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Physicochemical and sensory characteristics of sponge cakes supplemented with black tea powder

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홍차 분말을 첨가한 스펀지케이크의 품질 및 항산화 활성

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Abstract

Black tea is rich in phenolic antioxidants that has shown diverse health benefits such as protection against cardiovascular diseases and cancers. Thus, it is rational to incorporate black tea into suitable food products such as sponge cakes to enhance their nutritional and functional qualities. The aim of this study was to investigate the effect of the addition of black tea powder (BTP) on the quality of sponge cake. The pH of cakes ranged from 7.00~7.17, with no remarkable differences. Height decreased while baking loss rate and hardness significantly increased with increases in the content of BTP in the formulation ($p<0.05$). For crumb color values, L^*-value decreased while a^* and b^*-values increased as a result of BTP substitution. 2,2-Diphenyl-1-picrylhydrazyl (DPPH) and 2,2'-azino-bis-3-ethylbenzthiazoline-6-sulphonic acid (ABTS) radical scavenging activities were significantly increased ($p<0.05$) with increases in the content of BTP which were well correlated. Hedonic sensory results indicated that sponge cakes supplemented with 2~4% BTP obtained the most favorable acceptance scores. On the basis of the overall observations, sponge cakes supplemented with 2~4% BTP were found to be benefit from the functional properties of BTP, without compromising on consumer acceptance.

Key words : black tea powder, sponge cake, physicochemical properties, consumer acceptance, antioxidant properties

INTRODUCTION

Bakery products are popular and consumed in large quantities all over the world (1). Due to changes in consumer behavior and eating habits, development of new types of ready-to-eat convenience foods that provide health benefits is of great importance. Wheat flours used in cake elaboration can be replaced by some other types of flours since gluten does not play an important role in this kind of product (2-4). So far, research into the addition of such flours for manufacturing of sponge cake has focused on *Opuntia humifusa* powder (1), wheat-chickpea flour blends (5), garlic powder (6), mugwort powder (7), green tea powder (8), and pin-milled pea flour (9) to name a few.

Tea is one of the most popular beverages due to its distinctive flavor and taste and is often consumed in unfermented (green tea), semi-fermented (oolong), and fermented (black tea) forms (8). Tea consumption has increased worldwide due to its known health benefits. It is rich in polyphenolic compounds known as tea flavonoids, mainly catechins. Black tea has been shown to exhibit antioxidant effects (10-13). Several other studies have reported that black tea (extract) has anti-clastogenic (14), anti-hypercholesterolemic (15), anti-carcinogenic (16), and anti-diabetic (17) activities. Besides, polysaccharides from black tea are also reported to have protective effects against

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murine sepsis (18).

Rapidly growing concerns about healthy diets and increased demand for the use of new natural antioxidants, especially in bakery products (8), have led us to investigate wheat-based products with value-added ingredients, such as black tea powder (BTP). To the best of our knowledge, little to no information is available on the effects of BTP on the physicochemical and sensory properties of sponge cake. Incorporation of natural antioxidants into foods may inhibit lipid oxidation and improve food quality and safety (8). Black tea contains antioxidants, and if added to foods as a supplement, can provide health beneficial effects. Therefore, it would be beneficial to develop a novel formulation of sponge cake production with BTP.

The objectives of this research were to make sponge cakes with 0%, 2%, 4%, 6%, and 8% BTP substituted for cake flour in order to evaluate the effects of BTP on sponge cake quality and consumer acceptance as a result of supplementation. The antioxidant properties of sponge cakes were also determined.

MATERIALS AND METHODS

Materials

BTP was procured from Garunaral (Garunara, Seoul, Korea), and wheat flour (soft flour, CJ Cheiljedang, Yangsan, Korea), white sugar (CJ Cheiljedang, Seoul, Korea), salt (Sajohaepyo Co., Seoul, Korea), salt-free butter (Seoul Milk Coop., Yongin, Korea), and eggs were purchased from a local market.

Sponge cake preparation

A whole egg was poured into a bowl and then mixed by hand with an eggbeater. Sucrose and sodium chloride were added to the bowl, mixed with a whisk attachment in a mixer (K5SS, Kitchen Aid Inc., St. Joseph, MI, USA) on the speed 2 setting for 60 sec, and then mixed on the speed 6 setting for 8 min. The sifted cake flour and BTP were gradually poured into the mixer on the speed 2 setting for 30 sec. Ingredients were mixed by hand with a plastic scraper until smooth. The cake batter was immediately deposited into round cake pans. For each cake, 350 g of cake batter was poured into a cake pan and baked at 175℃ for 32 min in a preheated oven (KXS-4G+H, Salvia industrial S.A., Lezo, Spain).

The cakes were allowed to cool for 1 hr at room temperature, after which they were removed from the pans. The cooled cakes were packed in polypropylene bags at room temperature prior to the physicochemical and sensory evaluation. The test sponge cake samples prepared with 0%, 2%, 4%, 6%, and 8% BTP substituted for cake flour were designated as the control, BT2, BT4, BT6, and BT8, respectively.

Determination of selected physicochemical properties

A ground sample (10 g) of cake was mixed with 90 mL of distilled water and vortexed for 1 min. The mixture was held at ambient temperature for 2 hr in order to separate solid and liquid phases. The pH of the supernatant was measured using a pH meter (pH/Ion 510, Oakton Instruments, Vernon Hills, IL, USA). Loaf height at the center was measured using a caliper. The baking loss rate (%) of each type of sponge cake was calculated based on the percentage of cake weight lost after baking and the weight of the sponge cake batter.

Texture profile analysis (TPA) of cake samples (3×3×3 cm) from the midsection of cakes was carried out using a computer-controlled Advanced Universal Testing System (model LRX*Plus*, Lloyd Instrument Limited, Fareham, Hampshire, UK) at room temperature. Crusts of cake samples were removed for the cake texture determination. Each sample was compressed twice to 30% of its original height at a speed of 1 mm/sec speed under 100 N of compression load using a cylindrical-shaped probe (12.45 mm in diameter). Color determination of cake samples from the midsections of the cakes was carried out using a Chromameter (model CM-600d, Minolta Co., Osaka, Japan) set for CIELAB color space.

Determination of free radical scavenging activities

DPPH radical scavenging activities of the samples were measured in terms of their hydrogen donating or radical scavenging activity using stable DPPH radical. The assay was performed as previously described by Blois (19) with some modifications. Briefly, 0.15 mM solution of DPPH · radical in ethanol was prepared, after which 5 mL of this solution was added to 1 mL of sample solution in ethanol at different concentrations and then shaken and left to stand for 10 min. Decolorization of DPPH-donated protons was determined by measuring the absorbance at 517 nm using a spectrophotometer (Optizen 2020 UV Plus, Mecasys Co., Ltd., Daejeon, Korea). The scavenging activity of DPPH radical was calculated using the following equation:

$$\text{Radical scavenging activity (\%)} = [(Abs_{control} - Abs_{sample})/Abs_{control}] \times 100$$

The spectrophotometric analysis of ABTS$^{+}\cdot$ radical scavenging activity was determined according to the method used by Re et al. (20) with slight modifications. The ABTS$^{+}\cdot$ cation radical was produced by a reaction between 7.4 mM ABTS in H_2O and 2.6 mM potassium persulfate during storage in the dark at room temperature for 12 hr. Before use, ABTS$^{+}\cdot$ solution was diluted with methanol to obtain an absorbance of 1.1 at 734 nm. Subsequently, 3 mL of ABTS$^{+}\cdot$ solution was added to 0.1 mL of sample. After 10 min, the percent inhibition at 734 nm was calculated for each concentration relative to blank absorbance.

Sensory evaluation

Hedonic test was used to determine the degree of overall preference scores for sponge cakes. For this study, 40 untrained volunteer consumers were recruited from the University and informed that they would be evaluating sponge cakes. Five samples (3×3×3 cm) were presented in random order and were evaluated for consumer acceptance of color, flavor, taste, softness, and overall acceptability. Consumer participants were asked to evaluate preference levels for sponge cakes using a seven-point hedonic scale (7=like extremely, 6=like moderately, 5=like slightly, 4=neither like nor dislike, 3=dislike slightly, 2=dislike moderately, and 1=dislike extremely). Panelists received a tray containing the samples from the midsections of cakes at room temperature (randomly coded using a three-digit number), a glass of water, and an evaluation sheet. Participants were instructed on how to evaluate the samples, and were not required to expectorate or consume the entire volume served. Overall acceptance was evaluated first, and another session was held to evaluate the rest of the attributes. There was an inter-stimulus interval of 30 sec imposed between samples, to allow time to recover from adaptation. Participants were advised to rinse their palates between samples. Enough space was given to handle the samples and questionnaire, and evaluation time was not constrained. No specific compensation was given to the participants.

Statistical analysis

Each measurement was conducted five times, except for hardness (n=20), antioxidant activities (n=3), and sensory evaluation (n=40). The experimental data were subjected to an analysis of variance (ANOVA) using the general linear models (GLM) procedure to identify significant differences among the samples. Mean values were compared using Duncan's multiple range test. The significance was defined at the 5% level.

RESULTS AND DISCUSSION

Physicochemical characteristics

Table 1 describes the physicochemical characterization of sponge cakes supplemented with different levels of BTP. The pH ranged from 7.00 to 7.17 and significantly decreased upon addition of BTP ($p<0.05$). Nevertheless, only minor changes were observed. Thus, it seems that BTP supplementation could result in the production of sponge cakes of slightly lower pH. Similar reduction of pH was observed for sponge cakes added with pine leaf powder (21) and cinnamon powder (22) due to the weak acidic nature of the BTP (pH 6.37). Lee et al. (23) indicated that the pH range of sponge cakes is 7.3~7.6, in general. The pH of sponge cakes produced in this study was slightly lower, partially due to the different raw materials used in the formulation. Height significantly decreased upon addition of an increasing amount of BTP ($p<0.05$). This can probably be attributed to the impairment of gas retention by fibrous materials rather than gas formation (24). Similar reduction of loaf height has been observed with sponge cakes added with pine leaf powder (21).

Baking loss is described as a process in which gas is produced and vapor pressure increases due to the expansion of liquids when heat permeates cake batter in the baking process (1). If gas escapes, the cakes are damaged. Thus, baking loss and its effects on shelf-life are of concern for the structural transformation of cakes (1). The baking loss rate of samples ranged from 10.91 to 13.05% and increased upon addition of an increasing amount of BTP, with control sample exhibiting the lowest value ($p<0.05$). This implies

Table 1. Physicochemical properties of sponge cakes with different levels of BTP

Property		BTP level (%) 0	2	4	6	8
pH		7.17±0.01$^{a1)}$	7.11±0.01^{b}	7.06±0.01^{c}	7.04±0.01^{d}	7.00±0.01^{e}
Height (mm)		68.94±0.26^{a}	67.81±0.39^{b}	65.92±0.54^{c}	63.88±0.64^{d}	58.64±0.66^{e}
Baking loss (%)		10.91±0.08^{d}	11.89±0.08^{c}	12.26±0.11^{b}	12.98±0.04^{a}	13.05±0.01^{a}
Hardness (N)		0.54±0.06^{c}	0.56±0.10c	0.59±0.16^{c}	0.70±0.11^{b}	1.12±0.12^{a}
Color	L^*	82.49±0.65^{a}	60.34±0.69^{b}	54.90±0.42^{c}	50.09±0.62^{d}	44.90±0.62^{e}
	a^*	2.35±0.15^{e}	6.51±0.24^{d}	8.89±0.19^{c}	9.65±0.42^{b}	11.77±0.63^{a}
	b^*	26.87±0.86^{b}	26.91±0.84^{b}	28.68±0.74^{a}	28.88±0.69^{a}	29.00±0.68^{a}

[1)a-e]Means within the same row without a common letter are significantly different ($p<0.05$).

that an excessive amount of BTP may lead to poor texture quality. A similar trend was also reported for sponge cakes supplemented with pine leaf powder (21), *Ecklonia cava* powder (25), and yacon powder (26).

The TPA results presented in Table 1 show that addition of an increasing amount of BTP from 0 to 8% resulted in elevated hardness of samples from 0.54 to 1.12 N. This increase in hardness can be directly attributed to lower cake volume (27). These results show that the sponge cakes containing 6% BTP or higher became significantly harder as compared to the control ($p<0.05$). Similar increased hardness was observed in green tea sponge cakes (8) as well as sponge cakes with wheat flour substituted by 100% pin-milled pea flour or any percentage of protein concentrate (9). In general, hardening phenomena in cakes are attributed to crumb dehydration (28) and starch retrogradation (29).

All color data were expressed as CIELAB L^*, a^*, and b^*-values corresponding to lightness, redness, and yellowness, respectively. Crumb color of samples was affected by replacement of cake flour with BTP (Table 1). As the level of BTP increased, the L^*-value decreased while a^* and b^*-values increased, indicating that a darker as well as less red and yellow crumb color was obtained as a result of BTP substitution. Baked cakes substituted with BTP were significantly darker than the control ($p<0.05$). These changes might be explained by the fact that sucrose participated in caramelization during baking, and tea pigments and polyphenol compounds underwent an oxidation reaction (8).

Free radical scavenging activities

Antioxidant activities were investigated based on DPPH radical scavenging activity and ABTS radical cation assay. The usage of BTP in the cake formulation enhanced antioxidant activities (Fig. 1), and the effectiveness of antioxidant properties were as follows in ascending order: control < BT2 < BT4 < BT6 < BT8. The results show that BTP supplementation greatly enhanced antioxidant properties of the cakes due to incorporation of phenolic compounds, mainly various catechins, which have been reported to possess antioxidant activity (30,31). The data also confirm a positive correlation between the results of antioxidant capacities. EDA increased as ABTS increased. A similar increase in the antioxidant properties of sponge cakes supplemented with green has been reported (8). Black tea sponge cake could be developed as a more effective functional food since black tea could be consumed in gram levels, as compared to Butylated hydroxyanisole (BHA) and α-tocopherol. Although it has good antioxidant activity, reducing power, and DPPH radical scavenging ability, BTP remains as an additive present in milligram levels in foods (8).

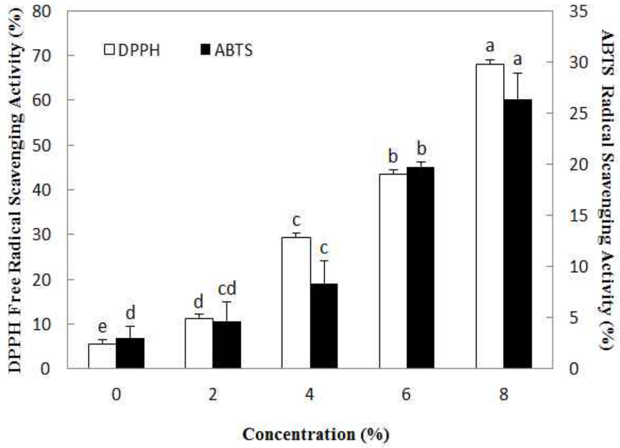

Fig. 1. DPPH and ABTS radical scavenging activities of sponge cakes upon supplementation of BTP.

a-e Means with in the same activity with out a common letter are significantly different ($p<0.05$).

Sensory findings

Color, flavor, taste, softness, and overall acceptance of control sponge cake and BTP-supplemented cakes were evaluated, and the results are presented as a radar plot (Fig. 2). When evaluated by untrained consumers, statistically significant differences were detected in terms of color, flavor, taste, softness, and overall acceptability scores among control, BT2, BT4, BT6, and BT8 ($p<0.05$). BT2 and BT4 received significantly higher preference scores than others ($p<0.05$), but no significant difference as observed between the two in terms of flavor, taste, and overall acceptance ($p>0.05$). Color and softness preference scores for control were higher

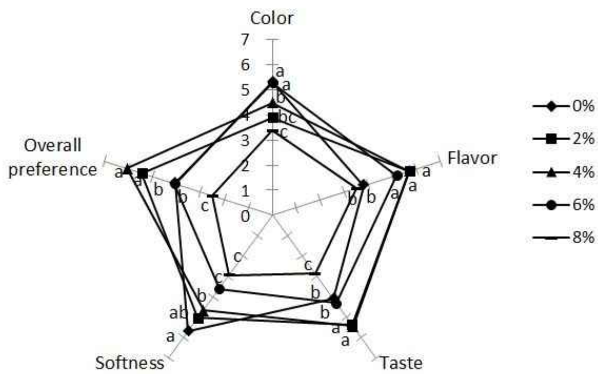

Fig. 2. Radar plot of sensory results of sponge cakes supplemented with 0~8% BTP.

a-c Means with different letters within the same attribute are significantly different according to Duncan's multiple range test ($p<0.05$).

than those of other cakes, although no significant difference was detected between BT6 and BT2 in terms of color or softness. Excessive addition of 8% BTP seemed to have a deteriorative effect on all sensory attributes evaluated. On a seven-point hedonic scale, BT2 received scores in the range of 5.03~5.70 except for color. Considering BT4 received the highest overall acceptance score of 6.07 and it was not significantly different from that of BT2, partial replacement of cake flour with 2~4% BTP in sponge cakes seems satisfactory.

요 약

홍차 분말의 첨가량을 0~8%로 달리하여 제조한 스펀지 케이크의 물리·화학적 품질, 항산화 활성 및 소비자 기호도를 비교하였다. 케이크의 pH와 높이는 홍차 분말의 첨가량이 증가할수록 유의적으로 감소하였으며(p<0.05), 굽기 손실률의 경우 홍차 분말의 함량이 증가함에 따라 유의적으로 증가하였다(p<0.05). 경도는 0~4% 시료 간에서는 유의적인 차이는 없었다(p>0.05). 한편 명도(L^*)는 붉은색을 띠는 홍차 분말 고유색의 영향으로 첨가량이 증가할수록 유의적으로 감소하였고(p<0.05), 적색도(a^*)와 유의적으로 증가하였다. 황색도(b^*)의 경우 증가하는 경향을 보였으나, 0~4%, 6~8% 시료 간에 유의적인 차이는 발견되지 않았다(p>0.05). 항산화 활성을 나타내는 전자공여능과 ABTS 라디칼 소거능 활성은 홍차분말을 첨가할수록 유의적으로 증가하는 경향이 나타났다(p<0.05). 소비자 기호도 결과 2~4% 첨가군이 색과 부드러움을 제외한 나머지 항목에서 대조군보다 높게 평가되었으며, 따라서 관능품질과 건강기능성 효과 등을 고려할 때 소비자의 기호를 충족시키기 위한 최적 첨가비율은 2~4%가 가장 적합한 것으로 판단된다.

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