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Physico-chemical, textural and sensory evaluation of sponge cake supplemented with pumpkin flour

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Abstract

The pumpkins slices were dried in an infrared–hot air dryer (238 W, 65°C and 2 m/s flow rate) and dried samples were milled and passed through a 125 mesh sieve and used in sponge cake formulation. In this study, the physico-chemical, textural and sensory properties of sponge cake supplemented with five different levels of pumpkin powder (0, 5, 10, 15 and 20%) were evaluated. The β-carotene content of cake increased from 6.84 to 9.78 mgr/100gr with increasing pumpkin powder levels from 0 to 20%. Increasing the level of substitution from 0 to 20% pumpkin powder decreased the volume of cakes from 68.26 to 51.35 cm3. The density, ash, β-carotene and protein of baked cakes increased with increasing pumpkin powder levels, whereas the moisture content and volume of samples showed a reverse trend. Sensory evaluation results indicated that cake with 10% pumpkin powder was rated the most acceptable. The hardness, cohesiveness, gumminess and chewiness values were in the range of 603.79-864.54 g, 0.58-0.66, 359.87-521.16 g and 328.36-475.65 g, respectively. The sponge cake with 10% pumpkin exhibited a color, with L^*, a^* and b^* equal to 81.37, 312 and 70.91, respectively.

Introduction

The post harvest loss of fresh fruits and vegetables are estimated to be 20-30%. In order to prevent the losses, there is a need to process the commodities into various value added products (Bhat and Bhat, 2013). Pumpkin flesh *(Cucurbita moschata)* is a delicious and fully appreciated additive in a diversity of products for children and adults (Nawirska *et al.*, 2009). In the fresh mass of the pumpkin fruit, total carotenoid content, a major contributory factor in the high nutritional value of pumpkins, ranges from 2 to 10 mg/100 g, the content of vitamins C and E accounting for 9–10 mg/100 g and 1.03–1.06 mg/100 g, respectively (Terazawa *et al.*, 2001; Nawirska *et al.*, 2009). Pumpkin fruit is also a valuable source of other vitamins, e.g., B6, K, thiamine, and riboflavin, as well as minerals, e.g., potassium, phosphorus, magnesium, iron and selenium. An experimental study was performed by Sacilik (2007) to determine the drying characteristics of hull-less seed pumpkin using hot air, solar tunnel and open sun drying methods. For the hot air drying, the test samples were dried in a laboratory scale hot air dryer at a constant air velocity of 0.8 m/s and air temperature in the range of 40–60 ◦C and for solar drying experiments, a solar tunnel dryer was constructed at a low cost with locally obtainable materials.

Fruit fibre have better quality due to higher total and soluble fibre content, water and oil holding capacity and colonic fermentability, as well as lower phytic acid content and caloric value (Sharoba *et al.*, 2013). Apart from their positive health benefit, they also possess unique functional properties such as their ability to hold a large amount of water (Puvanenthiran *et al.*, 2014). Sharoba *et al.* (2013) studied feasibility of using orange waste, carrot pomace, potato peels and green pea peels by-products from food industry, as a starting raw material to produce dietary fiber powders and the feasibility of producing cakes intended for people suffering from obesity or over weight and diabetes. The results showed that the fiber content of cake was increased with adding carrot powder. Pumpkin has a vast scope for diversification and can be utilized in the production of processed products like jam, pickle, beverage, candy, bakery products and confectionary (Bhat and Bhat, 2013). Preservation of pumpkins by drying is one of the best options of overcoming seasonal variation. Different drying methods of pumpkin such as solar, freeze,

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fluidized bed and hot air drying are practiced for pumpkin (Sojak, 1999; Alibas, 2007; Nawirska *et al*., 2009). One of the ways to shorten the drying time is to supply heat by infrared radiation. Their efficiency is between 80% and 90%, the emitted radiation is in narrow wavelength range and they are miniaturized (Sandu, 1986; Sakai and Hanzawa, 1994). Advantages of infrared radiation over convective heating include high heat transfer coefficients, short process times and low energy costs. Comparison of infrared drying with convective drying of apple showed that time of the process can be shortened by up to 50% when heating is done with infrared energy (Nowak and Lewicki, 2004).

Infrared radiation has some advantages over convective heating. In spite of these advantages, application of infrared energy in food processing is rather scarce. It is used for heating and cooking soybeans, cereal grains, cocoa beans and nuts, ready-to-eat products, braising meat and frying (Ratti and Mujumdar, 1995). Pan *et al.* (2008) used sequential infrared and freeze-drying (SIRFD) to produce high-quality dried fruits at reduced cost. The products dried using SIRFD had better color, higher crispness, higher shrinkage but poor rehydration propensity compared to those produced by using regular freeze-drying. Infrared drying was applied before or after freeze-drying of shiitake mushroom to shorten the drying time, to enhance the rehydration, and to better preserve the aroma compounds and color by Wang *et al.* (2015). The results showed that the combination of freeze-drying (for 4h) followed by infrared drying saves 48% time compared to freeze-drying while keeping the product quality at an acceptable level. The application of infrared drying also helps produce a more porous microstructure in dried shiitake mushrooms.

Ponkham *et al*. (2012) developed the mathematical model of pineapple rings during combined far-infrared radiation and air convection drying to investigate the evolutions of moisture content and qualities. The diffusion coefficient was influenced by far-infrared radiation intensity and air temperature but was not significantly influenced by air velocity. As expected at higher far-infrared intensity the higher heat absorption resulted in higher product temperature, higher mass transfer driving force, faster drying rate and consequently lesser drying time. Hebbar *et al.* (2004) demonstrated that combination drying gave better results over infrared heating alone for drying of carrots and potatoes. Moreover, infrared radiative drying is able to give better qualities of product such as color, shrinkage, hardness, crispness, ascorbic acid, and total phenol contents.

The combination of infrared with hot air provides the synergistic effect, resulting in an efficient drying process. Energy and quality aspects were studied during combined far infrared and convective drying of barley (Afzal *et al*., 1999). A laboratory scale batch dryer was used for this purpose. The total energy required for the combination mode drying reduced by nearly 245% when compared with hot air drying at 70°C. Combined infrared-vacuum drying of pumpkin slices was studied by Hosseini Ghaboos *et al*. (2016). With increasing in infrared radiation power from 204 to 272 W, β–carotene content of dried pumpkins decreased from 30.04 to 24.55 mg/100g. The rise in infrared power has a negative effect on the color changes (ΔE). The optimum condition was selected as power of 238 W and 5 mm slice thickness due to short time, high β–carotene content and bright color of the dried sample.

Since pumpkin is a valuable micronutrients source, dried pumpkin could be processed into flour for foods to increase fibers, vitamin A and mineral contents. Pumpkin flour is used because of its highly-desirable flavor, sweetness and deep yellow-orange color (See *et al.*, 2007). It has been reported to be used to supplement cereal flours in bakery products like cakes, cookies, bread, for soups, sauces, instant noodle and spice as well as a natural coloring agent in pasta and flour mixes (Ptitchkina *et al*., 1998; See *et al*., 2007). Infrared-hot air method, when properly applied, can be used for achieving a high-quality product. Therefore, the aim of this study was to determine the physico-chemical, textural and sensory properties of sponge cake supplemented with five different levels (0, 5, 10, 15 and 20%) of pumpkin powder dried in an infrared–hot air dryer.

Materials and Methods

Infrared –hot air drying of pumpkin

Fresh pumpkins *(Cucurbita moschata)* were obtained from market. Slices of pumpkin with 5 mm thickness were prepared with the aid of a steel cutter and were immediately placed into the dryer. The pumpkin slices were dried in an infrared –hot air dryer (Infrared radiation lamp (NIR), Philips, Germany) with 238 W power and 65°C with air at a velocity of 2 m/s (Hosseini Ghaboos *et al.*, 2016). The dried samples were milled and passed through a 125 mesh sieve. Then the milled powder was weighed and stored in an air-tight bottle till the experiments.

Sponge cake preparation

The formulae of sponge cakes at five different pumpkin powder levels were shown in Table 1. The

Table 1. Cake formula.

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

ingredients used in the formula of sponge cakes were cake flour, sucrose, sunflower oil, fresh eggs, whey, baking powder, vanilla, 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, water and nonfat dry milk powder was gradually poured into a bowl, and mixed for 4 min. Water was added to the bowl, and then mixed for 1 min (Salehi, Kashaninejad, Akbari *et al*., 2016; Salehi, Kashaninejad, Asadi *et al.,* 2016). For each cake, 30 g of cake batter was poured into a cake pan and baked at 195°C for 20 min in a oven toaster (Noble, Model:KT-45XDRC). 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 evaluation analyses. The test sponge cake samples prepared with 0% (control), 5%, 10%, 15 and 20% replacement of cake flour with pumpkins powder.

Physico-chemical characteristics of cakes

The physico-chemical characteristics of cake including moisture, protein, fat, carbohydrate and ash were measured. Moisture content of the samples was determined in a oven at 105°C for 4 h (AOAC, method no. 934.06). The nitrogen conversion factor used for crude protein calculation was 6.25. The carbohydrate content (%) was calculated by subtracting the contents of crude protein, fat, ash, and moisture from 100% of cakes. 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.

β – Carotene content

One gram of cake was dried and then crushed in 10-15 ml of acetone with the help of pestle and mortar and few crystals of anhydrous sodium sulphate were added. The supernatant was decanted into a beaker. The process was repeated twice and combined supernatant was transferred to a separating funnel, then 10-15 ml of petroleum ether was added and mixed thoroughly. Two layers separated out on standing. The lower layer was discarded and upper layer was collected in 100 ml volumetric flask. The volume was made to 100 ml with petroleum ether and optical density was recorded at 452 nm using petroleum ether as blank (Bhat and Bhat, 2013). The β-carotene was calculated using the following formula:

$$\beta\text{-carotene (mg/100g)} = \frac{\text{Optical density of sample} \times 13.9 \times 104 \times 100}{\text{Weight of sample} \times 560 \times 1000} \quad (1)$$

Color measurement

The crumb colour determinations of cake samples from the midsection of the cakes were measured with a HP Scanner (Hp Scanjet G3110). 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 (Salehi and Kashaninejad, 2015). In the $L^*a^*b^*$ space, the color perception is uniform, and therefore, the difference between two colors corresponds approximately to the color difference perceived by the human eye. 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 (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 analyzer (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 recorded were hardness, cohesiveness,

Table 2. Physico-chemical characteristics and crumb color of sponge cakes prepared with pumpkin powder.

Samples	Volume (cm^3)	Density (kg/m^3)	Moisture (%)	Fat (%)	Protein (%)	Carbohydrate (%)	Ash (%)	L^*	a^*	b^*
Control	68.26 ^{a}	366 ^{a}	19.57 ^{a}	23.34 ^{ab}	6.19 ^{d}	49.97 ^{b}	0.94 ^{e}	88.84±4.14 ^{a}	-2.19±1.47 ^{d}	39.01±3.27 ^{c}
5%	66.98 ^{a}	373 ^{a}	19.25 ^{a}	24.11 ^{a}	6.41 ^{c}	49.10 ^{c}	1.14 ^{d}	80.60±5.00 ^{b}	1.20±1.52 ^{c}	59.62±4.49 ^{b}
10%	63.08 ^{b}	396 ^{b}	18.98 ^{b}	23.25 ^{ab}	6.58 ^{c}	49.91 ^{b}	1.29 ^{c}	81.37±5.12 ^{c}	3.12±2.76 ^{b}	70.91±4.17 ^{a}
15%	56.52 ^{c}	442 ^{c}	18.60 ^{b}	22.62 ^{b}	6.75 ^{b}	50.59 ^{a}	1.45 ^{b}	74.14±5.74 ^{d}	4.59±0.73 ^{b}	71.82±3.43 ^{a}
20%	51.35 ^{d}	487 ^{d}	17.88 ^{c}	23.43 ^{ab}	6.89 ^{a}	50.17 ^{b}	1.63 ^{a}	72.76±4.52 ^{d}	8.84±2.82 ^{a}	71.52±3.72 ^{a}

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

adhesiveness, springiness, resilience, gumminess, and chewiness, and the texture parameter of cake was averaged from 3 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 informed that they would be evaluating sponge cakes. For the sponge cake manufacturing study, 15 consumers received five samples and were asked to rate them based on degree of liking on a nine-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, 9 = like extremely). Samples were placed on 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 any residual effect.

Statistical analysis

Each measurement was conducted in quadruplicate, except for the sensory evaluation (n=15). The experimental data were subjected to an analysis of variance (ANOVA) for a completely random design using a statistical analysis system (SAS 9.1 Institute, Inc.). Duncan's multiple range tests were used to determine the difference among means at the level of 0.05.

Results and Discussion

Physico-chemical characteristics of cakes

Bakery products like cakes, cookies, bread etc are very much liked by both young and old generation in rural and urban areas. So, an attempt was made to develop wholesome and nutritious cake by blending whole wheat flour and pumpkin, along with other ingredients. Changes in cake characteristics with added pumpkin powder are shown in Table 2. The fat content of sponge cakes was not significantly different

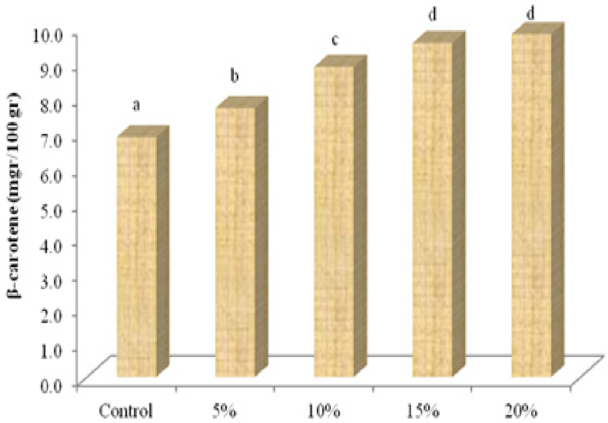

Figure1. The β-carotene content of sponge cake prepared with pumpkin powder. Means with different letter within columns are significantly different (P<0.05).

and was in the range of 22.62-24.11%. The moisture content of sponge cakes decreased significantly with the increasing pumpkin powder level whereas the protein and ash contents of cake showed a reverse trend. Increasing the level of substitution from 0 to 20% pumpkin powder increased the protein and ash content of cakes from 6.19 to 6.89% and 0.94 to 1.63%, respectively. The increase in protein and ash content is because of higher protein and ash content in pumpkin powder.

A significant decrease in cake volume was noted with an increase in the pumpkin powder level. The control sample had an average cake volume of 68.26 cm^3, decreasing to 66.98, 63.08, 56.52 and 51.35 cm^3 for 5, 10, 15 and 20%, respectively. Masoodi *et al*. (2002) reported that the cake volume decreased with increasing apple pomace levels. Increasing the pumpkin powder level from 0 to 20% increased the density of cakes from 366 to 487 kg/m3. In addition, increasing the level of substitution from 0 to 20% pumpkin powder increased the β-carotene content of cakes from 6.84 to 9.78 mg/100g (Figure 1).

The potential of carrot powder was evaluated for production of fiber rich sponge cakes by Salehi, Kashaninejad, Akbari *et al.* (2016). The density,

Table 3. TPA parameters of sponge cakes prepared with pumpkin powder.

Samples	Hardness (g)	Springiness	Cohesiveness	Gumminess (g)	Chewiness (g)	Resilience
Control	603.79 c	0.91 a	0.60 bc	359.87 d	328.36 d	0.23 b
5%	614.16 c	0.92 a	0.62 b	380.97 d	352.10 c	0.26 a
10%	738.83 b	0.87 b	0.66 a	473.88 b	407.37 b	0.26 a
15%	771.51 b	0.89 b	0.58 c	449.28 c	401.21 b	0.22 b
20%	864.54 a	0.91 b	0.60 bc	521.16 a	475.65 a	0.23 b

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

Table 4. Sensory evaluation of pumpkin sponge cakes.

Samples	Crumb colour	Porosity	Flavour	Texture	Overall
Control	8.0 a	4.7 b	5.5 b	6.6 b	5.7 c
5%	6.1 b	5.8 a	7.2 a	7.4 a	7.4 a
10%	6.6 b	6.1 a	7.1 a	7.1 ab	7.5 a
15%	4.2 c	5.7 a	5.8 b	6.8 b	6.5 b
20%	4.8 c	6.0 a	5.9 b	6.6 b	6.6 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).

ash, β-carotene and moisture content of baked cakes increased with increasing carrot powder levels from 0 to 30%, whereas the protein and carbohydrate content of samples showed a reverse trend. Sensory evaluation results indicated that cake with 10% carrot powder was rated the most acceptable. Increasing the level of substitution from 0 to 30% carrot powder increased the β-carotene content of cakes from 4.98 to 19.94 mg/100g.

Color measurement

The results of color measurement of sponge cake supplemented with pumpkin powder dried in an infrared–hot air dryer are presented in table 2. The crumb colour of samples was affected by the replacement of cake flour with pumpkin powder. In general, as pumpkin powder level increased, the crumb colour became darker. For crumb colour, as the level of pumpkin powder increased, the L^* value decreased but the a^* and b^* value increased, indicating that a darker, redder and yellow crumb was obtained as a result of pumpkin powder substitution. The sponge cake with 10% pumpkin exhibited a color, with L^*, a^* and b^* equal to 81.37, 312 and 70.91, respectively.

Textural properties of cakes

In texture profile analysis the hardness of samples measured showed that the cake became harder with increasing levels of pumpkin powder from 0 to 20% (Table 3). The hardness of cakes was directly related to the density of the tested materials (indirectly to its volume). The weight of samples was 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. Springiness measures elasticity by determining the extent of recovery between the first and second compression. The springiness values of sponge cake with pumpkin were in the range of 0.87-0.92.

Cohesiveness quantifies the internal resistance of food structure. Briefly, cohesiveness is the ability of a material to stick to itself. The cohesiveness values of sponge cake with pumpkin were in the range of 0.58-66. 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 increase in the cake gumminess and chewiness with increased level of pumpkin powder from 0 to 20%. The gumminess and chewiness values were in the range of 359.87-521.16 g and 328.36-475.65 g, respectively.

Resilience is the ratio of recoverable energy as the first compression is relieved. The results showed not significantly different in the cake resilience values. Salehi, Kashaninejad, Asadi *et al*. (2016) improvement quality attributes of sponge cake using infrared dried button mushroom. TPA results showed a decrease in the cake consistency with an increased level of button mushroom powder. The consistency values decreased from 4578.83 to 1797.03 g.s with increasing button mushroom powder levels from 0 to 15%. Overall, as the percentage of button mushroom powder increased, consistency, hardness, gumminess, and chewiness decreased whereas cohesiveness increased.

Sensory evaluation

For measuring product liking and preference, the hedonic scale is a unique scale, providing both reliable and valid results (Stone *et al.*, 2012). Statistically significant differences evaluated by the trained consumers were found in the crumb colour, flavour, texture and overall liking scores among the control, 5, 10, 15 and 20% (Table 4). However, the sensory characteristics liking scores of 0% were lower than those of the other cakes and the 20% was slightly darker. The sensory characteristics liking results pointed out that a partial replacement of cake flour with up to 10% pumpkin powder in sponge cakes is satisfactory.

Conclusion

Infrared-hot air method, when properly applied, can be used for achieving a high-quality product. In this study a novel formulation of sponge cake production with pumpkin was developed. Addition of pumpkin powder to the cake formula led to increase in the β-carotene of cakes. The protein and ash contents of sponge cakes increased significantly with the increasing pumpkin powder level whereas the moisture content showed a reverse trend. For crumb colour, as the level of pumpkin powder increased, the L^* values decreased but the a^* and b^* values increased, indicating that a darker, redder and yellow crumb was obtained as a result of pumpkin powder substitution. The gumminess and chewiness values were in the range of 359.87-521.16 g and 328.36-475.65, respectively. The sensory characteristics liking results pointed out that a partial replacement of cake flour with up to 10% pumpkin powder in sponge cakes is satisfactory.

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