Progress in Nutrition 2016; Vol. 18, N. 2: 176-183

Quality characteristics and antioxidant properties of sponge cakes containing black carrot (*Daucus carota ssp. sativus* var. atrorubens Alef) flour

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Summary. Black carrot contains limited calories, plentiful simple sugars, dietary fiber, and anthocyanins. It also attenuates retrogradation of cake and has an anticancer effect. Our aim was to find an optimal proportion of black carrot flour (BCF) in sponge cake. Black carrot sponge cakes were prepared by 0%, 2%, 4%, 6%, and 8% replacement of wheat flour with BCF and were designated as the Control (without black carrot flour), BCF2, BCF4, BCF6, and BCF8, respectively. Control and BCF6 showed low specific gravity: 0.45 and 0.47, respectively. The baking loss was significantly lower (6.88%) in BCF6. The *L*, *a*, and *b* values of color tended to decrease with increased proportion of BCF, except for the *a* value of crumbs. The Control and BCF8 were slightly alkaline: pH 7.50 and 7.09, respectively. Hardness was the lowest in BCF4 (153.57 g/cm^2), followed by that in BCF6 (163.50 g/cm^2). The polyphenol content of sponge cakes supplemented with BCF increased with increasing proportion of BCF, as did the scavenging activity toward the 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical. A seven-point test showed that BCF6 had the best flavor and sweetness. Our data indicate that the optimal proportion of BCF for sponge cake in terms of rheological properties and antioxidant activity is 6%.

Key words: black carrot, sponge cake, rheological properties, antioxidant activity

Introduction

Black carrots *(Daucus carota* ssp. *sativus* var. atrorubens Alef) are becoming more and more popular as a source of natural food colorants (1). Because of strong legal restrictions and the consumer demand for natural food, coloring agents originating from plants, such as anthocyanins, are gaining popularity (2).

Cultivated carrots are classified into two groups: the eastern (or anthocyanin) carrot like black carrot *(Daucus carota* ssp. *sativus* var. atrorubens Alef) and the western (or carotene) carrot *(Daucus carota* ssp. *sativus* var. sativus) (3). Black carrots originated in Turkey, Afghanistan, Egypt, Pakistan, India, and in the Far East (3).

Black carrots have a strong antioxidant activity because of high concentration of the pigment anthocyanin: 1750 mg/kg (no dry weight) and a high level of acylated anthocyanins (4). Black carrot extract consists of four major anthocyanins (41% of them acylated), namely, cyanidin 30-sinapoyl-xylosyl-glucosyl-galactoside (27.5%) and cyanidin 3-feruloyl-xylosyl-glucosyl-galactoside (13.5%) and their acylated forms (4, 5). Antioxidants play a role in protection of humans from infections and degenerative diseases by inhibiting and scavenging free radicals (6). Extracts from black carrots and isolated anthocyanins have a strong antioxidant activity (3). Thus, the use of anthocyanins from black carrots as coloring agents may provide many benefits for health (3).

As the baking industry develops, the demand for health and functional foods (containing functional ingredients) is increasing instead of the use of cake flour only. Sponge cake is one category of various cakes and is produced by denaturation of egg protein in bubbled dough

(7). There is a growing number of studies on sponge cake that is supplemented with grain, vegetable, or fruit flour to improve the sensory and physicochemical properties, for example, flour made of *Helianthus tuberosus* (8), Korean sweet potato (*Ipomoea batatas L.*) cultivars (9), wheat-lentil composite (10), and green tea (11).

In the present study, optimal composition of black carrots in sponge cake was determined in order to improve the rheological properties and antioxidant activity of sponge cake containing black carrot flour. The samples of sponge cake were prepared with 0%, 2%, 4%, 6%, and 8% replacement of wheat flour with black carrot flour and were designated as the Control, BCF2, BCF4, BCF6, and BCF8, respectively.

Materials and Methods

Materials

The ingredients used in preparation of sponge cake were as follows: cake flour (CJ Cheiljedang Co., Ltd, Korea), butter (Seoul Milk, Co., Ltd, Korea), fresh eggs (Pulmuone Co., Ltd, Korea), sugar (CJ Cheiljedang Co., Ltd, Korea), salt (CJ Cheiljedang Co., Ltd, Korea), citric acid (Bread Garden Co., Ltd, Korea), and black carrot (Jeju, Korea). We used a table mixer (KMC010, Kenwood, England) and a microwave oven (MC366GAAW5A, Youngreem Electron, Korea) for making sponge cake.

Methods

Black carrot flour

The black carrot (Jeju, Korea) was freeze-dried and ground to fine flour that was passed through 40 mesh sieve after washing and drying at room temperature for one day.

Preparation of sponge cake

The sponge cake recipe was published previously (12, 13, 14), and we modified it as follows. The recipes for sponge cakes containing different proportions of black carrot flour are shown Table 1. A whole egg was poured into a bowl and beaten by means of the table mixer (KMC010, Kenwood, England) at the speed setting “1” for 30 s and then mixed at the speed setting “3” for 5 min with sugar, salt, and citric acid. 0.3% citric acid was used to adjust pH of sponge cake and to prevent degradation of anthocyanin during cooking. And then mixed at speed “1” for 30 s. The sifted cake flour (that was passed through sieve three times), black carrot flour, and butter were poured into a bowl 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 the microwave oven (MC366GAAW5A, Youngreem electron, Seoul, Korea). The sponge cakes were allowed to cool for 1 h and then were removed from the pans. The cooled sponge cakes were packed in polypropylene bags at room temperature before physicochemical and sensory evaluation.

Table 1. The recipe for sponge cakes prepared with different proportions of black carrot flour.

Ingredients	**Black carrot flour content (g/100 g of wheat flour)**				
	Control	**BCF2**	**BCF4**	**BCF6**	**BCF8**
Flour	100	98	96	94	92
Black carrot flour (BCF)	0	2	4	6	8
Butter	20	20	20	20	20
Egg	180	180	180	180	180
Sugar	120	120	120	120	120
Citric acid	0.3	0.3	0.3	0.3	0.3
Salt	1	1	1	1	1

BCF: Black carrot flour. Control: Without added BCF. BCF2: Addition of 2 g of BCF per 100 g of wheat flour. BCF4: Addition of 4 g of BCF per 100 g of wheat flour. BCF6: Addition of 6 g of BCF per 100 g of wheat flour. BCF8: Addition of 8 g BCF per 100 g of wheat flour.

Batter analysis

The physical characteristics of sponge cake batter including specific gravity, baking loss, and dough yield were measured in triplicate. The specific gravity of batter was determined by dividing the density of the batter (g/mL) by density of water (g/mL) (15).

Specific gravity (dimensionless) = Density of cake dough/Density of water

Baking loss (%) = 100 x (Weight of dough - Weight of cake) ÷ Weight of cake

Dough yield (%) = (Weight of cake/Weight of dough) x 100

The baking loss and the dough yield of the batter were calculated using the following equation expressed as the percentage of the loss of sponge cake weight after baking and weight of the batter per kilogram of flour, respectively.

Color analysis of sponge cake

The color of the sponge cake was quantified from the midsection of the crust and crumb. The L (lightness), a (redness), and b (yellowness) of the color were determined using a color-measuring spectrophotometer (CR-400, Minolta, Tokyo, Japan) set to Hunter's value, and ΔE (total color difference) was calculated. The results on the L, a, b, and ΔE were averaged from the triplicates.

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

Determination of pH

The pH of the sponge cake was measured in triplicate by a pH meter (SP-701, Suntex, Taiwan). The analysis was conducted.

Textural profile analysis (TPA)

After cooling for 1 h, cake was cut in pieces from the center of each sponge cake (30 × 30 × 30 mm). The texture profile analysis of sponge cake was performed on the midsection of the pieces using a rheometer (Compac-100©, Sun scientific Co., Ltd., USA). The texture profile was determined by means of the two-bite compression test with a cylindrical probe (20 mm in diameter). The texture parameters of each sponge cake were recorded as hardness, cohesiveness, springiness, and chewiness; the texture parameters of each sponge cake were averaged from the triplicates.

Determination of total phenolic content

The total phenols in the sponge cake were quantified by the Folin-Ciocalteu method (cat. # 96703-8130, Junsei Chemical Co., Ltd, Japan) as described previously (16) with Na_2CO_3 (cat. # 1.93211.0500, Merck, Germany). Garlic acid (cat. # 8.42649.0025, Merck, Germany) was used as a standard.

Determination of antiradical activity

Scavenging activity toward the 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical was determined as described previously (17), with modifications. The mixture was reacted with 100 μL of 1,1-diphenyl-2-picrylhydrazyl (DPPH) (cat. # 1898-66-4, Sigma, USA) in ethanol (cat. # 1.11727.1000, Merck, Germany) and incubated for 30 min in the dark at room temperature. The absorbance of the samples was measured on an Infinite 200 PRO multimode reader (804003459, Tecan, Switzerland) at 520 nm. Ethanol was used as a blank sample. The inhibition percentage was calculated using the following equation:

Inhibition (%) = [(absorbance of control − absorbance of sample) ÷ absorbance of control] x 100

Sensory evaluation

The seven-point test was used to determine the degree of overall acceptability of sponge cakes (1 = strongly dislike, 4 = neither like nor dislike, 7 = strongly like). In this study, a panel of 25 trained experts received five samples (10 x 10 x 10 mm), and each expert was asked to rate how much he/she liked the sponge cakes. The samples were placed on white plates (20 cm in diameter) and identified with random three-digit numbers. The panelists evaluated the samples in a testing room and were instructed to rinse their mouths with water between the samples to minimize any residual effects.

Statistical analysis

All the data were expressed as mean ± standard deviation of the triplicates. We used one-way analysis of variance (ANOVA). Duncan's multiple-range test was also used to separate significant differences between means at the significance level ($p < 0.05$) in the SPSS 12.0 software (SPSS Inc., Chicago, USA).

Table 2. Specific gravity, baking loss, and dough yield of sponge cakes prepared with different proportions of black carrot flour.

Properties	Black carrot flour content (g/100 g of wheat flour)				
	Control	BCF2	BCF4	BCF6	BCF8
Specific gravity (dimensionless)	0.45±0.01[1)c]	0.48±0.01[a]	0.47±0.01[b]	0.47±0.00[ab]	0.45±0.01[c]
Baking loss (%)	7.45±0.00[c]	7.82±0.03[b]	7.35±0.01[d]	6.88±0.03[e]	7.95±0.01[a]
Dough yield (%)	92.55±0.00[c]	92.18±0.03[d]	92.65±0.01[b]	93.12±0.03[a]	92.05±0.01[e]

1)The data are mean ± S.D. in triplicates. a–eDifferent superscripts within the same row are significantly different by Ducan's multiple range test ($p < 0.05$). BCF: Black carrot flour. Control: Without added BCF. BCF2: Addition of 2 g of BCF per 100 g of wheat flour. BCF4: Addition of 4 g of BCF per 100 g of wheat flour. BCF6: Addition of 6 g of BCF per 100 g of wheat flour. BCF8: Addition of 8 g of BCF per 100 g of wheat flour.

Results and Discussion

Batter characteristics

The physical characteristics of the sponge cakes containing black carrot flour are shown in Table 2. Specific gravity significantly increased with the increase in the proportion of black carrot flour to 0.45–0.48 but decreased in BCF8. The possible explanation for this is that the proportion of black carrot flour reduced gluten content with the increase of water absorption and decreased gas retention of the batter. The results are similar to the studies on quality of sponge cakes containing yacon powder (18) and quality characteristics of sponge cake supplemented with masangi powder (19). The baking loss of BCF8 was the greatest (7.95%), and that of BCF6 was the lowest (6.88%).

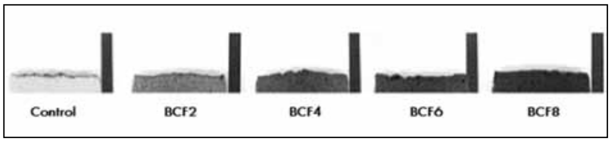

Figure 1. A photograph of sponge cakes with various proportions of black carrot flour.

The baking loss is losses caused by structural deformation and by the exit of the low-boiling-point liquid (water) into the gas phase or losses resulting from formation of pores, which are caused by swelling during the process of baking of the cake: water vapor pressure increases with heat and thus the vapor penetrates the dough (20). BCF6 showed the highest dough yield: 93.12%. This finding is consistent with the results of Lee et al. (19) and Lee & Chin (21).

Color properties

As shown in Fig. 1, 0.3% of citric acid was used to maintain stability of the anthocyanin pigments (14). Color of the crust and crumb in the samples was affected by the proportion of black carrot flour, and all color data were expressed as Hunter's values (Tab. 3). As the proportion of black carrot flour increased, the crumb color became darker. For the crumb color, as the proportion of black carrot flour increased, the L and b values decreased, but a increased. The ΔE value showed a decreasing trend. For the crust, L, a, b and ΔE all decreased with the addition increased. These results are similar to those reported by Ekici et al. (22). Changes in a and b values were caused by the discoloration in the course of heating at the high temperature and by the addition of the supplemental flour (23). The major factors affecting the color of sponge cake have been reported: the type and color of the flour, the amino-carbonyl reaction during the baking process, and browning due to thermal decomposition (24).

pH properties

The pH data from the sponge cakes containing black carrot flour are shown in Fig. 2. As the proportion of black carrot flour in sponge cakes increase, the pH was moved to more neutral (7.0) from slightly alkaline (7.50). Ekici et al. (22) reported that an increase in the amount of black carrot concentrate (BCC) causes a significant decrease in pH of cake samples. The pH value was found to be 5.26 for the sample supplemented with 0.5 g of BCC, whereas pH was 4.69 in the sample containing 2 g of BCC.

Table 3. Color values of sponge cakes prepared with different proportions of black carrot flour.

Hunter's color value		Black carrot flour content (g/100 g of wheat flour)				
		Control	BCF2	BCF4	BCF6	BCF8
L	Crust	45.43±0.77[1)a]	44.68±0.85[a]	41.50±0.76[b]	38.35±0.85[c]	36.52±0.21[d]
	Crumb	82.48±0.56[a]	56.33±0.97[b]	43.07±1.59[c]	37.99±2.67[d]	34.97±0.43[e]
a	Crust	14.57±0.10[a]	12.38±0.12[b]	12.06±0.03[c]	11.21±0.11[d]	10.77±0.02[e]
	Crumb	-5.12±0.09[d]	-1.28±0.19[c]	2.33±0.16[b]	2.84±0.28[a]	2.98±0.25[a]
b	Crust	20.71±0.31[a]	18.92±0.48[b]	17.30±0.35[c]	14.85±0.36[d]	13.82±0.27[e]
	Crumb	22.87±0.52[a]	5.32±0.54[b]	0.08±0.32[c]	-3.01±0.49[d]	-3.16±0.12[d]
ΔE	Crust	36.67±30.70[a]	2.25±0.92[b]	2.58±1.01[b]	2.76±0.85[b]	1.37±1.20[b]
	Crumb	51.59±30.26[a]	24.00±0.54[b]	20.91±0.54[b]	21.63±1.37[b]	19.43±0.97[b]

1)The data are mean ± S.D. in triplicates. a–eDifferent superscripts within the same row are significantly different by Ducan's multiple range test ($p < 0.05$). BCF: Black carrot flour. Control: Without added BCF. BCF2: Addition of 2 g of BCF per 100 g of wheat flour. BCF4: Addition of 4 g of BCF per 100 g of wheat flour. BCF6: Addition of 6 g of BCF per 100 g of wheat flour. BCF8: Addition of 8 g of BCF per 100 g of wheat flour.

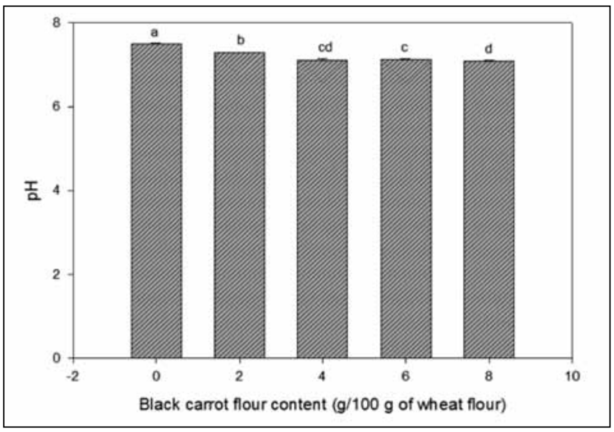

Figure 2. The pH values of sponge cake supplemented with black carrot flour.

Textural properties

Hardness of the samples decreased in the sponge cakes with increasing proportion of black carrot flour (Table 4). This phenomenon is related to cake volume (25): the higher the fiber percentage in a cake formula, the greater the volume. This could be explained by the increase in the gas retention capacity (the gases incorporated during mixing) (26). In a study on bread (27), the researchers found that small quantities of fiber also reduce textural changes during storage: this phenomenon is attributed to the higher water-holding capacity of fiber and possible interactions between fiber and starch that can attenuate the retrogradation process. The springiness showed no significant differences and was in the range 87.96–89.31%. Similar results were also obtained with other baked goods (25). In the study by Gomez and coworkers, addition of hydrocolloids to fresh yellow layer cakes does not significantly change springiness in comparison with the control, but addition of alginate produces a decrease (25). Also in the present study, cohesiveness was not significantly different and chewiness decreased with greater proportion of black carrot flour (control: 305.29% and BCF8: 188.93%). These changes resemble our other findings here where cohesiveness was no statically different in different samples with the increase in the amount of BCC in the sample formula (22).

Antioxidant properties

In the polyphenol analysis, the polyphenol content of black carrot sponge cakes increased with the increasing level of black carrot flour in the range 0.27–0.36 g garlic acid equivalent (GAE)/mg (Fig. 3). These results are similar to those reported by Ekici et al. (22) and Khandare et al. (28). Sucuk dough containing BCC showed a significant increase in the total phenolic content. Control had the lowest total phenolic content, at 785.94 mg GAE/kg, and the highest total phenolic content was observed in the sample containing 2 g of BCC: 1201.48 mg GAE/kg. Measurements of the DPPH radical scavenging activity in the black carrot sponge cakes is shown Fig. 4. As the proportion of black carrot flour increased, the scavenging activ-

Table 4. Textural properties of sponge cakes prepared with different levels of black carrot flour.

Textural properties	Black carrot flour content (g/100 g of wheat flour)				
	Control	**BCF2**	**BCF4**	**BCF6**	**BCF8**
Hardness (g/cm²)	248.80±0.211[a]	229.27±0.30[a]	153.57±0.10[b]	163.50±0.19[b]	173.23±0.33[b]
Springiness (%)	89.31±2.18[a]	87.96±0.64[a]	89.87±0.88[a]	87.87±0.60[a]	88.92±1.69[a]
Cohesiveness (%)	80.32±3.81[a]	77.43±1.02[a]	77.38±1.36[a]	79.35±1.21[a]	78.23±0.57[a]
Chewiness (g·cm)	305.29±45.32[a]	251.63±30.73[a]	157.50±5.09[b]	195.59±17.77[b]	188.93±34.28[b]

1)The data are mean ± S.D. in triplicates. abDifferent superscripts within the same row are significantly different by Ducan's multiple range test ($p < 0.05$). BCF: Black carrot flour. Control: Without added BCF. BCF2: Addition of 2 g of BCF per 100 g of wheat flour. BCF4: Addition of 4 g of BCF per 100 g of wheat flour. BCF6: Addition of 6 g of BCF per 100 g of wheat flour. BCF8: Addition of 8 g of BCF per 100 g of wheat flour.

ity toward the DPPH radical also increased. BCF6 and BCF8 showed the scavenging activity of 91.33% and 92.33%, respectively. The 50% inhibitory concentration (IC_{50}) values of the DPPH radical scavenging activity in black carrot sponge cakes were 779.33 µg/mL (Control), 340.99 µg/mL (BCF2), 276 µg/mL (BCF4), 81.95 µg/mL (BCF6), and 73.71 µg/mL (BCF8); ascorbic acid was used as a standard (38.81 µg/mL). The effectiveness of antioxidant properties correlated with the IC_{50} value where the effect is 50%. Therefore, the scavenging activity toward the DPPH radical increased with the increasing proportion of black carrot flour. This result was similar to the Sucuk samples that were significantly affected by addition of BCC, showing an increase in DPPH radical scavenging activity from 15.22% to 65.18% for control and the sample containing 2 g of BCC, respectively (22).

Sensory properties

In the analysis of product likeability and consumer preferences, significant differences were found in color, flavor, moistness, sweetness, chewiness, and overall quality. A seven-point hedonic scale was used by a trained panel; the sensory characteristic scores of BCF6 were found to be higher than those of the other samples in terms of flavor, sweetness, and overall quality (Fig. 5). The results on sensory characteristics indicated that partial replacement of sponge cake flour with up to 6% of black carrot flour in sponge cake yields satisfactory results. This finding is similar to the results on preferences for muffins supplemented with beetroot flour: the highest overall acceptability was in the order 6% > 9% > 3% > 0% (29).

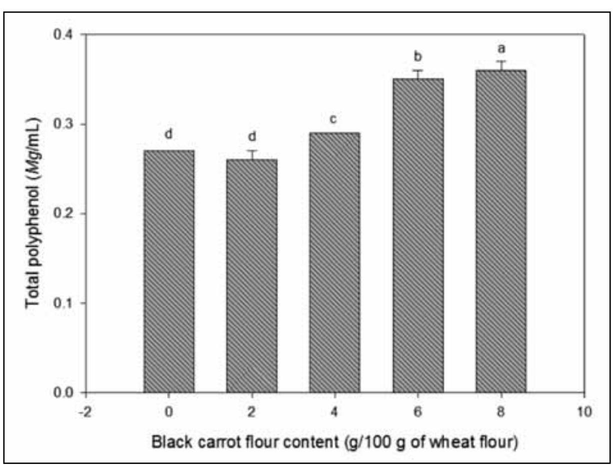

Figure 3. Total polyphenol content of sponge cake supplemented with black carrot flour

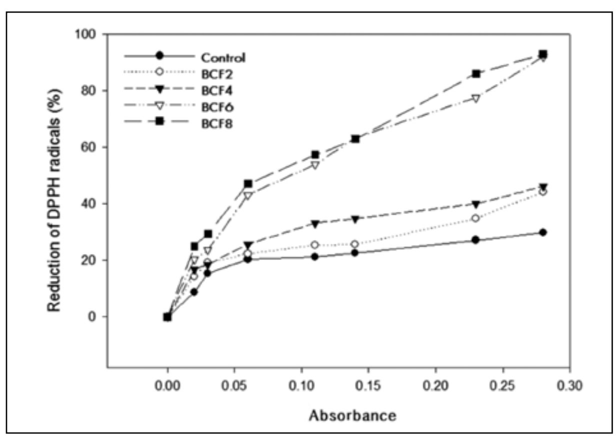

Figure 4. Scavenging activities toward 1,1-diphenyl-2-picrylhydrazyl (DPPH) radicals in sponge cake supplemented with black carrot flour.

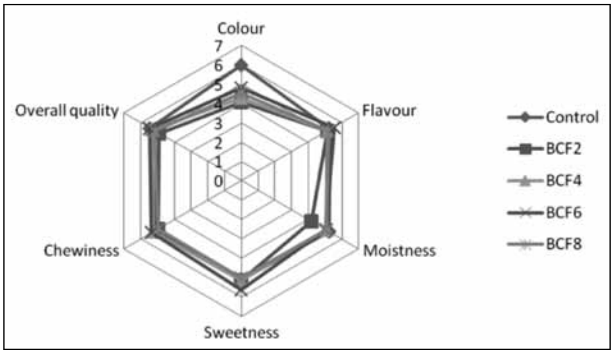

Figure 5. Sensory preference scores for sponge cake supplemented with black carrot flour.

Conclusion

In this study we evaluated quality characteristics and antioxidant properties of black carrot sponge cakes. The baking loss of black carrot sponge cake batter was the highest for BCF8, at 7.95%, and BCF6 showed the lowest value: 6.88%. The dough yield for BCF6 was the greatest, at 93.12%. The color of crumb (*L* and *b* values) decreased with the addition of BCF, but the *a* value increased. The hardness decreased with the addition of BCF and the springiness did not show significant changes. The cohesiveness and chewiness decreased with the increasing level of BCF. The sensory properties according to the trained panel of 25 experts revealed that BCF6 was the best for flavor, sweetness, and overall likeability. Our data demonstrated that BCF6 could improve the quality characteristics and antioxidant properties of sponge cake.

In conclusion, our optimized results show black carrot is a good sauce for production of better sponge cake, and black carrot sponge cake satisfies the consumer preferences and is beneficial for health.

Acknowledgements

This research was supported by Korea University Grant (K1422581), and grateful acknowledgements.

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