	1.77 ± 1.89^{a}	3.13 ± 1.28^{c}	1.40 ± 1.19^{a}	3.67 ± 1.27^{c}	2.00 ± 1.66^{a}	1.30 ± 1.21^{a}
J1	3.61 ± 0.85^{C}	2.23 ± 1.22^{A}	3.21 ± 0.81^{B}	2.76 ± 1.3^{A}	2.9 ± 1.13^{A}	3.9 ± 1.06^{C}
JPP2	3.86 ± 0.73^{C}	2.27 ± 1.43^{A}	3.53 ± 0.95^{B}	2.23 ± 1.22^{AB}	3.38 ± 1.23^{AB}	4.35 ± 0.65^{C}
JPP3	2.18 ± 0.69^{B}	2.3 ± 1.18^{A}	2.53 ± 1.05^{A}	2.76 ± 1.38^{AB}	3.01 ± 1.2^{AB}	2.43 ± 1.05^{B}
JPP4	0.72 ± 0.66^{A}	2.41 ± 1.2^{A}	2.16 ± 1.12^{A}	4.25 ± 0.88^{AB}	3.46 ± 1.05^{AB}	1.73 ± 1.06^{A}
JPP5	1.06 ± 0.77^{A}	2.43 ± 1.11^{A}	2.65 ± 1.29^{A}	3.66 ± 0.81^{B}	3.6 ± 1.3^{B}	2.33 ± 1.13^{B}

Means of jams (A, B, C, D, E, F, G, H, I) in each column followed by different lower case letters are significantly different ($P < 0.05$); ±, standard deviation.
Means of pomegranate peel-based jams (J1, JPP2, JPP3, JPP4, JPP5) in each column followed by different capital letters are significantly different ($P < 0.05$); ±, standard deviation.

other samples. This decrease of pH could be resulted from the additional contribution of peel's organic acids.

Water activities varied between 0.736 and 0.816 which indicates that jam samples will be safe from development of the majority of bacteria.

The dry matter ranged between 59.8% and 66.5%. Jams incorporated with dry peel (JPP4 and JPP6) presented higher dry matter than those incorporated with lyophilized peel (JPP5 and JPP7). This observation could be explained by the fact that processes (such as drying and heating) affect the hydration properties of the fibre matrix (Thibault, Lahaye, & Guillon, 1992).

3.3.2. Colour

Table 4 illustrates the colour attributes of pomegranate jams incorporated with pomegranate peel. In pomegranate jam with a constant pectin content (0.2%), we observe differences in colour parameters between jam prepared with commercial pectin (J1) and that with pectin extracted from pomegranate peel (JPP2). As a matter of fact, JPP2 was less red, less yellow and darker than that of J1 as indicated by lower L*, a* and b* values. As the two samples contain the same amount of anthocyanin pigments, this differences in colour could be due to the differences of pectins' characteristics. Holzwarth et al. (2013) reported that anthocyanin pigment stability strongly depended on the pectin type used for strawberry jam. Pectin was shown to enhance anthocyanin stability which was mostly ascribed to electrostatic interactions between the positively charged flavylium cations and the dissociated carboxylic groups of the pectin backbone (Hubbermann, Heins, Stöckmann, & Schwarz, 2006).

Comparing JPP3 with JPP2, we notice changes in colour parameters. As shown in Table 4, incorporation of fibres increased L* and b* from 38.97 to 43.49 and from 0.95 to 1.35, respectively, which reflects a yellower and lighter jam (JPP3). However, the a* parameter decreased from 13.13 to 10.62 which reveals a less red jam. This result was consistent with that of Grigelmo-Miguel and Martin-Belloso (1999). They reported that the addition of dietary fibre turned the strawberry jams less red, yellower and lighter.

L*, a* and b* were found to decrease upon incorporation of peel powders in jams (JPP4, JPP5, JPP6 and JPP7) resulting in less red, less yellow and darker jams (comparing with JPP2 and JPP3). The darker colour resulted could be attributed to non-enzymatic (Maillard) browning. This observation was more pronounced in jam prepared with dry peel than that with lyophilized one, indicating that the drying system had a significant influence on the colour of the final product. Krokida and Maroulis (2000) reported that this difference in colour may be associated with the removal of water by the sublimation of ice that prevents enzymatic browning reactions and results in a relative stability of the colour.

3.3.3. Texture

Texture parameters, namely firmness, cohesiveness, elasticity and adhesiveness of jam prepared with pomegranate peel appear in Table 5.

3.3.3.1. Effect of substituting commercial pectin by that extracted from pomegranate peel. As shown in Table 5, differences in texture parameters were observed between jam prepared with pomegranate peel's pectin (JPP2) and the control jam prepared with commercial pectin (J1). Substituting commercial pectin by pomegranate peel pectin decreased firmness from 0.418 to 0.340 N, however cohesiveness, elasticity and adhesiveness increased. This could be due to the differences of pectins' physicochemical characteristics. Abid, Cheikhrouhou, & Cuvelier, et al. (2017) reported that chemical characteristics of pectins have a large influence on pectin gel properties.

3.3.3.2. Effect of fibre addition. Table 5 shows that fibres incorporation at 3% had an effect on textural parameters. Indeed, comparing JPP2 and JPP3, we remark that sample enriched with fibre (JPP3) exhibited higher firmness and adhesiveness (1.084 N and 0.431 N versus 0.340 N and 0.216 N, respectively). Dhingra, Michael, Rajput, and Patil (2012) reported that incorporation of fibre can change the consistency, texture and rheological behaviour of the end products. The incorporation of fibres in pomegranate jam seems to favour entanglements of the network formed by pectin. These findings are consistent with those of Igual, Contreras, and Martinez-Navarrete (2014) who found that Bamboo fibre incorporation at 1% significantly increased the consistency of the jam.

3.3.3.3. Effect of pomegranate peel powders' incorporation. Jam samples JPP4 and JPP5 were incorporated with 3% of pomegranate peel powder (containing 0.2% pectin). Comparing samples JPP4 and JPP2 (prepared with 0.2% pomegranate pectin), we remark that incorporation of 3% of dry peel, containing 0.2% pectin, has led to an increase of firmness from 0.340 N to 0.609 N, and a decrease of both cohesiveness and elasticity from 0.633 to 0.396 and from 8.949mm to 6.362mm, respectively. This could be attributed to the presence of other compounds in peel besides pectin. From results obtained for JPP3, fibres are thought to be responsible for this change in textural behaviour (increase of firmness and decrease of elasticity). Results show also that jam prepared with lyophylized peel (JPP5) is more elastic than that with dry peel (JPP4). This clearly indicate that processes had an effect on textural properties of jams, which could be explained by the fact that processes modifies the physical properties of the fibre matrix (Thibault et al., 1992). Guillon and Champ (2000) reported that the physico-chemical properties of fibre can be manipulated through treatments: chemical, enzymatic, mechanical, thermal or thermo mechanical to improve their functionality.

Jam samples JPP6 and JPP7 were incorporated with 8.85% of pomegranate peel powder (containing 3% fibre). Comparing jams JPP6 and JPP3 (prepared with 3% fibre) we remark that both samples had almost the same firmness however JPP6 was less elastic than JPP3. Although JPP6 contains more pectin (0.7%) than JPP3 (0.2%), it seems that in the presence of 3% fibre, the increase of pectin content had no remarkable effect on the firmness while it adversely affects the elasticity, what could be explained probably by the saturation of synergy between pectin and fibre.

As found for jam prepared with 3% of peel, jam containing 8.85% of lyophilized peel was more elastic than that with dry peel, which confirms the influence of the process on textural properties of jams. Lyophilisation is reported as one of the most advanced dehydration methods which produces superior product quality (porous structure and minimum shrinkage) (Ahmed & Al-Attar, 2015).

3.3.4. Sensory evaluation

Table 6 shows the sum of the scores of jams with different formulations (J1, JPP2, JPP3, JPP4 and JPP5). Pomegranate jams were considered acceptable with the exception of jams JPP6 and JPP7 containing high amount of peel (8.85%). These two samples were not analyzed because of their intense bitterness. In the case of the taste, JPP2 showed higher sweetness than other samples prepared with peel powders and fibres (JPP3, JPP4 and JPP5). The low sweetness of jams prepared with peel powders (JPP4 and JPP5) was is related to the bitterness because of high tannin content in pomegranate peel (Kushwaha, Bera, & Kumar, 2013). Although JPP4 and JPP5 are incorporated with the same amount of peel, JPP4 showed less overall-acceptability than JPP5 which could be attributed so to the drynig method. Calín-Sánchez et al. (2013) reported that the drying method significantly affected the intensities of the main sensory attributes of dried pomegranate arils. In general, significant reductions in the contents of sugars, organic acids, and total polyphenols were associated with the drying process.

The colour of JPP2 jam was more appreciated by the panellists than that of JPP3, JPP4 and JPP5 which could be due to the dark colour of these samples. The dark colour of JPP4 and JPP5, resulted by the addition of peel and attributed to the non-enzymatic (Maillard) browning during the drying process, was the less apreciated by the panellists.

From the sensory analyses it was concluded that the jam (JPP2) exhibited similar overall acceptability to that of the reference jam (prepared with commercial pectin). Nevertheless, comparing this sample (JPP2) to other pomegranate peel-based jams (JPP3, JPP4 and JPP5), it can be noticed that JPP2 had the best overall acceptability which could be attributed to its appreciated colour and sweetness.

4. Conclusion

Jam samples prepared with different formulations showed that pectin and fruit concentrations had a significant effect on colour, texture and overall aceptability of pomegranate jams. The most appreciated formulation by the panellists was that contaning 70% fruits and 0.2% pectin. This study showed also the possibility of subtituting commercial pectin by that extracted from pomegranate peel. Indeed, sensory evaluation revealed that the jam prepared with pectin extracted from pomegranate peel (JPP2) exhibited similar overall acceptability to that of the reference jam (prepared with commercial pectin). Nevertheless, JPP2 was more appreciated than jams incorporated with fibre, dry and lyophilized peel powders, which could be attributed to its appreciated colour and sweetness. According to the colour and texture measurements, JPP2 was more reddish and less firm than other pomegranate peel-based jams. Texture measurements showed also that jam prepared with lyophylized peel was more elastic than that with dry peel, which clearly indicates that drying processes of pomegranate peel had a significant effect on textural properties of pomegranate jam. Results from this work revealed that commercial pectin could be replaced by that extracted from pomegranate peel for the preparation of pomegranate jam without altering its organoleptic properties.

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