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The Effect of Quince Powder on Rheological Properties of Batter and Physico-Chemical and Sensory Properties of Sponge Cake

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ABSTRACT: The potential of quince powder was evaluated for the production of fiber rich sponge cakes. In this study, quinces slices were dried in an infrared–hot air dryer (375 W, 60°C and 1 m/s flow rate). The rheological properties of cake batters and physico-chemical, textural and sensory properties of the sponge cake supplemented with five different concentrations (control, 5, 10, 15 and 20 %) of quince powder were evaluated. The physical (volume, density, color) and chemical (moisture, protein, fat, carbohydrate and ash) attributes of the cakes were determined. The apparent viscosities of cake batters were increased from 11.47 to 33.63 Pa.s by increasing quince powder levels from 0 to 20 % (shear rate = 45.6 s^{-1}). Increasing the level of substitution of quince powder from 0 to 20 % decreased the volume of cakes from 66.67 to 56.91 cm^3. The density, consistency and hardness values of baked cakes increased with increasing quince powder levels from 0 to 15 %, whereas the volume, cohesiveness, resilience, chewiness and crumb L values of the samples showed a reverse trend. The results of sensory evaluation indicated that the cake with 10 % quince powder was rated the most acceptable.

Keywords: *Infrared, Image Processing, Quince, Rheology, Sponge Cake, Texture.*

Introduction

Quince, (*Cydonia oblonga Miller*) from Rosaceae family, is a tree cultivated as a medicinal and nutritional plant in the Middle East, South Africa, and central Europe (Hemmati *et al.*, 2012). They are used to make jam, marmalade, jelly and quince pudding (de Escalada Pla *et al.*, 2010). Drying is one of the important preservation methods employed for storage of quince. Drying kinetics of quince slices was investigated by Kaya *et al.* (2007) and the effects of drying methods on bulk density, substance density, porosity, and shrinkage of quinces at various moisture contents were studied by Koç *et al.* (2008). One of the ways to shorten the drying time is to supply the heat by infrared radiation. The efficiency is between 80% and 90% and the emitted radiation is in narrow wavelength range and are miniaturized (Sakai & Hanzawa, 1994; Sandu, 1986). The advantages of infrared radiation over convective heating include high heat transfer coefficients, short processing time and low energy costs. It is used for heating and cooking soybeans, cereal grains, cocoa beans and nuts, ready-to-eat products, braising meat and frying (Ratti & Mujumdar, 1995). Comparison of infrared drying with convective drying of apple showed that the time of the process can be shortened by up to 50% when heating is conducted with infrared energy (Nowak & Lewicki, 2004). The combination of infrared with hot air provides the synergistic effect, resulting in an efficient drying process. Energy and quality aspects were studied

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during combined far infrared and convective drying of barley (Afzal *et al.*, 1999). A laboratory scale batch dryer was employed for this purpose. The total energy required for the combination mode drying was reduced substantially when compared to hot air drying at 70°C.

Bakery products are consumed all over the world and the enrichment of these products with fibers and polyphenols may be achieved through the incorporation of riched fibers and polyphenols sources. Masoodi *et al.* (2002b) studied making of cake with flour blends using apple pomace at different concentrations in order to make a cake with enriched fiber. Chen *et al.* (1988) used apple pomace in cookie and muffin formulations at the concentration of 4% to improve the quality of the end product and make it acceptable. The benefits of fibers for the gut are amply recognized, a fact that has determined its consideration as a nutrient. Besides fiber can be used for technological purposes due to its functional properties. Quince is considered as a good source of fiber, with a great potential (de Escalada Pla *et al.*, 2010). Silva *et al.* (2006) reported profiles of fiber, phenolic compounds, organic acids and free aminoacids of *Cydonia oblonga Miller*.

Infrared-hot air method, when applied properly, can provide a high-quality product. Therefore, the aim of this study was to evaluate the rheological properties of batters and physico-chemical, textural and sensory properties of sponge cake supplemented with different concentrations of dried quince powder employing infrared–hot air dryer.

Materials and Methods

- *Infrared –Hot air drying of quince*

Fresh quince (*Cydonia oblonga Miller*) was obtained from the market and kept in cold storage at 4–5°C. Slices of quince with 5 mm thickness were prepared with the aid of a steel cutter and were immediately placed into the dryer. The slices were dried in an infrared –hot air dryer (Infrared radiation lamp (NIR), Philips, Germany) with 375 W power and 60°C with an air current of 1 m/s. The dried samples were milled and passed through a 50 mesh sieve and were weighed and stored in an air-tight bottle for further application.

- *Sponge cake preparation*

The formulae of sponge cakes at different concentrations of added quince powder are shown in Table 1. The ingredients of the sponge cakes consisted of cake flour, sucrose, sunflower oil, fresh eggs, whey, baking powder, vanilla, xanthan gum, water and nonfat dry milk powder.

Sucrose and sunflower oil were poured into a bowl, and mixed for 4 min. Whole egg was added to the bowl, and then mixed for 2 min. The sifted cake flour, whey, baking powder, vanilla, xanthan gum, water and nonfat dry milk powder was gradually poured into a bowl, and mixed for 4 min.

Table 1. Formulation of sponge cakes.

Samples	Quince (gr)	Cake flour (gr)	Whole egg (gr)	Sucrose (gr)	Sunflower oil (gr)	Whey (gr)	Nonfat dry milk (gr)	Baking powder (gr)	Vanilla (gr)	Xanthan gum (gr)	Water (gr)
Control	0	100	72	72	57	4	2	2	0.5	0.25	30
5 %	5	95	72	72	57	4	2	2	0.5	0.25	30
10 %	10	90	72	72	57	4	2	2	0.5	0.25	30
15 %	15	85	72	72	57	4	2	2	0.5	0.25	30
20 %	20	80	72	72	57	4	2	2	0.5	0.25	30

Water was added to the bowl, and then mixed for 1 min (Salehi *et al.*, 2016).

For each cake, 30 g of the cake batter was poured into a pan and baked at 195°C for 20 min in an oven toaster (Noble, Model:KT-45XDRC) (Salehi *et al.*, 2015). The cakes were allowed to cool for 30 min, and then were removed from the pans. The cooled cakes were packed in polypropylene bags at room temperature before physico-chemical and sensory analyses. The sponge cake samples were prepared with 0% (control), 5, 10, 15 and 20% replacement of cake flour with quinces powder.

- *The rheological properties of cake batters*

The viscosity of sponge cake batters was measured using a rotational viscosimeter manufactured by Brookfield Engineering Laboratories (Brookfield, model RVDV- II+ pro, USA). Immediately after mixing, 200 ml of cake batter was poured into a 200 ml beaker and the viscosity was measured. The rheological parameters of cake batters at different shear rate of 1.9 to 76 s^{-1} were studied using spindle No.S07 at 18 rotations and 25°C.

- *Physico-chemical characteristics of cakes*

Moisture contents of the samples were determined in a oven at 105°C for 4 h (AOAC, method no. 934.06). Protein, fat and ash contents were determined according to (Pearson, 1973). The nitrogen conversion factor used for crude protein calculation was 6.25. The carbohydrate content was calculated by difference. The proximate compositions of sponge cakes were averaged from four replications. Results were expressed on a wet basis. The volume and density of the sponge cake was determined by the canola displacement method. The empty cake pan was filled with canola. The volume of sponge cake was averaged from four replications.

- *Color measurement*

The crumb colour determinations of the cake samples from the midsection of the cakes were measured with a HP Scanner (Hp Scanjet G3110, China). Since the computer vision system perceived color as RGB signals, which is device-dependent, the taken images were converted into $L^*a^*b^*$ units to ensure color reproducibility. In the L*a*b* space, the color perception is uniform, and therefore, the difference between the two colors corresponds approximately to the color difference perceived by the human eye (Salehi & Kashaninejad, 2015). L^* (lightness/darkness that ranges from 0 to 100), a^*(redness/greenness that ranges from -120 to 120) and b^* (yellowness/blueness that ranges from -120 to 120) were measured according to Salehi and Kashaninejad (2014). In this study, the image analyses of sponge cakes were performed using Image J software version 1.42e, USA.

- *Textural properties of cakes*

The texture profile analysis of sponge cake samples (2×2×2 cm) from the midsection of the cakes were performed using a texture analyser (TA-XT Plus, Stable Micro Systems Ltd., Surrey, UK) with a 36 mm diameter cylindrical probe, 50% compressing and a test speed of 1.0 mm s^{-1} . The crust of cake samples was removed in cake texture determination. A double cycle was programmed and the texture profile was determined using Texture Expert 1.05 software (Stable Microsystems). Other parameters were defined as: pre-test speed 2.0 mm s^{-1}, post-test speed 2.0 mm s^{-1} and trigger force 5 g. The texture parameters consisted of consistency, hardness, cohesiveness, adhesiveness, springiness, resilience, gumminess, and chewiness, and the texture determinations were the averaged of 4 replications.

- Sensory evaluation

The hedonic test was used to determine the degree of overall liking for the sponge cakes. For this study, trained consumers were recruited from the students, staff and faculty at Gorgan University. All consumers were interested volunteers and were informed that they will be evaluating the sponge cakes. For this study, 10 consumers received five samples and were asked to rate them based on the degree of liking on a nine-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, 9 = like extremely). Samples were placed on the plates and identified with random three-digit numbers. Panelists evaluated the samples in a testing area and were instructed to rinse their mouths with water between samples to minimize the residual effect.

- Statistical analysis

Each measurement was conducted in quadruplicate, except for the sensory evaluation (n=10). The experimental data were subjected to analysis of variance (ANOVA) for a completely random design using a statistical analysis system (SAS 9.1 Institute, Inc, Cary, NC, USA). Duncan's multiple range tests were used to determine the differences among means at the level of 0.05.

Results and Discussion

- The rheological properties of cake batters

A good cake batter must retain sufficient viscosity to prevent the incorporated air bubbles from rising to the surface and being lost during initial heating (Lu *et al.*, 2010). Shear rate dependency of the apparent viscosity of sponge cake batters has been presented in Figure 1. It was found that the apparent viscosity of cake batters decreased as the shear rate increased (shear thinning or pseudoplastic behavior). The apparent viscosity of cake batters clearly decreased from 44.0 to 9.92 Pa.s with increasing shear rate from 1.9 to 76 s^{-1} (10 % quince powder).

In general, the addition of quince powder to the cake formula led to the increase in the viscosity of cake batters (Figure 2). The batter with 20 % quince powder exhibited the highest viscosity among all the cake batters. In the present study, the apparent viscosity of cake batters varied from 11.47 to 33.63 Pa.s (shear rate=45.6 s^{-1}) depending on the concentration of quince powder. De Fouw *et al.* (1982) reported an increase in batter viscosity when 15% flour was replaced with either unheated or roasted navy bean hulls. Masoodi *et al.* (2002a) also reported that batter viscosity increased with increasing apple pomace level with decreasing particle size.

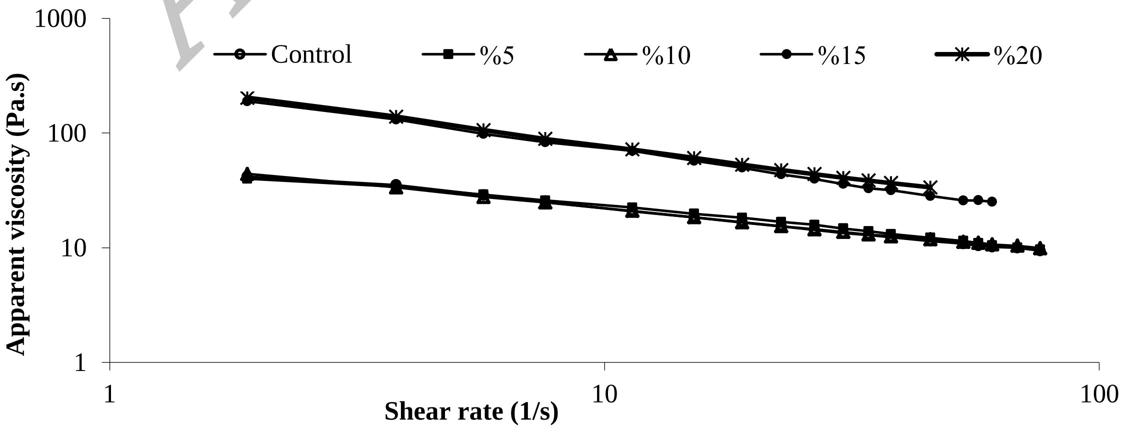

Fig. 1. The rheological properties of sponge cake batters as a function of shear rate.

- Physico-chemical characteristics of cakes

Changes in cake characteristics with added quince powder are shown in Table 2. The fat contents of sponge cakes were not significantly changed. The moisture and the ash contents of sponge cake increased significantly with the increasing quince powder level whereas the protein and carbohydrate contents of cake showed a reverse trend. Increasing the level of substitution from 0 to 20 % quince powder increased the ash content of cakes from 0.81 to 1.02 %.

Significant decreases in cake volume were observed with increases in the quince powder level. The control sample had an average cake volume of 66.67 ml and decreased to 63.85, 63.29, 60.36 and 56.91 cm^3 after the addition of 5, 10, 15 and 20 % quince powder, respectively. Masoodi *et al.* (2002a) reported that the cake volume decreased with increasing apple pomace levels. Increasing the quince powder level from 0 to 20 % increased the density of the cakes from 379 to 450 kg/m^3.

- Color measurement

The results of color measurement of sponge cake supplemented with quince powder dried in an infrared–hot air dryer are presented in Table 3. The crumb colours of the samples were affected by the replacement of cake flour with quince powder. In general, as quince powder level increased, the crumb colour became darker. The sponge cake with 10 % quince powder

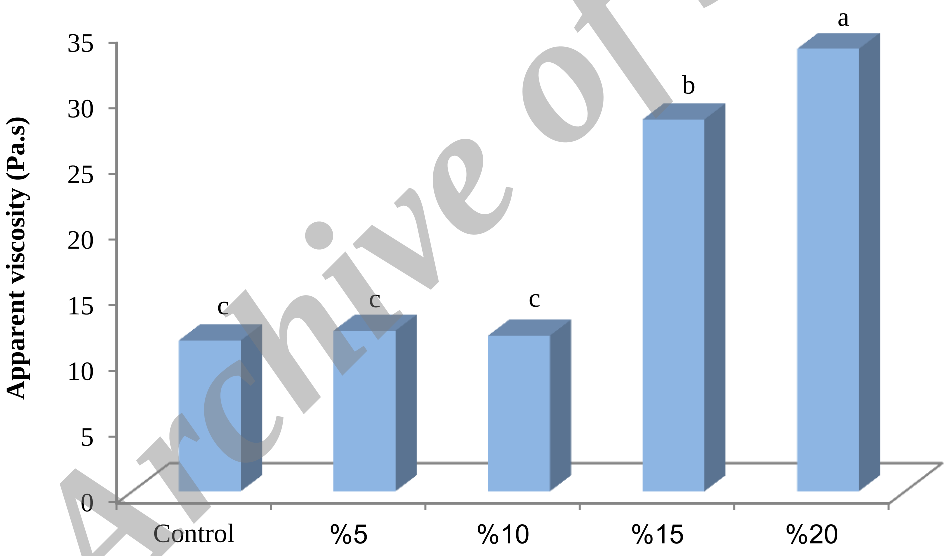

Fig. 2. The apparent viscosity of sponge cake batters prepared with quince powder (shear rate=45.6 s^{-1}). Means with different letter within columns are significantly different (P<0.05).

Table 2. Physico-chemical characteristics of sponge cakes prepared with quince powder.

Samples	Volume (cm^3)	Density (kg/m^3)	Moisture (%)	Fat (%)	Protein (%)	Carbohydrate (%)	Ash (%)
Control	66.67 [a]	379 [a]	18.40 [a]	23.34 [a]	5.95 [c]	51.50 [b]	0.81 [a]
5 %	63.85 [b]	403 [b]	18.55 [ab]	23.35 [a]	5.81 [b]	51.44 [b]	0.85 [a]
10 %	63.29 [b]	404 [b]	18.50 [a]	23.37 [a]	5.76 [b]	51.46 [b]	0.91 [b]
15 %	60.36 [c]	415 [c]	18.65 [b]	23.39 [a]	5.62 [ab]	51.38 [ab]	0.96 [c]
20 %	56.91 [d]	450 [d]	18.78 [b]	23.43 [a]	5.55 [a]	51.22 [a]	1.02 [d]

Means with different letter within columns are significantly different (P<0.05).

exhibited a color with L*, a* and b* of 77.10, 1.45 and 33.97, respectively. For crumb colour as the level of quince powder increased, the L value decreased but the value increased, indicating that a darker and redder crumb was obtained as the result of quince powder substitution.

- *Textural properties of cakes*

The measured hardness of the samples showed that the cake became harder with increasing levels of quince powder (Table 4). The hardness of cakes was directly related to the density of the tested materials (indirectly to its volume). The weights of the samples were not significantly different among any of the cakes in this study. Thus, the increase in hardness was mainly related to the volume of these cakes. The area under the curve up to the target deformation was taken as a measurement of consistency. Texture profile analysis (TPA) results showed an increase in the cake consistency with an increased level of quince powder. The consistency values increased from 4578.83 to 8760.07 g.s with increasing quince powder levels from 0 to 20 %.

Cohesiveness quantifies the internal resistance of food structure. Briefly, cohesiveness is the ability of a material to stick to itself. TPA results indicated significant difference in the cake cohesiveness and was decreased with increasing levels of quince powder from 0 to 15 %.

Springiness measures elasticity by determining the extent of recovery between the first and second compression. Resilience is the ratio of recoverable energy as the first compression is relieved. TPA results showed a decrease in the cake springiness with increasing level of quince powder from 0 to 15 %.

Gumminess is determined by hardness multiplied by cohesiveness. Chewiness is determined by gumminess multiplied by springiness, and represents the amount of energy needed to disintegrate a food for swallowing. TPA results showed a decrease in the cake gumminess and chewiness with increased level of quince powder from 0 to 10 % but they were increased with increasing quince powder level from 15 to 20 %.

- *Sensory evaluation*

In order to measure the product liking and preference, the hedonic scale that is a unique scale and provide both reliable and valid results is applied (Stone *et al.*, 2012). Statistically significant differences among the samples were evaluated by the trained consumers in respect of the crumb colour, flavour, texture and overall liking and compared to the control (Table 5). The sensory characteristics results indicated that partial replacement of cake flour up to 10 % with quince powder is desirable.

Table 3. Crumb color of sponge cakes prepared with quince powder.

Samples	L*	a*	b*
Control	88.78±4.15 [a]	-2.60±1.04 [a]	33.47±3.70 [a]
5 %	82.03±5.68 [b]	0.11±1.18 [b]	30.29±3.29 [a]
10 %	77.10±6.71 [c]	1.45±1.41 [c]	33.97±3.55 [a]
15 %	76.31±6.14 [c]	3.88±1.75 [d]	38.22±3.65 [b]
20 %	73.50±7.35 [c]	3.34±1.73 [d]	38.60±3.78 [b]

Means with different letter within columns are significantly different (P<0.05).

Table 4. TPA parameters of sponge cakes prepared with quince powder.

Samples	Consistency (g.s)	Hardness (g)	Springiness	Cohesiveness	Gumminess (g)	Chewiness (g)	Resilience
Control	4578.83 [a]	861.11 [a]	0.90 [a]	0.58 [a]	503.21 [b]	450.56 [b]	0.22 [a]
5 %	4808.94 [b]	875.95 [a]	0.90 [a]	0.54 [b]	474.45 [c]	424.82 [bc]	0.20 [ab]
10 %	4952.77 [b]	974.54 [b]	0.89 [a]	0.49 [c]	415.19 [d]	371.50 [d]	0.18 [b]
15 %	6578.85 [c]	1117.82 [c]	0.87 [b]	0.42 [d]	466.69 [c]	404.70 [c]	0.16 [c]
20 %	8760.07 [d]	1457.80 [d]	0.90 [b]	0.49 [c]	711.96 [a]	638.33 [a]	0.18 [b]

Means with different letter within columns are significantly different (P<0.05).

Table 5. Sensory evaluation of sponge cakes.

Samples	Crumb colour	Porosity	Flavour	Texture	Overall
Control	8.0 [a]	7.8 [a]	5.4 [c]	7.6 [a]	5.5 [c]
5 %	6.8 [b]	7.3 [a]	6.8 [b]	7.5 [a]	6.5 [b]
10 %	6.2 [b]	6.8 [ab]	8.2 [a]	6.7 [b]	7.8 [a]
15 %	5.5 [c]	6.3 [b]	7.5 [b]	6.0 [c]	7.0 [b]
20 %	5.3 [c]	5.3 [c]	7.3 [b]	5.2 [c]	6.7 [b]

Nine-point hedonic scale with 1, 5, and 9 representing extremely dislike, neither like nor dislike, and extremely like, respectively. Means with different letter within columns are significantly different (P<0.05).

Conclusion

Infrared-hot air, if applied properly, might be used to achieve a high-quality product. In this study a novel formulation of sponge cake production with quince powder was developed. The addition of quince powder to the formula led to an increase in the viscosity of the cake batter. The moisture and ash contents of sponge cake increased significantly by increasing the quince powder level where as the protein content showed a reverse trend. The crumb colour was affected and the L* values decreased while the a* value increased, indicating that a darker and redder crumb was obtained as the result of quince powder substitution. The sensory characteristics indicated that the partial replacement of cake flour with up to 10 % quince powder in sponge cakes is desirable.

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