PAPER

EFFECTS OF BASIL (*OCIMUM BASILICUM* L.) SEED MUCILAGE SUBSTITUTED FOR FAT SOURCE IN SPONGE CAKE: PHYSICOCHEMICAL, STRUCTURAL, AND RETROGRADATION PROPERTIES

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ABSTRACT

Seeds of the herb plant basil (*Ocimum basilicum* L.) are a source of dietary fiber that are used in desserts and beverages in some parts of Asia. The mucilage extracted from basil seeds contains polysaccharide, mainly composed of glucomannan and xylan. It has high non-gelling and shear-thinning properties and can be used abundantly in foods. The purpose of this study was to investigate the possibility and effects of substituting basil seed mucilage (BSM) extracted by hot water for fat. In sponge cake, BSM was added as a substitute for fat (butter). 1 g of BSM replaced 15 g of butter, resulting in a 75% reduction in total fat content after addition of 1% BSM. Therefore, BSM is considered preferable to use as substitute for fat in foods, which can improve the quality and health properties of manufactured foods.

Keywords: basil seed mucilage (BSM), sponge cake, fat, substitute

1. INTRODUCTION

The fat content of cake is generally between 15% and 25% of dough weight (RODRÍGUEZ-GARCÍA *et al.*, 2012). Fat is an important ingredient in cakes, as it assists in the entrapment of air during the creaming process, resulting in the creation of a more tender product. Fat is dispersed in the dough or batter during mixing, which softens the structure and obstructs starch and protein from forming a continuous network (RODRÍGUEZ-GARCÍA *et al.*, 2012). Fat generates a desirable flavor and softer texture in the cake (LAKSHMINARAYAN *et al.*, 2006). In addition, fat can delay starch gelatinization by retarding water transfer into starch granules, thereby improving tenderness, moisture content, and flavor, while extending the shelf-life of the product (BENT *et al.*, 2013; PIZARRO *et al.*, 2013).
Owing to consumer demand, the baking industry is currently focused on developing low-calorie or reduced-fat products that have at least one-third fewer calories compared to traditional products; however, the reduced-fat product can be also be considered nutritious food (Sanchez *et al.*, 1995). Fat is associated with several health hazards, including cardiovascular disease, atherosclerosis, diabetes, and obesity (HASSEL, 1993). However, several problems, including lower volume, denser crumbs, firmer texture, and reduced flavor are encountered when making reduced-fat products and cakes as compared to normal cakes (HASSEL, 1993). Accordingly, it is necessary to replace the role of fat in baked products (CAUVAIN and Young, 2006; FELISBERTO *et al.*, 2015). Reduction of fat content can be made possible throughout the use of fat substitutes, which produce lower fat content in baked products (BRENNAN and TUDORICA, 2008). Substitutes can be classified as carbohydrate-, lipid-, or protein-based materials (SANCHEZ *et al.*, 1995). Carbohydrate-based substitutes combined with water form a gel-type structure, resulting in desirable texture (Hassel, 1993). In particular, dietary fibers, that are carbohydrate-based materials can act as a thickener and stabilizer to provide an effective fat substitute in foods (BRENNAN and TUDORICA, 2008).
Hydrocolloids are used as thickening, texturizing, stabilizing, and gelling agents. Hydrocolloids are hydrophilic and generally not considered to be an effective surfactant compared to proteins that have strong hydrophilic and hydrophobic regions (Huang *et al.*, 2001). However, as protein residues were found in the hydrophilic phase of hydrocolloids, their role as emulsifiers has emerged (AKHTAR *et al.*, 2002). Hydrocolloids like arabic gum, guar gum, locust bean gum, pectin, and galactomannans are able to act as emulsifying and foaming agents (NAJI-TABASI and RAZAVI, 2016). The hydrophilic and hydrophobic properties of hydrocolloids promote surfactant and emulsifier effects as active agents (GARTI and LESER, 2001).
Basil (*Ocimum basilicum* L.) is an herb that is produced primarily in warm regions of India, Iran, and Africa (Fekri *et al.*, 2008). Basil seeds have traditionally been used as natural remedies for the treatment of dyspepsia, ulcers, diarrhea, sore throat, and kidney disease. In some Asian regions, basil is used in desserts and beverages as a source of dietary fiber (SIMON *et al.*, 1999). The polysaccharides from basil seeds consist mainly of glucomannans (43%) and 1,4-linked xylan (24.3%) (ANJANEYALU and GOWDA, 1979). Mucilage extracted from basil seeds has high non-gelling and high shear-thinning properties and can be used not only as a fat substitute but also as a surfactant and emulsifier in foods (HOSSEINI-PARVAR *et al.*, 2010).
Sponge cake is made up according with the AACC method (2000), by denaturalization of the egg protein to foam dough as the base of the cake. By using whole eggs product resulting is characterized by the pores, creamy bubbles, and a moist shiny texture. Recently, to improve the quality of sponge cake, additions such as grains, vegetables, and

fruits have been used rather than flour; however, few studies have evaluated the production of reduced-fat sponge cakes.
In this study, we aimed to determine the effects of basil seed mucilage (BSM), a type of dietary fiber, as a fat substitute in cake.

2. MATERIALS AND METHODS

2.1. Materials

Basil seed (Herbalkart, India) and cake flour (CJ Cheiljedang Co., Ltd, Incheon, Korea) were used for this study. Butter (Seoul Milk, Co., Ltd, Ansan, Korea), fresh eggs (Pulmuone Co., Ltd, Seoul, Korea), sugar (CJ Cheiljedang Co., Ltd, Incheon, Korea), and salt (CJ Cheiljedang Co., Ltd, Incheon, Korea) were purchased from local markets.

2.2. BSM extraction

Mucilage was extracted from basil seeds according to the method published by RAZAVI *et al*. (2009). Basil seeds were washed and soaked in water for 20 min at 50°C under the optimized condition (water: seeds = 50:1 (w/w)) and processed for 2 hr at 68°C using an extractor. After extraction, the mucilage was collected with a rough plate and filtered through cheesecloth. The mucilage obtained was freeze-dried (FD8508, Ilshinbiobase Co., Ltd, Dongducheon, Korea), ground, packed, and stored at -20°C (KF-600F, Lassele Co., Ltd, Dongducheon, Korea) (Fig. 1).

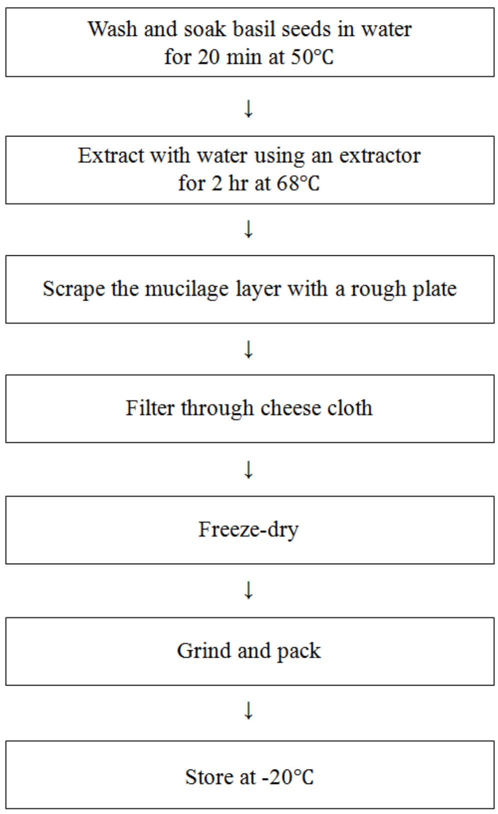

Figure 1. Flow chart of extraction procedure of mucilage from basil seeds.

2.3. Sponge cake preparation

The recipes for sponge cakes are shown in Table 1. A whole egg was poured into a bowl, beaten by a table mixer (KMC010, Kenwood, Havant, England) at 40 rpm for 30 s, and then mixed at 79 rpm for 5 min with sugar and salt.

Table 1. Formula for sponge cake prepared containing different levels of butter and gums.

Samples	Ingredients (g)						
	Cake flour	Butter	Guar gum	Basil seed mucilage (BSM)	Egg	Sugar	Salt
Control	100	20	0	0	180	120	1
Guar-0	100	0	1	0	180	120	1
Guar-25	100	5	1	0	180	120	1
Guar-50	100	10	1	0	180	120	1
Gaur-75	100	15	1	0	180	120	1
BSM-0	100	0	0	1	180	120	1
BSM-25	100	5	0	1	180	120	1
BSM-50	100	10	0	1	180	120	1
BSM-75	100	15	0	1	180	120	1

Control: Without added gum. Guar-0: Addition of 0% of butter with 1 g of guar gum. Guar-25: Addition of 25% of butter with 1 g of guar gum. Guar-50: Addition of 50% of butter with 1 g of guar gum. Guar-75: Addition of 75% of butter with 1 g of guar gum. BSM-0: Addition of 0% of butter with 1 g of basil seed mucilage. BSM-25: Addition of 25% of butter with 1 g of basil seed mucilage. BSM-50: Addition of 50% of butter with 1 g of basil seed mucilage. BSM-75: Addition of 75% of butter with 1 g of basil seed mucilage.

The sample was further mixed at 79 rpm for an additional 5 min followed by 40 rpm for 30 s. Cake flour was passed through a sieve three times, added to a bowl with gum and butter, and mixed. The sponge cake batter (350 g) was deposited into a round cake pan (8 inches in diameter). Then, the cake was baked at 170°C for 20 min in a microwave oven (MC366GAAW5A, Youngreem electron, Seoul, Korea). The sponge cakes were allowed to cool for 1 hr and were then removed from the pans. The cooled sponge cakes were packed in polypropylene bags at room temperature to prevent the cake from drying out (Fig. 2).

2.4. Specific gravity, dough yield, and baking loss of sponge cakes

The specific gravity, dough yield, and baking loss of sponge cakes were calculated using the following formulas, according to the methods described by the AACC (2000):

Specific gravity = Weight of cake dough / Weight of water
Dough yield (%) = (Weight of cake / Weight of dough) × 100
Baking loss (%) = (Weight of dough - Weight of cake) × 100

Figure 2. Photograph of sponge cake prepared containing different levels of butter and gums.
Control: Without added gum. Guar-0: Addition of 0% of butter with 1 g of guar gum. Guar-25: Addition of 25% of butter with 1 g of guar gum. Guar-50: Addition of 50% of butter with 1 g of guar gum. Guar-75: Addition of 75% of butter with 1 g of guar gum. BSM-0: Addition of 0% of butter with 1 g of basil seed mucilage. BSM-25: Addition of 25% of butter with 1 g of basil seed mucilage. BSM-50: Addition of 50% of butter with 1 g of basil seed mucilage. BSM-75: Addition of 75% of butter with 1 g of basil seed mucilage.

2.5. Volume and symmetry indices of sponge cakes

The volume and symmetry indices of the sponge cakes were measured after cutting through the midsection of the cake, according to the methods described by the AACC (2000). The calculation method is shown in Fig. 3.

Volume index = A + B + C
Symmetry index = 2B – A – C

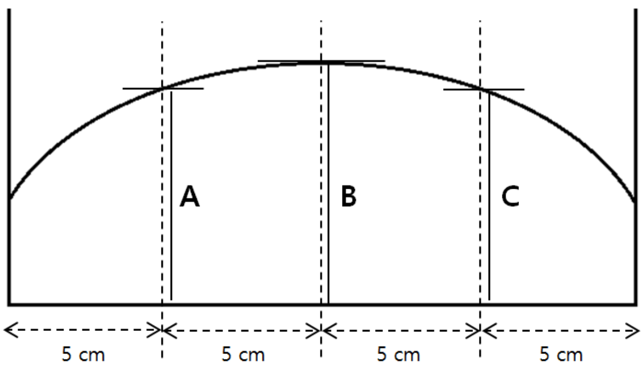

Figure 3. Measurement of volume index and symmetry index of sponge cake prepared with different levels of butter and gums.

2.6. pH of the sponge cakes

For pH determination, 10 g of crumb was mixed with 90 mL distilled water and shaken using a homogenizer (Ingenieurburo CATM. Zipperer, Staufen, Germany) for 1 min by ZHANG *et al*. (2015). pH was measured with a pH meter (SP-701, Suntex, New Taipei City, Taiwan) and the experiments were carried out in triplicate.

2.7. Moisture content of sponge cakes

5 g of sample was cut to 1 cm thickness and incubated at 105°C. When the weight of the sample ceased to change, an infrared moisture analyzer (MB35, OHAUS, Zurich, Switzerland) was used to measure the moisture content.

2.8. Color of sponge cakes

The color of the sponge cake was quantified from the midsection of the crust and crumbs by SONG *et al*. (2015). The $L^{\cdot}$ (lightness), $a^{\cdot}$ (redness), and $b^{\cdot}$ (yellowness) of the color were determined by using a color-measuring spectrophotometer (CR-400; Minolta, Tokyo, Japan) set to Hunter's value. The total color difference (ΔE) compared to the control was calculated. The results of the $L^{\cdot}$, $a^{\cdot}$, $b^{\cdot}$, and ΔE were averaged from triplicate measurements. For the standard white plates used in this study, the $L^{\cdot}$, $a^{\cdot}$, and $b^{\cdot}$ values were 95.74, 0.34, and 1.87, respectively.

$$\Delta E = \sqrt{(L_{sample} - L_{standard})^2 + (a_{sample} - a_{standard})^2 + (b_{sample} - b_{standard})^2}$$

ΔE was used to determine the total color difference discernible by the human eyes, as follows:

$\Delta E < 1$ – color differences were not obvious to the human eye
$1 < \Delta E < 3$ – color was not appreciably different to the human eye
$\Delta E > 3$ – color differences were obvious to the human eye

2.9. Textural profile analysis (TPA) of sponge cakes

The texture profile analysis of sponge cakes was carried out by using a rheometer (Compac-100II; Sun Scientific Co., Ltd, Tokyo, Japan) by ZHANG *et al*. (2015). Samples were excised from the center of each sponge cake (30 × 30 × 30 mm). The texture profile was determined by means of a two-bite compression test with a cylindrical probe (20 mm in diameter). The texture parameters recorded in this study were hardness, springiness, cohesiveness, gumminess, and chewiness. Texture values were averaged from triplicate measurements (Table 5).

2.10. Retrogradation rate of sponge cakes during storage

The retrogradation rates of sponge cakes during storage were measured by using a rheometer (Compac-100II; Sun Scientific Co., Ltd, Tokyo, Japan). The Avrami exponent (n) and time constant (1/k) were determined using the Avrami equation (AVRAMI, 1939; CHUNG *et al*., 2003), as follows:

$$\theta = (T_\infty - T_t)/(T_\infty - T_0) = \exp(-kt^n) \qquad (1)$$

$$T_\infty - T_t = (T_\infty - T_0) \exp(-kt^n)$$

$$T_t = (T_\infty - T_0) \exp(-kt^n) \qquad (2)$$

where θ is the remaining amorphous portion after time (t), k is the rate constant, n is the Avrami exponent, t is the storage time, T_0 is the hardness at the initial time (t = 0), T_t is the hardness after time (t), and T_∞ is the highest hardness that can theoretically be reached.

2.11. Scanning electron microscopy (SEM)

Samples (2 × 2 × 2 mm) were freeze-dried using a freeze-dryer (FD8508; Ilshinbiobase Co., Ltd, Dongducheon, Korea). The surface of a freeze-dried sample was mounted on a specimen holder and coated with gold palladium alloy under vacuum for 120 s with an automatic magnetron sputter coater (JSM670-1F; JEOL Co., Ltd, Tokyo, Japan). Morphology of samples was investigated in random order using scanning electron microscopy (JSM-6701F; JEOL Co., Ltd, Tokyo, Japan). Images were obtained at an accelerating voltage of 15 kV with 200× magnification.

2.12. Statistical analysis

All data are shown as the means of triplicate experiments with their standard deviations. Data analysis was carried out using one-way ANOVA. Duncan's multiple range test was also used to identify significant differences between the means at significance level $p<0.05$ using SPSS 12.0 (SPSS Inc., Chicago, Quarry Bay, Hong Kong) statistical software.

3. RESULTS AND DISCUSSION

3.1. Specific gravity, dough yield, and baking loss of sponge cakes

The physical properties of reduced-fat dough are shown in Table 2. The specific gravity of dough ranged from 0.42 to 0.58. Lower values for specific gravity indicate that the dough contains a lot of air, whereas higher values for specific gravity indicate that the bubble content of the dough is lower, resulting in reduced cake volume (PARK *et al*., 2009). If the specific gravity of the dough is high, the dough becomes heavy due to a lack of air, and the pores are small and dense, making the texture hard (KIM *et al*., 2014). Unlike bread, sponge cake quality varies depending on the amount of air contained during kneading. In general, the appropriate specific gravity of sponge cake prepared using common methods is 0.5 ± 0.05 (KIM *et al*., 2014). This specific gravity is consistent with that of the dough in our experiment. Dough yield was 90.37%-93.09%. Guar-75 showed the highest yield (93.09%), and this value was significantly different from those of other samples. Baking loss increased as the fat content increased, ranging from 7.71% to 9.63%. The lowest baking loss was observed for BSM-25.

Table 2. Specific gravity, dough yield, baking loss, volume index, symmetry index and pH of sponge cake prepared containing different levels of butter and gums.

Samples	Specific gravity	Dough yield (%)	Baking loss (%)	Volume index	Symmetry index	pH
Control	0.47±0.01[1)f]	91.99±0.14[d]	8.01±0.14[d]	12.90±0.17[ab]	0.50±0.17[a]	8.22±0.06[bc]
Gaur-0	0.47±0.01[f]	91.23±0.01[e]	8.77±0.01[c]	8.47±0.51[f]	0.43±0.06[a]	8.21±0.08[bc]
Guar-25	0.45±0.01[g]	91.99±0.01[d]	8.01±0.01[d]	12.23±1.64[bc]	0.67±0.46[a]	8.32±0.07[b]
Guar-50	0.52±0.01[d]	90.97±0.01[f]	9.03±0.01[b]	11.10±0.10[cde]	0.70±0.26[a]	8.05±0.03[d]
Guar-75	0.42±0.00[h]	93.09±0.01[a]	6.91±0.01[g]	13.50±0.44[a]	0.50±0.10[a]	8.68±0.08[a]
BSM-0	0.49±0.01[e]	92.18±0.01[c]	7.82±0.01[e]	8.33±0.55[f]	0.77±0.32[a]	7.69±0.02[d]
BSM-25	0.53±0.01[c]	92.29±0.02[b]	7.71±0.02[f]	12.07±0.38[bcd]	0.53±0.23[a]	8.28±0.06[bc]
BSM-50	0.58±0.00[a]	91.99±0.01[d]	8.01±0.01[d]	10.77±0.06[d]	0.53±0.12[a]	8.18±0.05[c]
BSM-75	0.57±0.01[b]	90.37±0.01[g]	9.63±0.01[a]	10.97±0.15[de]	0.63±0.25[a]	8.05±0.08[d]

[1)]The data are mean±SD in triplicates.

[a-g]Different letters within the same column are significantly different by Duncan's multiple range test (p<0.05).

3.2. Volume and symmetry indices of sponge cakes

Table 2 shows the volume indices of sponge cakes. The Guar-0 and BSM-0 cakes showed the lowest values, ranging from 8.33 to 8.47, whereas the Guar-75 and BSM-25 cakes showed the highest values (13.50 and 12.07, respectively). The volume index of the cakes increased as the amount of fat substitute was reduced, and this effect was related to the type and amount of fat or fat substitute. The symmetry index did not differ significantly among samples (range: 0.43-0.77). These results were similar to those reported by FELISBERTO *et al*. (2015), who evaluated fat percentages in pound cakes and showed that 25% fat substitute resulted in the highest specific volume. Moreover, in the present study, replacement with vegetable fat substitute, chia, or chia mucilage gel (CMG) did not cause differences greater than 50% in specific volume as compared to that with other formulations (BEDOYA-PERALES and STEEL, 2014; FELISBERTO *et al*., 2015; PIZARRO *et al*., 2013).

3.3. pH of sponge cakes

The pH of control (8.22) was similar to that of Guar-0 (8.21); however, that of BSM-0 was lower (7.69; Table 2). Groups with added BSM showed significantly lower pH than other samples. The pH of 1% guar solution was 6.39, and that of 1% BSM solution was 7.58. The pH of the cake was determined by the main ingredients and the shape of swelling. Additionally, sugar, shortening, and baking powder did not affect pH (KWON and LEE, 2015). The degree of coloring of the cake has also been reported to be related to pH (LEE *et al*., 2002). pH affects the color and texture of the final product. When the pH is nearly alkaline, the pores become rough, the crust becomes thicker, and the volume increases; in contrast, when the pH is more acidic, the pores become small, the crust becomes soft, and the volume decreases (LEE and LEE, 2013).

3.4. Moisture content of sponge cakes

As shown in Table 3, moisture content was not significantly different among samples except for Guar-75, which had the highest moisture content of 38.87%. This could be related to the combination of fat and guar gum in this sample. Moisture content in foods is important for achieving desirable sensory properties, particularly softness, which is critical for cakes (DADKHAH *et al*., 2012). Moreover, the moisture content did not differ as the amount of added fat substitute (guar gum and xanthan gum) increased (ZAMBRANO *et al*., 2004). Retention of water in foods is caused by interactions between moisture content and dietary fiber (MORAES *et al*., 2010).

3.5. Colors of sponge cakes

The colors of sponge cakes are shown in Table 4. Color is an important property affecting the appearance of the cake, and the color of the crust is influenced by the Maillard reaction. Additionally, the color of crumbs is affected by the ingredients in the formula (AKESOWAN, 2007). The crust of sponge cakes showed a decrease in L, a, and b values as the fat level increased; however, the total difference was increased. In crumbs, L and b values were generally decreased as the fat level increased, although the values showed an overall increase. This could be explained by the color values of butter ($L^{\cdot}$ = 85.93, $a^{\cdot}$ = -5.89, $b^{\cdot}$ = 31.53), guar ($L^{\cdot}$ = 88.62, $a^{\cdot}$ = -1.10, $b^{\cdot}$ = 9.63), and BSM ($L^{\cdot}$ = 67.70, $a^{\cdot}$ = 0.83, $b^{\cdot}$ = 7.86). The low $L^{\cdot}$ values of BSM affected the $L^{\cdot}$ values of cakes to a greater degree compared with those of guar and butter. FELISBERTO *et al*. (2015) observed a reduction in $b^{\cdot}$ with the addition of CMG. Similarly, CMG showed a low $L^{\cdot}$ of 66.41 compared with that of vegetable margarine (81.81); this affected the L* color in cakes, resulting in a darker appearance (IDRIS *et al*., 1996). For ΔE, the crust showed values of 51.03-54.66, without significant differences among the samples. In crumbs, ΔE tended to be higher in the BSM groups than in the control and guar gum additive groups (range: 25.48-32.64).

3.6. Textural properties of sponge cakes

As shown in Table 6, the hardness of sponge cake was high in the Guar-0 and BSM-0 samples (11.98 and 14.60 N, respectively). However, the Guar-75 and BSM-25 samples showed low values (3.84 and 6.95 N, respectively) compared with the control (4.87 N). Springiness did not differ significantly among groups, except for that of BSM-0 one. Guar-0 and Guar-75 showed the highest significantly cohesiveness values at 0.77 and 0.76, respectively. Gumminess in Guar-0 and BSM-0 was also high (9.17 and 10.49 N, respectively). The gumminess of control was 3.55 N. Chewiness was significantly higher in the Guar-0 and BSM-0 samples (125.69 and 126.62 N·mm). Hydrocolloids, except for alginate acid, locust bean gum, and hydroxypropyl methylcellulose (HPMC), generally increase the hardness of crumbs as the amount of additive is increased, and the hardness of guar gum cake increased up to 140% compared with that of the control (GOMEZ *et al*., 2007). However, hardness varied depending on the type of hydrocolloids added, and in the case of carrageenan, pectin, and guar gum, the hardness tended to increase further after storage for 48 hr (GOMEZ *et al*., 2007). Xanthan gum decreased the hardness by 40% relative to the control because the chemical interactions between hydrocolloids and starches differed, resulting in changes to moisture content or hardness (GOMEZ *et al*., 2007).

Hardness is also related to the amount of hydrocolloids added. For example, when the amount added is less than 1%, the volume of the cake increases, and the hardness tends to decrease (Gularte *et al*., 2012). However, when the amount of hydrocolloids added is 20%, the volume of the cake decreases, and the hardness tends to increase (GULARTE *et al*., 2012). Chewiness and gumminess are dependent on the results of hardness and therefore showed results similar to those for hardness. GOMEZ *et al*. (2007) also showed that there were no significant differences in springiness with the addition of hydrocolloids, except for alginate acid.

Table 3. Moisture content of sponge cake prepared containing different levels of butter and gums for 72 hr.

Samples	Storage time (hr)			
	0	24	48	72
Control	32.28±0.72[1)]^{b}	33.72±0.58^{ab}	34.18±0.33^{ab}	34.31±0.33^{NS}
Gaur-0	33.07±1.59^{b}	35.44±1.71^{a}	34.45±0.26^{ab}	34.80±0.61
Guar-25	31.61±3.41^{b}	34.38±0.78^{ab}	34.65±0.14^{ab}	34.57±0.07
Guar-50	32.39±0.99^{b}	33.47±0.91^{b}	34.34±0.56^{ab}	34.90±0.25
Guar-75	38.87±0.75^{a}	33.42±0.46^{b}	33.77±0.35^{b}	34.85±0.87
BSM-0	32.90±1.80^{b}	34.46±0.90^{ab}	34.66±0.77^{ab}	34.13±0.29
BSM-25	33.54±2.05^{b}	34.63±0.67^{ab}	34.62±0.53^{ab}	34.14±0.72
BSM-50	33.55±1.30^{b}	34.31±0.56^{ab}	34.69±0.49^{a}	34.72±0.13
BSM-75	33.94±0.69^{b}	34.76±1.59^{ab}	34.06±0.38^{ab}	34.70±0.48

[1)]The data are mean±SD in triplicates.

[ab]Different letters within the same column are significantly different by Duncan's multiple range test (p<0.05).

[NS]Not significant.

Table 4. Color values of sponge cake prepared with different levels of butter and gums.

Samples	Crust				Crumb			
	$L^{*2)}$	a^*	b^*	ΔE	L^*	a^*	b^*	ΔE
Control	47.04±3.06$^{1)ab}$	9.29±0.66^{abc}	12.84±1.13^{b}	51.98±2.99^{ab}	73.89±0.91^{b}	-4.90±0.10^{d}	17.95±0.29^{c}	28.52±0.60^{b}
Gaur-0	48.32±1.46^{a}	9.58±0.20^{a}	13.90±0.48^{ab}	51.03±1.28^{b}	83.80±0.83^{a}	-5.22±0.04^{e}	21.22±0.12^{a}	23.95±0.52^{c}
Guar-25	45.10±0.27^{ab}	9.43±0.16^{ab}	12.98±0.55^{b}	53.88±0.11^{ab}	73.91±0.56^{b}	-4.50±0.09^{b}	16.59±0.41^{d}	27.68±0.41^{b}
Guar-50	44.05±2.35^{b}	8.76±0.37^{c}	10.85±0.53^{c}	54.39±2.33^{a}	71.12±1.53^{c}	-4.73±0.12^{cd}	18.50±0.50^{b}	31.07±0.98^{a}
Guar-75	44.21±1.22^{b}	9.15±0.50^{abc}	12.77±1.37^{b}	54.66±0.83^{a}	74.04±2.84^{b}	-4.69±0.21^{bc}	17.86±0.43^{c}	28.35±2.15^{b}
BSM-0	47.92±1.95^{a}	9.24±0.06^{abc}	15.07±0.22^{a}	51.64±1.89^{ab}	75.69±1.20^{b}	-2.74±0.03^{a}	15.66±0.32^{e}	25.48±0.91^{c}
BSM-25	47.46±1.77^{a}	9.11±0.19^{abc}	13.33±0.60^{b}	51.64±1.64^{ab}	68.24±0.84^{d}	-2.79±0.09^{a}	14.48±0.03^{f}	31.46±0.76^{a}
BSM-50	47.99±0.84^{a}	8.91±0.20^{bc}	13.80±1.01^{ab}	51.20±0.76^{b}	67.09±1.44^{d}	-2.80±0.09^{a}	14.79±0.12^{f}	32.64±1.29^{a}
BSM-75	44.04±1.01^{b}	8.78±0.17^{c}	11.36±0.21^{c}	54.49±1.01^{a}	67.39±1.35^{d}	-2.66±0.17^{a}	14.54±0.12^{f}	32.26±1.20^{a}

[1)]The data are mean±SD in triplicates.

[2)]L^*: lightness (0 black↔white +100), a^*: redness (-80 green↔red +100), b^*: yellowness (-80 blue↔yellow +70), ΔE: total color difference.

[a~f]Different letters within the same column are significantly different by Duncan's multiple range test (p<0.05).

Table 5. The operating conditions of rheometer for texture of sponge cake.

Parameters	Operating conditions
Probe	20 mm cylinder probe
Head speed	120 mm/min
Strain	33.33%
Trigger force	10 kg
Option	TPA (texture profile analysis)
Distance	1 mm

Table 6. Textural properties of sponge cake prepared with different levels of butter and gums.

Samples	Hardness (N)	Springiness (mm)	Cohesiveness	Gumminess (N)	Chewiness (N·mm)
Control	4.87±0.62[1)de]	13.57±0.15[a]	0.73±0.01[b]	3.55±0.45[de]	48.18±6.46[c]
Gaur-0	11.98±0.73[b]	13.65±2.30[a]	0.77±0.04[a]	9.17±0.88[b]	126.62±34.50[a]
Guar-25	5.55±1.91[d]	13.62±0.06[a]	0.74±0.01[b]	4.09±1.39[d]	55.73±18.86[bc]
Guar-50	7.47±0.81[c]	13.63±0.09[a]	0.72±0.00[b]	5.39±0.57[c]	73.51±7.65[b]
Guar-75	3.84±0.43[e]	13.61±0.10[a]	0.76±0.00[a]	2.92±0.31[e]	39.70±4.22[c]
BSM-0	14.60±1.79[a]	11.98±0.22[b]	0.72±0.01[b]	10.49±1.24[a]	125.69±14.73[a]
BSM-25	6.95±0.23[c]	13.67±0.10[a]	0.74±0.00[b]	5.12±0.16[c]	70.00±1.86[b]
BSM-50	7.75±0.91[c]	13.66±0.09[a]	0.72±0.00[b]	5.54±0.62[c]	75.62±8.20[b]
BSM-75	7.18±0.22[c]	13.63±0.10[a]	0.72±0.01[b]	5.18±0.16[c]	70.61±2.11[b]

[1)]The data are mean±SD in triplicates.

[a~e]Different letters within the same column are significantly different by Duncan's multiple range test ($p<0.05$).

3.7. Avrami exponent (n) of sponge cakes during storage

The sponge cakes were stored at 4°C and the hardness was measured after 0, 24, 36, and 72 hr, as shown in Table 7. The Avrami equation was used to analyze the retrogradation rate of sponge cakes, as shown in Table 8. The Avrami exponent (n) indicates the crystallization form according to formation time and rate; values of 1-2 indicate that the crystallization is constant, whereas values of 3-4 indicate that the crystallization progresses until the crystal nucleation becomes sporadic and the saturation is complete (Korea Food Research Institute, 1997). The Avrami exponent (n) of the control was 0.0655, and those of Guar-25 and Guar-50 samples were 0.0149 and 0.0647, respectively. For the BSM-additive group, the Avrami exponents ranged from 0.0221 to 0.0449, indicating that retrogradation was inhibited compared to the control. The time constant (1/k) is the reciprocal of the rate constant (k), which represents the rate of progression of retrogradation; smaller rate constants indicate a greater time constant (1/k), reflecting the inhibition of retrogradation (KIM and CHUNG, 2010). The time constant (1/k) for Guar-50 was 285.71, which was higher than that of the control (100.00), and in the BSM-additive group, this value ranged from 270.27 to 588.24, indicating that BSM inhibited retrogradation. In particular, BSM-25 exhibited the highest time constant (1/k), indicating that this sample showed the greatest inhibition of retrogradation. This is because the water content or hardness was changed due to the chemical interaction between the hydrocolloids and starch, and the difference in the hardness could be due to water retention in the sample (GOMEZ *et al.*, 2007). When carboxymethyl cellulose (CMC) and k-carrageenan were added to bread, the increase in hardness was lower than that of the control (LEE *et al*., 2008).

Table 7. Hardness of sponge cakes prepared with different levels of butter and gums for 72 hr.

Samples	Storage time (hr)			
	0	24	48	72
Control	$4.95\pm0.28^{1)d}$	3.17 ± 0.47^{cd}	3.64 ± 0.26^{b}	4.20 ± 0.30^{c}
Gaur-0	12.16 ± 0.37^{b}	7.09 ± 0.81^{a}	5.91 ± 0.10^{a}	8.82 ± 0.35^{a}
Guar-25	5.24 ± 0.99^{d}	3.83 ± 0.05^{c}	3.86 ± 0.17^{b}	3.13 ± 0.09^{e}
Guar-50	7.77 ± 0.64^{c}	2.40 ± 0.18^{de}	2.90 ± 0.40^{c}	3.24 ± 0.49^{de}
Guar-75	3.76 ± 0.36^{e}	3.45 ± 0.15^{c}	3.82 ± 0.35^{b}	3.72 ± 0.25^{cd}
BSM-0	14.91 ± 0.91^{a}	4.90 ± 1.09^{b}	5.79 ± 0.23^{a}	5.90 ± 0.50^{b}
BSM-25	6.90 ± 0.10^{c}	2.27 ± 0.24^{de}	2.05 ± 0.10^{e}	2.25 ± 0.03^{f}
BSM-50	7.78 ± 0.67^{c}	1.95 ± 0.15^{e}	2.50 ± 0.25^{d}	2.84 ± 0.28^{c}
BSM-75	7.25 ± 0.06^{c}	2.38 ± 0.07^{de}	2.32 ± 0.07^{de}	2.68 ± 0.30^{ef}

[1)]The data are mean±SD in triplicates.

[a~f]Different letters within the same column are significantly different by Duncan's multiple range test ($p<0.05$).

Table 8. Avrami exponent (n), rate constant (k) and time constant (1/k) of sponge cakes prepared with different levels of butter and gums.

Avrami equation analysis	Avrami exponent (n)[1)]	Rate constant (k)[2)]	Time constant (hr) (1/k)
Control	0.0653	1.00×10^{-2}	100.00
Gaur-0	0.4793	2.58×10^{-2}	38.76
Guar-25	0.0149	1.50×10^{-2}	66.67
Guar-50	0.0647	0.35×10^{-2}	285.71
Guar-75	0.1887	12.38×10^{-2}	8.08
BSM-0	0.0291	0.37×10^{-2}	270.27
BSM-25	0.0221	0.17×10^{-2}	588.24
BSM-50	0.0318	0.33×10^{-2}	303.03
BSM-75	0.0449	0.33×10^{-2}	303.03

[1)]Values obtained from slop of plot $\log\{-\ln(T_\infty-T_t)/(T_\infty-T_0)\}$ vs log t.

[2)]Values obtained from slop of plot $\ln(T_\infty-T_t)$ vs time.

3.8. Micrographs of sponge cakes

Fig. 4 shows micrographs of sponge cakes prepared with different amounts of butter and gum. Fig. 4A shows a micrograph of crumbs from the control. Starch granules were observed around gluten protein. The microscopic analysis of starch granules allows visualization of the gluten protein matrix, with thin and irregularly shaped sheets (ASHWINI *et al*., 2009). However, the starch granules lose their shape following gelatinization (SOWMYA *et al*., 2009). Pores and fractions appeared as the content of the gums and butter varied. The presence of many pores and fractions indicated that cakes were more porous. Fig. 4B and 4F show micrographs of the crumbs from cakes prepared without fat. Fig. 4F, showing samples containing 1% BSM, demonstrated the presence of medium size pores. As the amount of fat substitute increased, the crumb matrix became irregular. Fat in baked food acts as a lubricant, interconnecting and forming a continuous matrix with all ingredients (RODRÍGUEZ-GARCÍA *et al*., 2012). Additionally, fat substitutes, such as gums, can limit hydration of gluten and starch, causing the formation of a less developed structure (RODRÍGUEZ-GARCÍA *et al*., 2012).

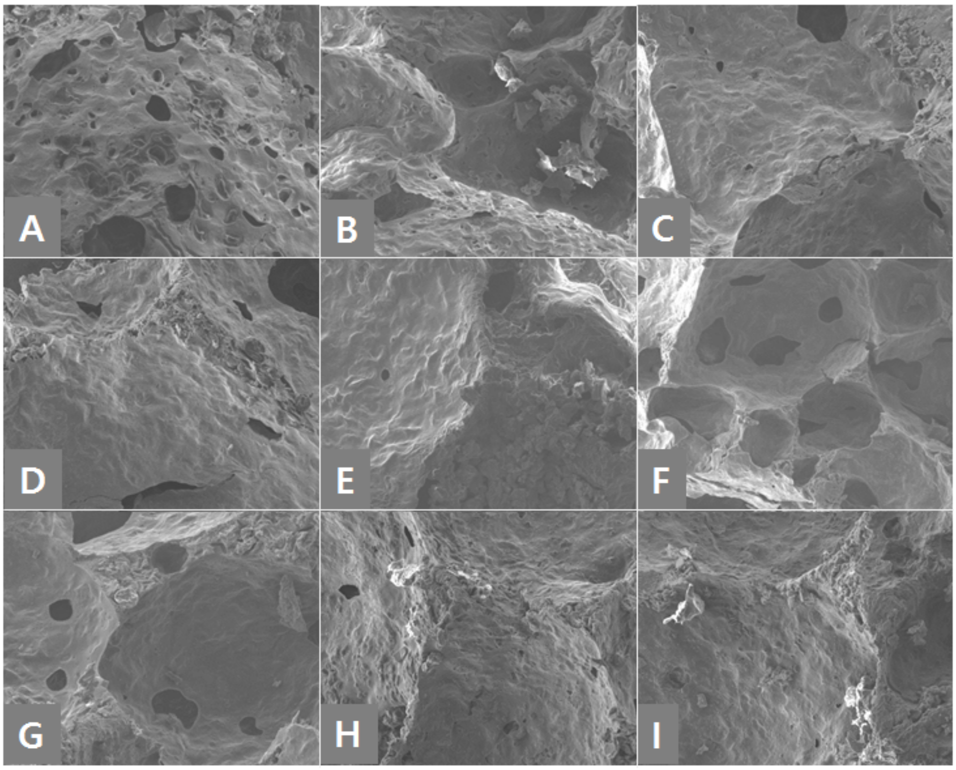

Figure 4. Micrographs of sponge cake prepared with different levels of butter and gums.
A: Control, B: Guar-0, C: Guar-25, D: Guar-50, E: Guar-75, F: BSM-0, G: BSM-25, H: BSM-50, I: BSM-75.

4. CONCLUSIONS

For sponge cakes, the physicochemical properties of the dough, including specific gravity, dough yield, baking loss, volume index, and symmetry index, were improved in Guar-25, Guar-50, and BSM-25 samples compared to those in other samples. The Guar-75 sample showed the highest moisture content, and groups with added hydrocolloids showed increased in hardness compared with the control. However, the hardness of samples prepared with added hydrocolloids tended to decrease compared with the control during storage. We also confirmed that the Guar-50 and BSM-25 samples inhibited retrogradation, as determined using the Avrami equation. Therefore, we found that the quality characteristics of the cakes were different according to the type of hydrocolloid. Based on these findings, BSM, which can inhibit retrogradation and reduce 75% of the fat content by substituting only 1% BSM, was considered the most effective fat substitute.

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REFERENCES

AACC. 2000. Approved methods of the American Association of Cereal Chemists 10th ed. pp. 10–91. St. Paul, MN:American Association of Cereal Chemists, Inc.

Akesowan A. 2007. Effect of a konjac flour/soy protein isolate mixture on reduced-fat, added water chiffon cakes. Assumption University Journal of Technology. 11(1):23-27.

Akhtar M, Dickinson E, Mazoyer J. and Langendorff V. 2002. Emulsion stabilizing properties of depolymerized pectin. Food Hydrocoll. 16(3):249-256.

Anjaneyalu Y.V, and Gowda D.C. 1979. Structural studies of an acidic polysaccharide from *Ocimum basilicum* seeds. Carbohydrate Research. 75:251-256.

Ashwini A, Jyotsna R. and Indrani D. 2009. Effect of hydrocolloids and emulsifiers on the rheological, microstructural and quality characteristics of eggless cake. Food Hydrocoll. 23(3):700-707.

Avrami M. 1939. Kinetics of phase change. I General theory. J Chem Phys. 7(12):1103-1112.

Bedoya-Perales N.S., and Steel C.J. 2014. Effect of the concentrations of maltogenic α-amylase and fat on the technological and sensory quality of cakes. Food Sci. Technol. (Campinas). 34(4):760-766.

Bent A.J, Bennion E.B. and Bamford,G. 2013. The Technology of Cake Making:Springer Science and Business Media.

Brennan C.S. and Tudorica C.M. 2008. Carbohydrate-based fat replacers in the modification of the rheological, textural and sensory quality of yoghurt: comparative study of the utilisation of barley beta-glucan, guar gum and inulin. Int J Food Sci Technol. 43(5):824-833.

Cauvain S, and Young L. 2006. Ingredients and their influences. Medical innovation: Science, Technology and Practice. pp. 72-98. Oxford, Blackwell Publishing.

Chung M.S, Lee, J.K. Hur N.Y, Kim D.S. and Baik M.Y. 2003. Textural analysis for bread staling. Food Sci. Biotechnol. 12(6):727-736.

Coorey R., Tjoe A. and Jayasena V. 2014. Gelling properties of chia seed and flour. J Food Sci. 79(5):859-866.

Dadkhah A., Hashemiravan M. and Seyedain-Ardebili M. 2012. Effect of shortening replacement with nutrim oat bran on chemical and physical properties of shortened cakes. Ann Biol Res. 3(6):2682-2687.

Fekri, N., Khayami, M., Heidari, R. and Jamee R. 2008. Chemical analysis of flaxseed, sweet basil, dragon head and quince seed mucilages. Res J Biol Sci. 3(2):166-170.

Felisberto M.H.F., Wahanik A.L, Gomes-Ruffi C.R, Clerici M.T.P.S, Chang Y.K. and Steel C.J. 2015. Use of chia (*Salvia hispanica* L.) mucilage gel to reduce fat in pound cakes. LWT-Food Sci. Technol. 63(2):1049-1055.

Garti N. and Leser M.E. 2001. Emulsification properties of hydrocolloids. Polym. Adv. Technol. 12(1-2):123-135.

Gomez M, Ronda F, Caballero P.A, Blanco C.A. and Rosell C. M. 2007. Functionality of different hydrocolloids on the quality and shelf-life of yellow layer cakes. Food Hydrocoll. 21(2):167-173.

Gularte M.A., de la Hera E., Gómez M. and Rosell C.M. 2012. Effect of different fibers on batter and gluten-free layer cake properties. LWT-Food Sci. Technol. 48(2):209-214.

Hassel C. 1993. Nutritional implications of fat substitutes. Cereal Foods World. 38(3):142.

Hosseini-Parvar S., Matia-Merino L., Goh K., Razavi S., and Mortazavi S. 2010. Steady shear flow behavior of gum extracted from *Ocimum basilicum* L. seed: Effect of concentration and temperature. J Food Eng. 101(3):236-243.

Huang X., Kakuda Y., and Cui W. 2001. Hydrocolloids in emulsions: particle size distribution and interfacial activity. Food Hydrocoll. 15(4):533-542.

Idris, N. A, Tang, T, and Chong, C. 1996. Chemical composition and physical properties of soft (tub) margarines sold in Malaysia. J. Am. Oil Chem. Soc. 73(8):995-1001.

Korea Food Research Institute. 1997. Development of automated single equipment for rice cake production. pp. 45-46. Ministry of Agriculture, Food and Rural Affairs, Sejong, Korea.

Kim M.K, Lee E.J. and Kim K.H. 2014. Effects of Helianthus tuberosus powder on the quality characteristics and antioxidant activity of rice sponge cakes. J. Korean Soc. Food Culture. 29(2):195-204.

Kim S.S and Chung H.Y. 2010. Retarding retrogradation of Korean rice cakes (Karedduk) with a mixture of trehalose and modified starch analyzed by Avrami kinetics. Korean J. Food Nutr. 23(1):39-44.

Kwon M. and Lee M. 2015. Quality characteristics of sponge cake added with rice bran powder. Korean J Culinary Res. 21(3):168-180.

Lakshminarayan S.M, Rathinam V. and KrishnaRau L. 2006. Effect of maltodextrin and emulsifiers on the viscosity of cake batter and on the quality of cakes. Sci. Food Agric. 86(5):706-712.

Lee K., Lee Y. and Yang J. 2002. Effects of irradiated egg white on the quality of angel food cake. Korean J. Food Cookery Sci. 18:30-33.

Lee S.E. and Lee J.H. 2013. Quality and antioxidant properties of sponge cakes incorporated with pine leaf powder. Korean J. Food Sci. Technol. 45(1):53-58.

Lee S.J., Cho S.K. and Lee S.J. 2008. Study on the texture and staling of breads with addition of various hydrocolloids. Korean J Food Cookery Sci. 24(5):636-644.

Mathews S, Singhal R. and Kulkarni P. 1993. *Ocimum basilicum*:a new non-conventional source of fibre. Food Chem. 47(4):399-401.

Moraes É.A, Dantas M.I.D.S, Morais D.D.C, Silva C.O.D, Castro F.A.F.D, Martino H.S.D. and Ribeiro S.M.R. 2010. Sensory evaluation and nutritional value of cakes prepared with whole flaxseed flour. Food Sci. Technol. (Campinas). 30(4):974-979.

Naji-Tabasi S. and Razavi S.M.A. 2016. New studies on basil (*Ocimum bacilicum* L.) seed gum: Part-Emulsifying and foaming characterization. Carbohydrate Polymers. 149:140-150.

Park J.E, Jeong, H.D. and Jang M.S. 2009. Optimization of ingredient mixing ratio for preparation of sponge cake with bamboo (Pseudosasa japonica Makino) leaves powder. Korean J Food Cookery Sci. 25(3):317-329.

Pizarro P.L., Almeida E.L, Sammán N.C and Chang Y.K. 2013. Evaluation of whole chia (Salvia hispanica L.) flour and hydrogenated vegetable fat in pound cake. LWT-Food Sci Technol. 54(1):73-79.

Razavi S., Mortazavi S.A., Matia-Merino L., Hosseini-Parvar S.H., Motamedzadegan A., and Khanipour E. 2009. Optimisation study of gum extraction from Basil (*Ocimum bacilicum* L.) seeds. Int. J. Food Sci. Technol. 44(9):1755-1762.

Rodríguez-García J., Puig A., Salvador A. and Hernando I. 2012. Optimization of a sponge cake formulation with inulin as fat replacer: structure, physicochemical, and sensory properties. J. Food Sci. 77(2):189-197.

Sanchez C., Klopfenstein C. and Walker C. 1995. Use of carbohydrate-based fat substitutes and emulsifying agents in reduced-fat shortbread cookies. Cereal Chem. 72(1):25-29.

Simon J.E., Morales M.R., Phippen W.B., Vieira R.F., and Hao Z. 1999. Basil: a source of aroma compounds and a popular culinary and ornamental herb. Perspectives on New Crops and New Uses. 499-505.

Song, K.Y., O H., Zhang Y.Y., Joung K.Y. and Kim Y.S. 2016. Effects of pumpkin (*Cucurbita moschata* Duch.) leaf powder on quality characteristics, antioxidant activities, and retarding retrogradation by shelf-life of sponge cake. Korean J. Food Nutr. 29(6):930-937.

Sowmya M., Jeyarani T., Jyotsna R. and Indrani D. 2009. Effect of replacement of fat with sesame oil and additives on rheological, microstructural, quality characteristics and fatty acid profile of cakes. Food Hydrocoll. 23(7):1827-1836.

Zambrano F., Despinoy P., Ormenese R. and Faria E. 2004. The use of guar and xanthan gums in the production of 'light' low fat cakes. Int. J. Food Sci. Technol. 39(9):959-966.

Zhang Y.Y, Song K.Y, O H., Choi B.B and Kim Y.S. 2015. Quality and antioxidant characteristics of sponge cake with asparagus (*Asparagus officinals* L.) powder. Korean J. Food Cookery Sci. 31(5):642-651.

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