doi: 10.17221/551/2015-CJFS

Effect of Psyllium Husk on Physical, Nutritional, Sensory, and Staling Properties of Dietary Prebiotic Sponge Cake

Samira BEIKZADEH[1], *Seyed Hadi PEIGHAMBARDOUST*[2], *Mehdi BEIKZADEH*[1], *Mohammad ASGHARI JAVAR-ABADI*[3] *and Aziz HOMAYOUNI-RAD*[4]

[1]*Faculty of Nutrition and Food Sciences, Tabriz University of Medical Sciences, Tabriz, Iran;* [2]*Department of Food Science, College of Agriculture, University of Tabriz, Tabriz, Iran;* [3]*Road Traffic Injury Research Centre, Faculty of Hygiene, Tabriz University of Medical Sciences, Tabriz, Iran;* [4]*Department of Food Science and Technology, Faculty of Nutrition and Food Sciences, Tabriz University of Medical Sciences, Tabriz, Iran*

Abstract

Beikzadeh S., Peighambardoust S.H., Beikzadeh M., Asghari Javar-Abadi M., Homayouni-Rad A. (2016): **Effect of psyllium husk on physical, nutritional, sensory, and staling properties of dietary prebiotic sponge cake**. Czech J. Food Sci., 34: 534–540.

The effects of various levels of psyllium husk on the properties of dietary prebiotic sponge cakes was evaluated. The control sample showed the lowest specific gravity and apparent density, as well as the highest volume. During the increase of husk percentage, the cake water activity and protein content increased but then they decreased. In comparison with the control, an increase in moisture content and a decrease in symmetry were observed when the husk was added. The softest and the hardest samples were those which contained 7.5 and 15% of husk, respectively. With the addition of husk, the crumb became darker, more reddish, and less yellowish. An elevated level of ash and total fibre was observed in samples with 15% of husk. The overall acceptability of the samples with husk was closer to the property of the control.

Keywords: prebiotic cake; dietary fibre; quality properties; sensory evaluation

Dietary fibre is consumed at a much lower quantity than is its recommended value, resulting in various serious diseases (Mellen *et al*. 2008). The positive role of dietary fibre (DF) as a prebiotic component is its effect in the reduction of chronic diseases including cardiovascular disease, specific types of cancer, and constipation (Lairon *et al*. 2005; Homayouni 2009; Homayouni *et al*. 2012, 2014). It is thus essential to enrich various foods with a variety of dietary fibres. The main sources of fibres which are natural, affordable, and nutritious are cereal bran, fruits and vegetable peels, and polysaccharides separated from various seeds (Sudha *et al*. 2007; Homayouni 2008).

Psyllium can be obtained from seeds of the *Plantago* species. Psyllium husk constitutes the main portion derived from the seed. The husk, obtained from the psyllium seed, is composed of both soluble and insoluble fibres (Bijkerk *et al*. 2004). The molecular composition of the psyllium is: 75% xylose, 23% arabinose, traces of other sugars, and approximately 35% of non-reducing terminal residues. Including both (1→4) and β-(1→3) glycosidic bonds in the xylan backbone, the polysaccharide is a highly branched acidic arabinoxylan (Fischer *et al*. 2004). Due to its high water-binding capacity and stability at a variety of pH levels and temperatures, psyllium can be employed as a food additive, improving shelf life and consumer acceptance, and reducing stickiness (Ibuki 1989). Psyllium can be employed as an emulsifier, stabiliser, and substitute for fat and for wheat flour (Giuntini *et al*. 2003; Zandonadi *et al*. 2010). The inclusion of psyllium as a source of fibre in Japanese sponge cakes, Chinese steamed bread, regular white pan bread making, and Japanese *udon* noodles was

Supported by the Research Vice-Chancellor of Tabriz University of Medical Sciences, Tabriz, Iran

doi: 10.17221/551/2015-CJFS

recorded by Czuchajowska *et al.* (1992), as well as its effect on the quality of dough and bread (Nikouzadeh *et al.* 2008), and its use in the production of biscuits (Raymundo *et al.* 2014). The effects of psyllium on functional characteristics of main wheat-based products like sponge cakes had not yet been explored in the abovementioned studies. Utilising psyllium seed husk in the production of sponge cake and determining its most appropriate level in producing the cake of acceptable nutritional, sensory, and technological qualities were the main objectives of this study.

MATERIAL AND METHODS

The ingredients used in cake formulations were purchased in a local and medicinal herb market. Listed in Table 1 are the properties of the psyllium husk and the flour used.

Separating the husk of psyllium seed. A laboratory mill (Tefal, Paris, France) was used to mill the psyllium seed for 2 min in order to separate the husk. A mixture of sieve with mesh number 18 was used in order to separate the kernel from the shell (Askari *et al.* 2008).

Cake preparation. Listed in Table 2 are the formulations used for the sponge cakes. To prepare the cake batter, sugar and oil were stirred for 10 minutes. Then, eggs in the third stage were added and they were mixed for 2 minutes. The powder materials (milk powder, whey protein, baking powder, and flour) were added. Psyllium husk was added to the formulation as a functional food ingredient. Then vanilla was added. The batter was mixed for one minute. Water was added at the end. The batter was mixed for one minute. All cakes were produced under equal conditions. 1500 g of cake batter was prepared. 40 g of cake batter was then poured into each 4 × 5 × 8 cm metallic pan, and was baked for 20–25 min at 180–190°C. Cakes were stored in polyethylene packaging at room temperature.

Table 1. Flour and psyllium husk characteristics used for sponge cake (in % w/w)

Features	Wheat flour	Psyllium husk
Moisture	11.86 ± 0.01	9.46 ± 0.03
Protein	11.41 ± 0.15	1.52 ± 0.01
Gluten	23.6 ± 0.69	–
Ash	0.445 ± 0.02	2.67 ± 0.12
Total fibre	15 ± 0.11	21.03 ± 0.07

Values are mean ± SD of the mean of triplicate analyses

Table 2. The formulations used for sponge cakes

Ingredient	Grams based on the weight of cake flour	Method
Oil	57	creaming was done to produce light colour cake batter.(in about 10 min)
Refined sugar	72	
Eggs	72	added in 4–5 sections
Flour	100	sift together powder ingredients and add to make the dough become semi-smooth
Baking powder	1.34	
Milk powder	2	
Vanilla	0.5	
Whey powder	4	
Psyllium seed husk	0, 2.5, 5, 7.5, 10, 12.5, 15	
Water	25	after adding water, the dough was smooth

Physicochemical evaluation. Based on the number of AACC standard (2000), the moisture (44–15), protein (46–13), wet gluten (38–11), and ash (08–01) were measured. The symmetry index is an indicator of the surface contour, and high values indicate that the cake has more height in the centre than in the sides. Diameter of the cake was prepared. Then symmetry was determined using a plastic measuring template according to AACC method number 10–91. Water activity was also determined after the cakes cooled down at room temperature (Akesowan 2009). In accordance with AOAC method (17^{th} edition) and with the modifications specific to psyllium fibre suggested by Lee *et al.* (1995), the total dietary fibre content of psyllium was calculated. Specific gravity was evaluated by dividing the weight of a standard measure of the batter by the weight of an equal volume of water. The cake volume was determined through seed displacement (Lin *et al.* 2003). The weight to volume ratio is known as apparent density (Kocer *et al.* 2007). The cakes were sliced and placed into a box in order to evaluate factors such as their redness (a^*), yellowness (b^*), and brightness (L^*). A 14.5 Megapixel camera (Sony, Tokyo, Japan) was used to take crumb images (Sun 2008). Using the proposed reform method of Hess and Setser (1983) and a texture analyser (Model 1140; Instron, London, UK), the texture of the cakes was evaluated.

Sensory evaluation. Using a verbal hedonic scale featuring five points (1 – disliked extremely; 5 – liked extremely) according to the AACC method 10–90 with modifications by Ronda *et al.* (2005) and Lee *et al.* (2008), the acceptability of the softness and

doi: 10.17221/551/2015-CJFS

hardness, porosity, colour of crust and crumb, flavour, and the dry or doughy cake texture during chewing were evaluated by 30 untrained panellists consisting of Faculty of Nutrition and Food Sciences (Tabriz University of Medical Sciences) staff and students. The following equation was used to calculate:

Final score = total experience/total coefficients

Statistical analysis. A one-way analysis of variance was performed by processing the data with the Minitab Analysis System, and the existence of significant differences ($P < 0.05$) between mean values was tested using Sidak's multiple range test. All processes were repeated three times.

RESULTS AND DISCUSSION

Effect of husk on batter properties. The addition of psyllium husk always increased the specific gravity (Figure 1). The control sample thus had the minimum level of husk. Air bubbles which enter the batter during mixing negatively affect its specific gravity (Baeva 2000). Therefore, a decrease in the volume of air incorporated into the batter can directly explain these increases in specific gravities. As it is related to the final texture and volume of the cakes, the trapped air in the batter is a determinant factor for specific gravity (Campbell & Mougeot 1999).

Effect of husk on physical properties. An increase in husk percentage leads to a decrease in cake volume (Table 3). Generally, a decrease in the volume was caused by the husk and the control sample had the highest volume. Additionally, when high percentages of husk were added, an increase in cake apparent density was observed. A wide variety of factors affect the cake volume and density, including air bubbles trapped in the batter during mixing and the batter specific gravity. An inverse relationship exists between volume and specific gravity (Desrochers *et al*. 2004).

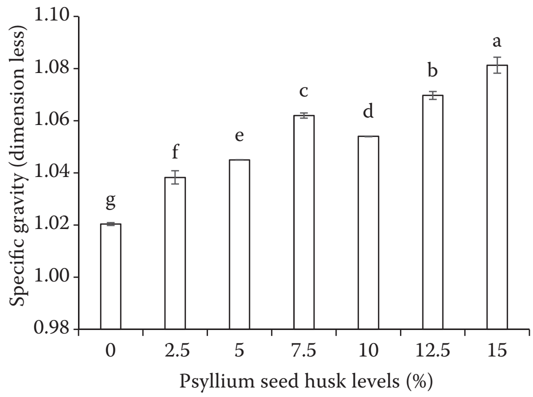

Figure 1. Specific gravity of sponge cake batter containing different levels of psyllium husk

Therefore, it seems that the increase seen in batter specific gravity is due to the influence of psyllium husk on the cake volume, and slows down the rate of gas diffusion, allowing the retention of the gas during the first step of baking. Furthermore, the addition of husk increased water absorption because of the hydrogen bonding interaction between the hydroxyl groups of water and those of polysaccharide macromolecules present in the fibre (Dikeman & Fahey 2006). If the water absorption increases dramatically, the batter of extremely high viscosity will be a result, in which air bubbles cannot be sufficiently trapped. An enhancement of batter viscosity could therefore decrease the cake volume and hinder expansion. Generally, with an increase in the psyllium husk percentage, the cake volume was reduced while its apparent density increased. Czuchajowska *et al*. (1992) found that the cake volume increased when psyllium husk was added at a level of 2%; however it decreased at a level of 4% in comparison with the control sample. The evaluations regarding symmetry conveyed that the addition of up to 7.5% of psyllium husk significantly ($P < 0.05$) decreased the cake symmetry. A reduction in the cake symmetry from 11.6 cm to 43 cm was observed when flour was supplemented with husk.

Table 3. Volume, apparent density, and symmetry properties of sponge cake containing different levels of psyllium husk

Husk level (%)	Volume (cm^3)	Apparent density (g/cm^3)	Symmetry (cm)
0	88.67 ± 5.13^{a}	0.395 ± 0.0236^{d}	11.667 ± 1.528^{a}
2.5	80.33 ± 6.81^{ab}	0.44833 ± 0.00351^{c}	11 ± 1^{a}
5	74.667 ± 1.528^{b}	0.46400 ± 0.02^{bc}	10.67 ± 2.52^{a}
7.5	75 ± 3^{b}	0.45500 ± 0.0141^{bc}	10.333 ± 0.577^{a}
10	56.667 ± 1.528^{c}	0.4997 ± 0.0297^{b}	6 ± 1^{b}
12.5	48.33 ± 4.51^{cd}	0.55767 ± 0.00586^{a}	5 ± 1^{b}
15	38 ± 2^{d}	0.56133 ± 0.1106^{a}	4.333 ± 1.155^{b}

Values are the mean of triplicates ± standard deviation; data followed by different letters are significantly different ($P < 0.05$)

doi: 10.17221/551/2015-CJFS

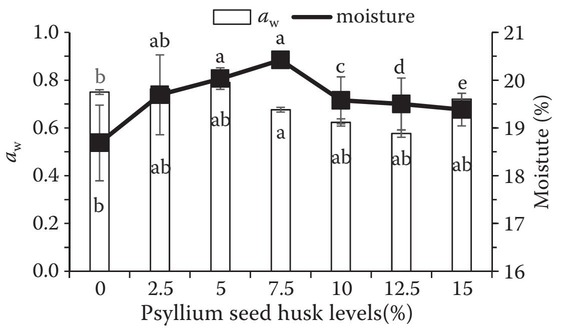

Figure 2. Interaction between a_w and the amount of moisture on first day after baking

Effect of husk on water retention and a_w. The increase of husk percentage up to 5% increased the cake water activity (Figure 2), after which it decreased. For cakes supplemented with fibre, it is acknowledged that a decrease in water activity could lead to an increase in shelf life. Similar results were obtained for the incorporation of psyllium husk in biscuits by Raymundo *et al.* (2014). Regarding the incorporation of mango peels in biscuits, the present results are in agreement with Ajila *et al.* (2008). As illustrated in Figure 3A, one day after baking, the sample featuring 7.5% of husk and the control sample had the highest and lowest moisture content, respectively, with a significant difference ($P < 0.05$) observed between the values. The range of moisture content decreased with the increase of psyllium content from 7.5% to 15%. Raymundo *et al.* (2014) established that the moisture of the control biscuit is significantly higher than that of the psyllium enriched formulations. As depicted in Figure 3B, the lowest amount of moisture was observed in the control sample 7 and 14 days after baking. The samples with 2.5, 5, and 7.5% of incorporated husk had maximum percentages of moisture, though the difference between them was not significant ($P < 0.05$). Nikouzadeh *et al.* (2008) also found that 10% of psyllium husk increased the bread moisture content. Czuchajowska *et al.* (1992) reported similar results. An increase in the absorption of water is caused by the interaction between the hydroxyl groups of water and those of polysaccharide macromolecules present in the husk (Dikeman & Fahey 2006).

Influence of husks on sponge cake texture. During 1, 7, and 14 days after baking, the textural analysis revealed that the increasing fibre content of cakes from 10% to 15% leads to a rise in textural hardness (Figure 3B). The softest and the hardest samples were those which featured 7.5 and 15% of husk, respectively. During maintenance, no significant differences in textural hardness were observed between the samples with 0, 2.5, and 5% of husk. The gluten network is positively strengthened by psyllium husk at lower concentrations, as found by Raymundo *et al.* (2014). However, lower values of hardness were observed at higher concentrations of husk. Significantly higher hardness ($P < 0.05$) is therefore observed in biscuits which have 3 and 6% (w/w) of husk. Hardness values similar to those of the control were observed in biscuits with higher fibre contents (13 and 15% w/w).

Effect of husk on colour properties. No significant differences ($P < 0.05$) were found between L^* and a^* values in comparison with all the other samples. In terms of b^* value, samples with up to 10% of husk showed a significant difference ($P < 0.05$) when compared to the control sample. Generally, the incorporation of psyllium husk caused the crumb to become more reddish (higher a-value), darker (lower L-value), and less yellowish (lower b-value). Amongst the main reasons for colour change are the natural pigments present in the psyllium seed husk. Sudha *et al.* (2007) reported the darkening of produced products due to the inclusion of fibre. It was found by Raymundo *et*

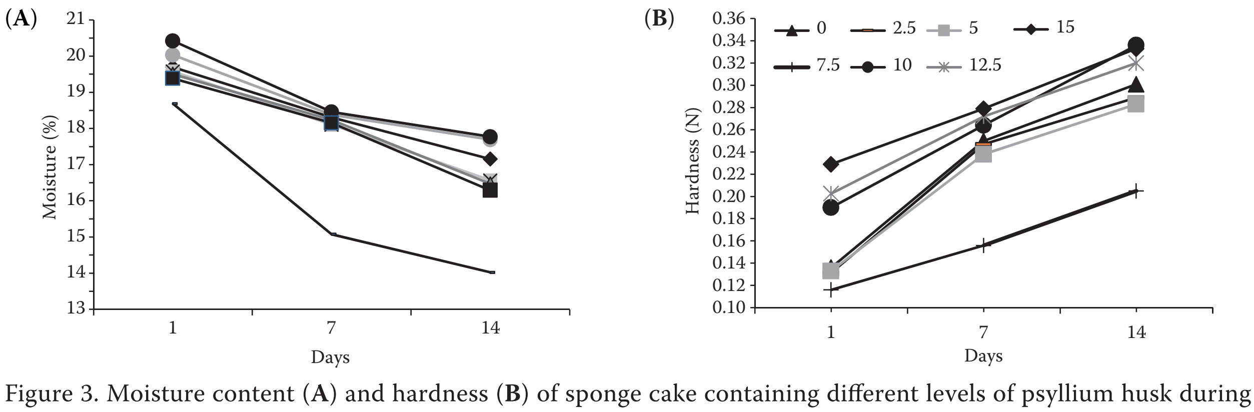

Figure 3. Moisture content (**A**) and hardness (**B**) of sponge cake containing different levels of psyllium husk during 1, 7, and 14 days after baking

doi: 10.17221/551/2015-CJFS

Table 4. Crumb colour characteristics of cakes containing different levels of psyllium husk

Psyllium levels (%)	L^*	a^*	b^*
0	68.75 ± 1.377[a]	–0.75 ± 1.702[a]	50.25 ± 2.394[a]
2.5	66.25 ± 2.462[a]	–1.5 ± 1.555[a]	48.75 ± 1.931[ab]
5	62.25 ± 3.544[a]	–1.75 ± 2.594[a]	46.00 ± 2.041[ab]
7.5	63.75 ± 2.869[a]	0.25 ± 1.652[a]	47.25 ± 1.931[ab]
10	61.75 ± 2.097[a]	0.5 ± 1.848[a]	39.00 ± 1.683[bc]
12.5	59.25 ± 1.652[a]	2.25 ± 0.946[a]	37 ± 1.291[bc]
15	57.25 ± 1.652[a]	2.75 ± 0.629[a]	35.5 ± 2.217[c]

Values are the mean of triplicates ± standard deviation; data followed by different letters are significantly different ($P < 0.05$)

al. (2014) that when increasing psyllium husk, the L^* value increased while the b^* and a^* values decreased.

Effect of husk on nutritional properties. The results showed that increasing husk percentages caused a significant increase in ash content of the samples (Table 5). The control sample had a lower level of ash compared to the samples with psyllium husk. An increase of ash is caused by the considerable content of minerals in the psyllium sample (2.67% w/w from Table 1). Raymundo *et al.* (2014) demonstrated similar results. The increase in psyllium percentage increases the protein content, which afterwards decreases (Table 5). Raymundo *et al.* (2014) also demonstrated that an increase in husk incorporation is associated with a decrease in the capacity of gluten development, as well as a significant ($P <$ 0.05) decrease of protein content and a reduction of firmness. The protein levels determine the impact of husk incorporation on the cake firmness. An increase in the protein level was reported to increase the firmness of cookies by Fustier *et al.* (2009). It was found that the total fibre was positively affected by increasing the levels of psyllium husk. The most numerous type of soluble fibre in the psyllium husk seed consists of a polymer of arabinose, galactose, galacturonic acid, and rhamnose (Nelson 2001).

Effect of husk on sensory evaluation. Besides flavour, all attributes of the cakes with psyllium husk were similar in terms of the sensory profile to the control cake (Figure 4). Flavour was negatively affected by the increases in the levels of psyllium husk. The score for flavour decreased from 5.0% for 5% psyllium husk to 3.6% for 15% psyllium husk incorporation. The lowest score for cake porosity, softness/hardness, and crumb

Table 5. Nutritional properties of sponge cakes containing different levels of psyllium husk

Husk level (%)	Ash % (w/w)	Fibre % (w/w)	Protein % (w/w)
0	1.131 ± 0.006[d]	0.613 ± 0.080[f]	7.073 ± 0.141[d]
2.5	1.370 ± 0.060[c]	0.916 ± 0.020[e]	7.140 ± 0.040[cd]
5	1.496 ± 0.065[c]	1.131 ± 0.011[d]	7.370 ± 0.026[bc]
7.5	1.803 ± 0.055[b]	1.520 ± 0.010[c]	7.980 ± 0.010[a]
10	1.910 ± 0.026[b]	1.600 ± 0.100[c]	7.391 ± 0.007[b]
12.5	1.803 ± 0.025[b]	1.800 ± 0.020[b]	6.816 ± 0.125[e]
15	2.193 ± 0.090[a]	1.953 ± 0.015[a]	6.400 ± 0.100[f]

Values are the mean of triplicates ± standard deviation; data followed by different letters are significantly different ($P < 0.05$)

Table 6. Overall acceptability of sponge cakes containing different levels of psyllium husk on days 1, 7, and 14 after baking in sensory and staling evaluation

Time (Day)	Psyllium husk levels (%)						
	0	2.5	5	7.5	10	12.5	15
1	4.233 ± 0.592[ab]	4.383 ± 0.257[ab]	4.766 ± 0.152[a]	4.633 ± 0.202[ab]	3.967 ± 0.401[ab]	3.683 ± 0.293[b]	3.683 ± 0.293[b]
7	3.5 ± 0.451[ab]	3.667 ± 0.191[ab]	4.25 ± 0.433[a]	3.833 ± 0.191[ab]	3.167 ± 0.289[b]	3.208 ± 0.260[b]	3.041 ± 0.072[b]
14	3.083 ± 0.072[cd]	3.167 ± 0.289[bc]	4.083 ± 0.072[a]	3.583 ± 0.072[b]	2.916 ± 0.072[cd]	2.708 ± 0.072[de]	2.458 ± 0.191[e]

Values are the mean of triplicates ± standard deviation; data followed by different letters are significantly different ($P < 0.05$)

doi: 10.17221/551/2015-CJFS

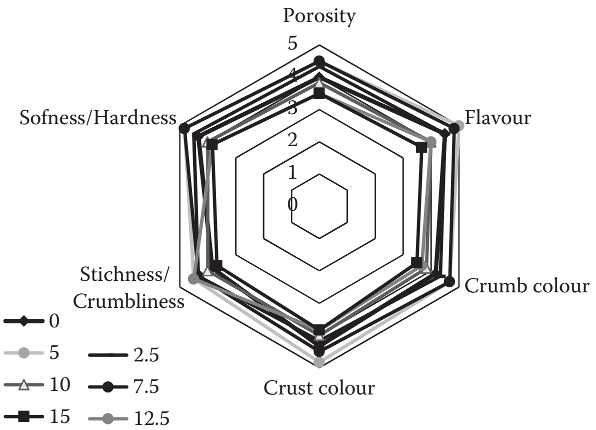

Figure 5. Spider-graph for the sensory profile of sponge cakes containing different levels of psyllium husk

colour was obtained by the sample with 15% of husk, with the highest scores being given to the samples with 5 and 7.5% of husk. No significant differences ($P < 0.05$) were found between these values. Regarding the stickiness/crumbliness and cake crust colour, similar results were obtained, with the 5% and 15% husk samples receiving the lowest and the highest scores, respectively. It was found by Park *et al.* (1997) that the addition of 10% of wheat husk and psyllium husk (at the 7 : 3 ratio) caused black spots on the crust of the produced sample. The samples which contained 15% of husk were harder than all the other samples in such a way that the results from sensory evaluation were similar to those obtained by using the device (Figure 4). The addition of about 5% of psyllium husk to bread has been shown to improve form, shape, crust, pores, and flavour in other studies. However, it had no significant effect on the texture softness and hardness or on chewiness (Nikouzadeh *et al*. 2008). In terms of overall acceptability, the characteristics of the test samples one day after baking were similar to those of the control (Table 6), with the 5% husk sample being the only one found to show a significant difference ($P < 0.05$) when compared to the 15% sample. Regarding the effect of psyllium husk on bread sensory properties, Nikouzadeh *et al.* (2008) found that the sample with 5% husk achieved the highest score. A negative impact on sensory assessment resulted from higher concentrations of added psyllium in the study of Park *et al.* (1997), in addition to difficulties in the processing of the product. Raymundo *et al.* (2014) demonstrated a similar effect. The chewiness, flavour, softness/hardness, and overall acceptability were evaluated for staling during storage (7 and 14 days after baking). In terms of overall acceptability at 7 and 14 days, the highest and the lowest scores were obtained by the 5 and 15% husk samples, respectively. The acceptability of the cakes with up to 7.5% of husk was greater than that of the control. When assessing the addition of 2 and 4% of psyllium husk to Japanese sponge cake, Czuchajowska *et al.* (1992) concluded that the overall sensory attributes of the products were reduced after 24 hours of storage at room temperature.

CONCLUSION

In the production of cakes, psyllium husk, which contains a high level of dietary fibre, can be a valuable additive. Unsurprisingly, various levels of incorporated psyllium have different effects on the quality of the batter and cake. In line with the results obtained, the batter density increased significantly when over 7.5% of psyllium husk was incorporated into the wheat flour. This would immensely impact the cake volume, symmetry, water activity, apparent density, hardness, moisture, ash, protein, total fibre, colour, and sensory characteristics. The highest overall acceptability in terms of sensory evaluation was achieved by the samples which contained 5% of psyllium seed husk. Generally, incorporating to 7.5% of psyllium seed husk can improve the overall quality of the sample.

References

Ajila C.M., Leelavathi K., Rao U.J.S.P. (2008): Improvement of dietary fiber content and antioxidant properties in soft dough biscuits with the incorporation of mango peel powder. Journal of Cereal Science, 48: 319–326.

Akesowan A. (2009): Quality of reduced-fat chiffon cakes prepared with erythritol-sucralose as replacement for sugar. Pakistan Journal of Nutrition, 8: 1383–1386.

Askari H., Farahnaky A., Aminlari M., Majzoobi M., Mesbahi G.H. (2008): Extraction of mucilage gum (*Plantago ovata* L.) and the study of its rheological properties. In: Proceedings 18th National Congress on Food Technology. Mashhad. Iran. [in Persian]

Baeva M.R., Panchev I.N., Terzieva V.V. (2000): Comparative study of texture of normal and energy reduced sponge cakes. Nahrung, 44: 242–246.

Bijkerk C.J., Muris J.W.M., Knottnerus J.A., Hoes A.W., De Wit N.J. (2004): Systematic review: the role of different types of fiber in the treatment of irritable bowel syndrome. Alimentary Pharmacology and Therapeutics, 19: 245–251.

doi: 10.17221/551/2015-CJFS

Campbell G.M., Mougeot E. (1999): Creation and characterization of aerated food products. Trends in Food Science and Technology, 10: 283–296.

Czuchajowska Z., Paszczynska B., Pomeranz Y. (1992): Functional properties of psyllium in wheat-based products. Cereal Chemistry, 69: 516–520.

Desrochers J.L., Seitz K.D., Walker C.E., Wrigley C., Colin W. (2004): Cakes, Chemistry of Manufacture. Encyclopedia of Grain Science. Elsevier: 129–133.

Dikeman C.L., Fahey Jr G.C. (2006): Viscosity as related to dietary fiber: a review. Critical Reviews in Food Science and Nutrition, 46: 649–663.

Fischer M.H., Yu N., Gray G.R., Ralph J., Anderson, L., Marletta J.A. (2004): The gel forming polysaccharide of psyllium husk (*Plantago ovata* Forsk). Carbohydrate Research, 339: 2009–2017.

Fustier P., Castaigne F., Turgeon S.L., Biliaderis C.G. (2009): Impact of commercial soft wheat flour streams on dough rheology and quality attributes of cookies. Journal of Food Engineering, 90: 228–237.

Giuntini E.B., Lajolo F.M., Menezes E.W. (2003): Potencial de fibra alimentar em países ibero-americanos: alimentos, produtos e resíduos. Archivos Latinoamericanos de Nutrición, 53: 14–19.

Hess A., Setser C.S. (1983): Alternative systems for sweetening layer cake using aspartame with and without fructose. Cereal Chemistry, 60: 337–341.

Homayouni A. (2008): Therapeutical effects of functional probiotic, prebiotic and synbiotic foods. Tabriz University of Medical Sciences.

Homayouni A. (2009): Letter to the editor. Food Chemistry, 114: 1073.

Homayoni A., Akbarzadeh F., Mehrabany E.V. (2012): Which are more important: Prebiotics or probiotics? Nutrition, 28: 1196-1197.

Homayouni A., Amini A., Keshtiban A.K., Mortazavian A.M., Esazadeh K., Pourmoradian S. (2014): Resistant starch in food industry: A changing outlook for consumer and producer. Starch, 66: 102-114.

Ibuki M. (1989): Moist pellet type feeds containing psyllium gum for culturing fishes. Japanese Kokai Tokkyo Koho, Japan Patent 01, 202, 262 (89, 202, 262). (Chemical Abstracts, 112, 7626y).

Kocer D., Hicsasmaz Z., Bayindirli, A., Katnas S.A. (2006): Bubble and pore formation of the high-ratio cake formulation with polydextrose as a sugar- and fat-replacer. Journal of Food Engineering, 78: 953–964.

Lairon D., Arnault N., Bertrais S., Planells R., Clero E., Hercberg S., Boutron-Ruault M.C. (2005): Dietary fiber intake and risk factors for cardiovascular disease in French adults. The American Journal of Clinical Nutrition, 82: 1185–1194.

Lee C.C., Wang H.F., Lin S.D. (2008): Effect of isomaltooligosaccharide syrup on quality characteristics of sponge cake. Cereal Chemistry, 85: 515–521.

Lin S.D., Hwang C.F., Yeh C.H. (2003): Physical and sensory characteristics of chiffon cake prepared with erythritol as replacement for sucrose. Journal of Food Science, 68: 2107–2110.

Mellen P.B., Walsh T.F., Herrington D.M. (2008): Whole grain intake and cardiovascular disease: a meta-analysis. Nutrition, Metabolism, and Cardiovascular Diseases, 18: 283–290.

Nelson A.L. (2001): High Fiber Ingredients. St. Paul, Egan Press.

Nikouzadeh H., Taslimy A., Azizi M.H. (2008): Effects of the addition of psyllium husk on the rheological characteristics of dough and quality of sangak bread. In: Proceedings 18th National Congress on Food Technol. Mashhad. Iran [in Persian].

Park H., Seib P.A., Chung O.K. (1997): Fortifying bread with a mixture of wheat fiber and psyllium husk fiber plus three antioxidants. Cereal Chemistry, 74: 207–211.

Raymundo A., Fradinho P., Nunes M.C. (2014): Effect of psyllium fibre content on the textural and rheological characteristics of biscuit and biscuit dough. Bioactive Carbohydrate and Dietary Fibre, 3: 96–105.

Ronda F., Gamez M., Blanko C.A., Caballero P.A. (2005): Effects of polyols and nondigestible oligosaccharides on the quality of sugar-free sponge cakes. Food Chemistry, 90: 549–555.

Sudha M.L., Vetrimani R., Leelavathi K. (2007): Influence of fiber from different cereals on the rheological characteristics of wheat flour dough and on biscuit quality. Food Chemistry, 100: 1365–1370.

Sun D. (2008): Computer Vision Technology for Food Quality Evaluation. Academic Press.

Zandonadi R.P., Botelho R.B.A., Araújo W.M.C. (2009): Psyllium as a substitute for gluten in bread. research and professional briefs. Journal of the American Dietetic Association, 109: 1781–1784.

Received: 2015–12–03
Accepted after corrections: 2016–11–17

Corresponding author:

Assoc Prof Aziz Homayouni-Rad, Tabriz University of Medical Sciences, Faculty of Nutrition and Food Sciences, Department of Food Science & Technology, Attar Nishabouri St. Ghol-Ghasht Ave, 5166614711 Tabriz, Iran;
E-mail: homayounia@tbzmed.ac.ir