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A new study on the quality, physical and sensory characteristics of cupcakes with *Althaea officinalis* mucilage

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Abstract

In this study, the functionality of *Althaea officinalis* mucilage (AOM) on cupcake quality and its potential use in retarding the staling process have been studied. For this purpose, the effects of different concentrations of AOM (0, 0.25, 0.5, and 1%) on some physical properties such as hardness and color and the sensory properties of cupcakes and their batter were determined. In general, the overall properties of cupcake were notably influenced by mucilage addition. The results demonstrated that the mucilage addition significantly ($p<0.05$) improved physical properties of cupcakes (moisture content, specific volume, and batter density and viscosity) compared with the control sample. Hardness during storage decreased significantly with the addition of mucilage. The results from the comparison of means for the color parameter, indicated that the lowest L* value and the highest L* of crust belonged to the control sample and those that featured 0.25 and 1% mucilage, respectively. The cakes with 0.75 and 1% mucilage obtained the highest scores of sensory analyses.

Keywords: *Althaea officinalis*; Sensory properties; Quality; Cupcake.

Introduction

Bakery products are a very significant part of the daily diet of consumers. Among them, cakes are particularly popular because of their favorable sensory properties, easy availability, and low cost.

High-quality cakes have numerous characteristics, including high volume, uniform crumb structure, softness, long shelf life and tolerance to staling (Gelinas *et al*., 1999). These characteristics mainly depend on various factors such as a balanced formula, the ingredients, aeration of cake batters, mixing conditions during batter preparation and process conditions. The quality of cake can be influenced by the addition of substances such as hydrocolloids that have an impact on these characteristics (Anderson *et al*., 1988).

Hydrocolloids have been widely applied in food production to improve food texture, delaying starch retrogradation, improve moisture retention, extend the shelf life and enhance the overall quality of the products during storage (Gomez *et al*., 2007). As gluten-substitutes (Kim and De Ruiter, 1968; Toufeili *et al*., 1994; Sahraiyan *et al*., 2014), antistaling agents in bread and cakes (Armero and Collar, 1996; Davidou *et al*., 1996; Schiraldi *et al*., 1996), fat replacement (Albert and Mittal, 2002; Shokri Busjin, 2004; Kalinga and Mishra, 2009; Song *et al*., 2017), and source of fiber (Apling *et al*., 1978), hydrocolloids are added to food products. The extensive use of hydrocolloids in foods has made the necessity to search for new natural sources of hydrocolloids with special functional properties and appropriate pricing, which can be applied instead of commercial gums (Koochaki and Hesarinezhad, 2017). One potential source of these natural hydrocolloids is *Althaea officinalis*.

A. officinalis, of the *Malvaceae* family, is one of the traditional medicinal plants especially for the treatment of cough and irritation of mucous membranes (Deters *et al.*, 2010). *Althaea officinalis*, also known as Khatmi in Iran, has many flowers. Studies

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have shown that an aqueous extract of *A. officinalis* flower has potential benefits in inflammation, gastric ulcer, and platelet aggregation with no visible adverse effects (Hage-Sleiman *et al.*, 2011; Mousavi *et al.*, 2019). Mucilage is a hydrocolloid, a complex polymer with the nature of carbohydrate having branched structures and soluble hydrophilic polysaccharides, which are thick, sticky substances (Naqvi *et al.*, 2011). AOM as a new source of hydrocolloid has interesting functional properties that enable it to be employed as a natural thickener, stabilizer, and anti-oxidant agent with high thermal tolerance for application in the food and pharmaceutical industries (Mousavi *et al.*, 2019). Previous studies have shown that AOM had high total carbohydrate content (75.01%) comprise a high amount of uronic acids (28.06%), revealing its strong polyelectrolyte nature and the relative number of acidic polysaccharides in the mucilage. It has been reported that the major monosaccharide of this mucilage was xylose (32.52%), together with substantial amounts of glucuronic acid (26.53%), mannose (10.83%), rhamnose (12.42%), arabinose (4.19%), galactose (5.84%), glucose (6.15%), and with traces of galacturonic acid (1.53%). Studies have also revealed that this mucilage has an interesting characteristic of scavenging DPPH (Mousavi *et al.*, 2019).

To the best of our knowledge, no systematic study has so far provided information on the application of this novel hydrocolloid in bakery products, particularly in the cupcake. Therefore, this study was undertaken to evaluate the impact of different concentrations (0%, 0.25%, 0.5%, and 1%) of AOM on the cupcake quality and consumer acceptance as a result of supplementation.

Materials and methods

Mucilage extraction

Marshmallow flowers were purchased from an herbal market in Mashhad, Iran. Extraction of mucilage from the dried flowers of *A. officinalis* was carried out by maceration process. The powders of dried flowers were soaked in distilled water (for 1 h, pH 6.63, 55°C, and water/powder ratio 80:1) (Mousavi *et al.*, 2019). The extracted solution was then filtered and dried in an oven at 50°C and finally the powder was milled, packed and kept at cool and dry condition. The dried mucilage was milled and passed through a 50 mesh sieve.

Cupcake preparation

The control cupcake formula was: 100% flour, 90% sugar, 65% egg, 65% milk, 50% sunflower oil, 0.2% vanillin, 1.11% sodium bicarbonate, 1.35% sodium acid pyrophosphate, and 0.2% mono-calcium phosphate (Lebesi and Tzia, 2011). Three different AOM levels were added to the cupcake formulae. Cake batter was prepared in a Kenwood mixer (Model KM 400, Kenwood, UK) using sugar batter method. The oil and the sugar were creamed in the mixer at 180 rpm (speed 4) during 10 min. Eggs were then added and mixed for 6 min at the same rotation. Vanillin was also added and mixed at speed 4 for 1 min. Flour, milk, and AOM were added and mixed at speed 2 (90 rpm) for 4 min. The required quantities of batter (30 g) were placed into fat-coated aluminum pans which have 35-mm diameter and 45-mm height. The samples were baked at 180 °C in a laboratory oven with air circulation (Noble, Model: KT-45XDRC) for 30 min. The oven trays were placed at the same level in the oven with the same number of cake pans per baking batch. The cooled cakes (at room temperature for 1 h) were packed in polyethylene bags before textural analyses (during 14 days) and sensory characteristics test (day 0).

Physical Profiles

The specific volume and density of the cupcake was evaluated by the canola displacement method (Hosseini Ghaboos *et al.*, 2018). It was averaged from four replications. The moisture content of the samples was determined in an oven at 105°C for 4 h (AOAC, method no. 934.06). The viscosity of the cake batter was measured using a rotational viscosimeter (Model RVDV-II$^+$ pro, Brookfield Engineering, Inc., USA).

Immediately after mixing, 200 ml of cake batter was poured into a 200 ml beaker and the viscosity was determined. The apparent viscosity of cake batters at constant shear rate (45.6 s^{-1}) were studied using spindle SC4-31 at 25°C.

Color measurement

In order to survey the effect of mucilage addition on color changes of the cupcake samples, a computer vision system was applied. Sample illumination was reached by two fluorescent lights (10 W, 40 cm in length), which were located in a black box (0.5m×0.5m×0.5m). The crumb color determinations of the midsection of the cakes, dough color, and crust of cupcakes were obtained by a high-definition camera (Canon Powershot G1X, Tokyo, Japan) which was located vertically at a distance of 20 cm from the samples. Due to the computer vision system perceived color as RGB signals, which is device-dependent (Fernandez *et al*., 2005), the 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 two colors corresponds approximately to the color difference perceived by the human eye (Pedreschi *et al*., 2007). The L* (lightness/darkness that ranges from 0 to 100) of cupcakes were performed using Image J software version 1.42e, USA.

Textural characteristics

Hardness of cupcakes was evaluated after removing the crust from the samples (2× 2× 2 cm) using a texture analyzer (Instron, Model 1140, UK). Instron is equipped with a load cell (5 N) and cylindrical probe with a diameter of 24 mm. The force needed for 40% compression was documented under the following conditions: 50 mm/min probe speed, 1in sample thickness, and 5– 50 N of force exerted by the load cell device. According to F_{max}, the maximum compressive force exerted on the sample was reported. The hardness unit is based on Newton. By averaging four readings, the reported values were determined. The hardness of the samples was evaluated at 1, 7 and 14 days after cooking in order to evaluate the interactions between different percentages of mucilage and storage time on the produced cupcakes (Beikzadeh *et al.*, 2017).

Sensory evaluation

Sensory evaluation was assessed by a panel of 15 trained consumers using hedonic scales, scored 1–10, in which degree of liking were described (1= dislike extremely, 5= neither like nor dislike, 9= like extremely). The cupcake samples were placed on dishes and named with random 3-digit numbers (Lee *et al.*, 2008). Panelists evaluated the samples in a testing area and were instructed to rinse their mouths with water between samples to minimize any residual effect.

Results and discussion

Physical properties

The physical properties of cupcakes and batters containing different concentrations of mucilage are shown in Table 1. Moisture content is an important quality characteristic in baked products as its increase can improve the overall quality of the products during storage (Dadkhah *et al*., 2012).

The moisture content of cakes varied from 10.61 to 11.41%. Compared with the control, moisture contents were significantly higher in samples containing mucilage. With increase in concentrations of mucilage the moisture contents were increased, although the differences were statically insignificant ($p<0.05$). These results may be due to the hydrophilic property of the added hydrocolloid causing interaction between flour and water. The hydrogen bonding interaction between the hydroxyl groups of water and those of the mucilage lead to more water absorption (Friend *et al*., 1993; Oakenfull *et al*., 1999; McCarthy *et al*., 2005; Song *et al*., 2017).This feature of hydrocolloids depends on the type of hydrocolloid and its interactions with the other ingredients of formulation (Mousavi *et al.*, 2019).Our results coincide with the findings of Beikzadeh et al. (2018) when

Psyllium seed and xanthan gums were added to the sponge cakes (Samira Beikzadeh *et al.*, 2018). Sheikholeslami et al. (2017) also reported an increase in moisture content of sponge cake by increasing the amount of chubak extract and *Lallemantia royleana* seed gum as natural additives. Many researchers also obtained similar results with different gums (Ayoubi *et al.*, 2009; Gomez *et al.*, 2007; Shalini & Laxmi, 2007; Sidhu & Bawa, 2002; Tavakolipour & Kalbasi-Ashtari, 2007).

Table 1. Physical properties of cupcakes manufactured with and without (control) different concentration of AOM.

Concentration (%)	Physical properties			
	Apparent viscosity (Pa.s)	Moisture content (%)	Specific volume (cm^3/g)	Density of Batter (g/ml)
0.00	12.77±0.25[a]	10.61±0.10[a]	0.82±0.17[a]	1.13±0.10[a]
0.25	24.34±0.22[b]	11.25±0.14[b]	2.03±0.13[b]	1.16±0.11[a]
0.50	24.54±0.15[b]	11.38±0.15[b]	2.24±0.12[bc]	1.07±0.07[a]
1.00	37.69±0.20[c]	11.41±0.18[b]	2.41±0.10[c]	1.05±0.07[a]

Values are the average of triplicates ± standard deviation. For each characteristic, data followed by different letters are significantly ($P< 0.05$) different.

The density of batter samples varied from 1.13 to 1.05, but the differences among density of samples were statistically insignificant ($p>0.05$). Density indicates the amount of air incorporated in the dough (Allais *et al.,* 2006a); where it is inversely related to the air incorporation in the batter (Allais *et al*., 2006b; Gómez *et al.,* 2010). Ayoubi et al. (2009) reported that the addition of guar and xanthan gums to the cake reduced sample apparent density; whereas Gomez et al. (2007) showed that the presence of hydrocolloids reduced the amount of air retained on cake batter as demonstrated by the increase in its density.

The dough viscosity is an important quality property in cake influencing the volume of the cake. Evaluations with regard to apparent viscosity showed that it increased significantly, but the differences among 0.25 and 0.5% were not significant. This increasing trend can be directly related to the more air incorporated to the batter (Swami *et al.*, 2004). Swami et al. (2004) reported that an increase in water content or air incorporation level in the batter leads to a reduction in viscosity of batter samples. The batter with 1.00 % AOM powder exhibited the highest viscosity among all the cake batters. In the present study, the apparent viscosity of cake batters varied from 12.77 to 37.69 Pa.s (shear rate= 45.6 s^{-1}) depending on the concentration of AOM powder.

It is known that the specific volume of baked cake is an indicator of the air incorporation during mixing and retention during baking depending on batter viscosity and bubble distribution within the batter. A higher gas retention and higher expansion of the product leads to a higher specific volume (Gómez *et al*., 2008). As shown in Table1, the specific volumes of samples indicated a significantly higher value with increasing mucilage content showing a higher amount of air remained in the cake. Generally, with the increase in the amount of mucilage, the cake volume and batter viscosity were increased. These results are in disagreement with those found by Young and Bayfield (1963) who reported that the cake volume decreased when hydrocolloid was added.

The results obtained were in agreement with those obtained by Gomez et al. (2007) who found that the hydrocolloid addition lead to higher volumes. An improvement in the bread specific volume obtained when adding 0.5% HPMC and xanthan to wheat bread formulation (Rosell *et al.*, 2001). Similar results were found for cake by adding some other hydrocolloids (Miller and Hoseney, 1993; Gómez *et al.*, 2008; Sowmya *et al.*, 2009; Sheikholeslami et al., 2017; Beikzadeh *et al.*, 2018; Koocheki and Hesarinejad, 2019a,b).

Textural Properties

Figure 1 presents the influence of AOM on cupcake hardness during 1, 7 and 14 days post-baking. The hardness of the samples increased during storage. This increase was higher in the control sample and sample containing 0.25% mucilage. The addition of mucilage significantly decreased cake hardness compared to the control sample. With the increase in the mucilage percentage, hardness decreased excessively. As portrayed in Figure 1 the samples featuring 1% and 0.75% mucilage respectively had the lowest hardness that hardly changed during storage. The results obtained were in agreement with previous findings of Beikzadeh et al. (2017) who observed that the addition of 0.25% marve combined with 0.25% psyllium decreased cake hardness compared with the control sample. Similar results were reported by Hajmohammadi et al. (2014) and Ayoubi et al. (2008). Some researchers also reported the positive effect of different gums on making soft cake texture and reducing the staling during storage (Peighambardoust *et al*., 2016; Sheikholeslami *et al*., 2017; Beikzadeh *et al.*, 2017). This softening effect should be attributed to mucilage water retention capacity (Rosell *et al.*, 2001; Chaplin, 2003; Hug-Iten *et al*., 2003; Dikeman and Fahey, 2006), and a possible inhibition of the amylopectin retrogradation (Biliaderis *et al*., 1997; Collar *et al*., 2001). Davidou et al. (1996) reported that the addition of HPMC lead to soften the product texture because of the obstruction of interaction between the polymers of starch, and also protein with starch, by the chains of the gum, resulting in changes to hardness.

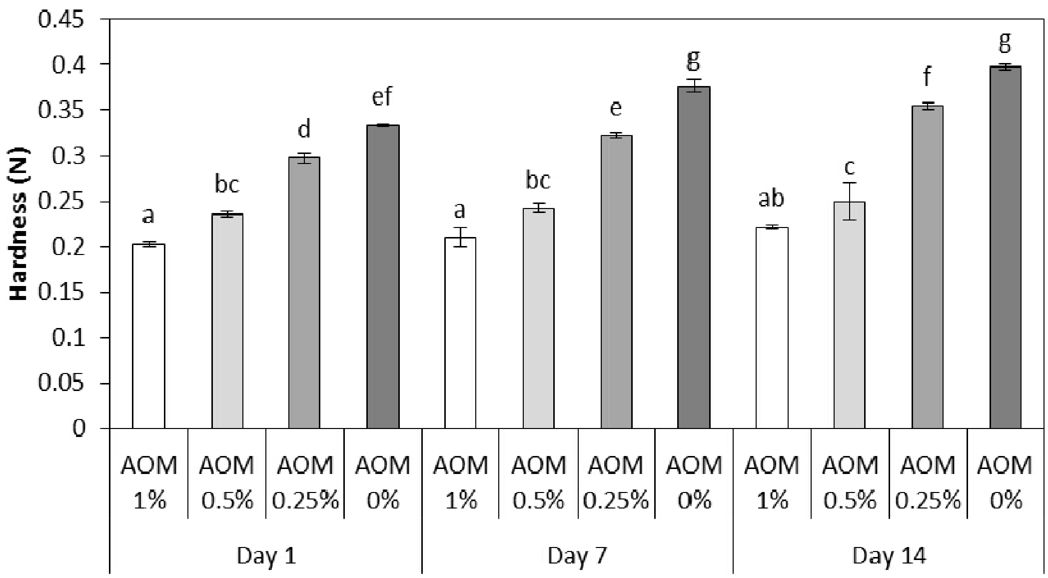

Fig. 1. Hardness of fresh and 14 days stored cupcakes containing different concentrations of AOM

Color measurement

Color is one of the most important characteristics affecting the appearance of the cake. The color of the crust is affected by the Millard reaction. Additionally, the color of crumbs is influenced by the ingredients in the formula (Akesowan, 2007). The effect of mucilage addition on color is shown in Table 2. The crumb of cupcakes showed a decrease in L* value as the amount of mucilage increased; however, the differences were insignificant. But the crust color was influenced by the amount of mucilage as indicated by change in L* values shown in

Table 2. Samples containing mucilage presented lighter crust color in comparison to the control sample. The L* values of the crust increased significantly. The darkest (the lowest L* value) and the lightest crust color (highest L*) were observed in the control sample and those that featured 0.25 and 1% mucilage, respectively. Increasing *L** value may be related to retention of moisture by the gums (Lazaridou *et al.*, 2007). Retention of moisture during the baking process reduced the level of crust changes in bakery products. The lightening of cake was due to changes of crust. Uniform crust more than non-uniform crust enhanced L* value (Lazaridou *et al.*, 2007). Beikzadeh et al. (2017), Sadeghnia *et al.* (2011) and Sahraiyan *et al.* (2014) obtained the same results with this study.

Table 2. Lightness index (L*) of dough and cupcakes with different concentrations of AOM

Concentration (%)	Cake crumb	Cake crust	Cake dough
0.00	54.07±0.92[a]	57.70±1.12[c]	69.10±1.15[b]
0.25	52.01±0.98[a]	75.78±1.31[a]	63.66±1.52[b]
0.50	53.99±1.01[a]	69.09±0.85[b]	60.70±2.08[b]
1.00	52.32±0.55[a]	72.96±1.06[a]	62.34±2.08[b]

Sensory evaluation

Sensory attributes play important role in determining the acceptability of product (Hesarinejad *et al*., 2017, 2019). Therefore, the sensory evaluation of samples was evaluated in terms of odor, flavor, porosity, appearance, Hardness and overall acceptability (Table 2). In general, with the addition of mucilage, all sensory attributes except odor desirability were significantly ($P<0.05$) enhanced compared with the control sample. Attending the odor desirability, Sensorial evaluation shows that there is not any significant difference among samples ($P<0.05$). But larger percentage of mucilage leads to a higher evaluation of porosity, appearance, flavor, Hardness and overall acceptability and the highest acceptance score was obtained when 0.5 and 1 % mucilage was added. The presence of gums increases acceptability relating to moisture retention, texture, softness and flavor (Bench, 2007). The improving effect of different gums addition on the texture of cake has been reported previously by other researchers (Gomez *et al.*, 2007; Sowmya *et al.*, 2009; Hajmohammadi *et al.*, 2014; Beikzadeh *et al.*, 2018).

Table 3. Sensory evaluation of cupcakes containing different concentrations of AOM

Concentration (%)	Crumb color lightness	Odor desirability	Porosity	Appearance	Flavor	Texture	Total acceptance
0.00	8.3±1.2[b]	7.4±1.0[a]	6.1±0.9[a]	6.1±1.0[a]	6.0±0.7[a]	5.7±1.0[a]	6.5±1.1[a]
0.25	7.3±1.0[a]	7.6±1.1[a]	6.9±0.8[ab]	7.0±1.1[b]	7.1±1.1[b]	6.1±0.8[ab]	6.9±0.9[ab]
0.50	7.8±1.1[a]	7.3±1.0[a]	7.6±1.0[bc]	7.3±0.9[b]	7.3±0.9[b]	6.5±0.8[b]	7.5±1.2[b]
1.00	7.5±1.2[a]	7.2±1.3[a]	8.0±0.09[c]	7.4±0.9[b]	7.4±1.0[b]	6.8±1.0[b]	7.6±0.9[b]

Nine-point hedonic scale with representing extremely dislike, neither like nor dislike, and extremely like.

Conclusion

This study showed that AOM does not have any undesirable effect on the physical and sensory properties of cupcakes. Moreover, results of the evaluations showed that the addition of mucilage improves physical properties without altering sensory properties of cakes. The highest viscosity, moisture content and specific volume was related to samples containing 1% mucilage. Presence of mucilage decreased cake hardness compared with the control sample. The results indicated that the addition of mucilage to the cupcake increased shelf-life. The results also showed that adding AOM increased the lightness of cupcake's crust. In conclusion, it is possible to take advantage of this mucilage to improve physical and sensory properties of foods such as cupcake. Further studies are recommended to determine the applicability of this novel additive in other bakery products.

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بررسی تأثیر افزودن موسیلاژ ختمی بر ویژگی‌های کیفی، فیزیکی و حسی کیک فنجانی

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چکیده

در این پژوهش عملکرد موسیلاژ ختمی (*Althaea officinalis* mucilage) بر ویژگی‌های کیفی کیک فنجانی و پتانسیل استفاده از آن در کنترل بیاتی مورد بررسی قرار گرفته است. برای این منظور، اثر غلظت‌های مختلف موسیلاژ ختمی (صفر، 0/25، 0/5 و 1 درصد) بر ویژگی‌های فیزیکی، سختی، رنگ و ویژگی‌های حسی کیک فنجانی و خمیر آن تعیین شد. به‌طور کلی، ویژگی‌های کیک با افزودن موسیلاژ تحت تأثیر قرار گرفت. نتایج نشان داد که افزودن موسیلاژ به‌طور معنی‌داری ($p<0/05$) باعث بهبود خصوصیات فیزیکی کیک و خمیر شامل رطوبت، حجم مخصوص، دانسیته و ویسکوزیته در مقایسه با نمونه شاهد شد. با افزودن موسیلاژ به کیک، سختی بافت در طول ذخیره‌سازی به‌طور قابل توجهی کاهش یافته است. نتایج حاصل از مقایسه میانگین پارامترهای رنگی نشان داد که کمترین مقدار روشنایی پوسته کیک (L^*) متعلق به نمونه شاهد و بیشترین مقدار آن مربوط به نمونه‌های حاوی 0/25 و 1 درصد موسیلاژ بودند. کیک‌های با 0/75 و 1 درصد موسیلاژ بالاترین امتیاز ارزیابی حسی را کسب کردند.

واژه‌های کلیدی: موسیلاژ ختمی، ویژگی‌های حسی، کیفیت، کیک فنجانی.

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