Prev. Nutr. Food Sci. 2015;20(3):204-209
http://dx.doi.org/10.3746/pnf.2015.20.3.204
pISSN 2287-1098 • eISSN 2287-8602

Physicochemical and Sensory Characteristics of Sponge Cakes with *Rubus coreanus* Powder

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ABSTRACT: To develop new type of sponge cake, the effects of partial (0∼40%) replacement with *Rubus coreanus* powder (RCP) on the quality characteristics of sponge cakes were investigated. The pH level and moisture content ranged from 4.05∼8.23 and 28.49∼36.59, respectively, and significantly decreased upon addition of RCP ($P<0.05$). Baking loss rate and cake firmness significantly increased with higher RCP content in the formulation, whereas morphological characteristics of cakes such as height, volume, and symmetry indices significantly decreased ($P<0.05$). For crumb color values, L^*- and b^*-values significantly decreased while a^*-value significantly increased as a result of RCP substitution ($P<0.05$). Hedonic sensory results indicated that sponge cakes supplemented with 30∼40% RCP showed the most favorable acceptance scores for most of the sensory attributes evaluated. Overall, *Rubus coreanus* sponge cake could be developed with comparable physicochemical qualities without sacrificing consumer acceptability.

Keywords: *Rubus coreanus* powder, sponge cake, physicochemical properties, consumer acceptance

INTRODUCTION

Sponge cake is a type of air-leavened cake based on wheat flour, sugar, and eggs. Cake qualities are dependent on many factors, including the ingredients used for batter preparation, aeration of batters, and processing conditions (1). Some ingredients in the formulation also affect its structure and eating quality (2). Wheat flour, which is the main ingredient in cake formulations, can be replaced by other types of flours to produce new kinds of sponge cakes with improved health benefits and consumer acceptance. Partial substitution of wheat flour with wheat-chickpea flour blends (3), mugwort powder (4), tigernut flour (5), pin-milled pea flour (6), *Opuntia humifusa* powder (7), or breadfruit flour (8) has been attempted.

Rapidly growing concerns about healthy foods and their increased consumer demand have led us to study wheat-based products with value-added ingredients, such as *Rubus coreanus*. Dried fruit of *R. coreanus* is well-known as '*bokbunja*' in Korea and has been used as a traditional herbal medicine for centuries (9) as well as for the management of impotence, spermatorrhea, enuresis, asthma, and allergic diseases (10). Aqueous extracts of incompletely ripened fruit of *R. coreanus* were previously shown to inhibit cell proliferation, stimulate apoptosis in HT-29 cells (11), and reduce immediate-type allergic reaction and inflammatory cytokine secretion (9). It has been suggested that *R. coreanus* concentrates have hepatoprotective effects and many improve symptoms of liver injuries in rats (12). Anti-inflammatory, anti-nociceptive, anti-gastropathic, anti-rheumatic and chemopreventive effects have also been reported (13-15). The active components of *R. coreanus* have been reported to be polyphenols, tannins, phenolic acids, organic acids, triterpenoids, flavonoids, gallotannin, ellagitannin, and anthocyanins (16-18).

In addition, the ethanol extracts from *R. coreanus* Miquel fruits produced in the Gochang-gun (GR) showed high hydroxyl radical scavenging activity and lipid peroxidation inhibitory activity, and had the highest antiproliferative activities on MDA-MB-231 and HepG2 cancer cells among four extracts (19). Antioxidative and aldose reductase-inhibitory effects of a fermentation filtrate of *R. coreanus* were also reported (20).

To the best of our knowledge, little to no information is available on the effects of *R. coreanus* on the physicochemical and sensory properties of sponge cakes. Incorporation of natural antioxidants into foods may inhibit lipid oxidation and may improve food quality and safety (21). *R. coreanus* contains antioxidants and other biologically active components as mentioned, and consider-

Received 15 May 2015; Accepted 29 August 2015; Published online 30 September 2015

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ing the findings that proteins in wheat flour might cause skin allergy especially for infants (22,23), and if added to foods as a supplement, may provide health beneficial effects. However, replacement or substitution of wheat flour would influence processing suitability or quality of the final product with respect to physicochemical and consumer acceptance characteristics. Therefore, it is of great importance to investigate the effects of partial substitution of *R. coreanus* powder (RCP) for cake flour on those properties for successful development of new types of sponge cakes.

The objectives of this research were to make sponge cakes with 0%, 10%, 20%, 30%, and 40% RCP substituted for cake flour in order to evaluate the effects of RCP on sponge cake quality and consumer acceptance as a result of supplementation.

MATERIALS AND METHODS

Materials

RCP was procured from Garunara (Seoul, Korea), whereas wheat flour (soft flour, CJ Cheiljedang, Yangsan, Korea), white sugar (CJ Cheiljedang), 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 using a mixer (K5SS, Kitchen Aid Inc., St. Joseph, MI, USA) on the speed 4 setting for 120 s, and then mixed on the speed 6 setting for 8 min. The sifted cake flour and RCP were gradually poured into the mixer on the speed 2 setting for 2 min. Ingredients were mixed by hand with a plastic scraper until smooth. The cake batter was immediately deposited into round cake pans. For each cake, 450 g of cake batter was poured into a cake pan (20 cm in diameter, 5 cm in depth) and baked at 160°C for 40 min in a preheated oven (KXS-4G+H, Salvia Industrial S.A., Lezo, Spain).

The cakes were allowed to cool for 1 h 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%, 10%, 20%, 30%, and 40% RCP substituted for cake flour were used and designated as the control, RC10, RC20, RC30, and RC40, respectively. The substitution level was determined by preliminary experiments so that the samples at the highest level should not produce a strong taste or flavor, which would not be accepted by the consumers.

Determination of physicochemical properties

A ground cake sample (10 g) was mixed with 90 mL of distilled water and homogenized for 1 min. The mixture was held at ambient temperature for 1 h in order to separate the solid and liquid phases. The pH of the supernatant was measured using a pH meter (pH/Ion 510, Oakton Instruments, Vernon Hills, IL, USA). The moisture content of the cake was determined by Approved Methods 44-19.01 (24) and expressed on a wet weight basis. 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. Symmetry, volume indices, and height were measured in accordance with AACC method 10-91 (25). This method determines these values in mm and takes the size of the pans used for the cake production into account. A digital caliper was used to measure cake height. The symmetry index was measured for three cakes, and the volume index for three slices from different cakes.

Texture profile analysis (TPA) of cake samples (3×3×3 cm) from the midsections 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/s 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 cakes was carried out using a Chromameter (model CM-600d, Minolta Co., Osaka, Japan) set for CIELAB color space.

Sensory evaluation

The hedonic test was used to determine the degree of overall preference for sponge cakes. For this study, 73 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 nine-point hedonic scale (9=like extremely, 5=neither like nor dislike, 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, after which another session was held to evaluate the rest of the attributes. There was an inter-stimulus interval of 30 s 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 symmetry and volume indices (n=3), hardness (n=15), and sensory evaluation (n=73). 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 RCP. The pH ranged from 4.05 to 8.23 and was significantly decreased upon addition of RCP ($P<0.05$). RCP supplementation resulted in production of sponge cakes with significantly lower pH. Several researchers have reported similar pH reduction upon incorporation of RCP into muffins (26), *jeungpyeon* (27), and eel sauce (28) due to the strong acidic nature of RCP (pH=2.45). Moisture content of sponge cakes varied from 28.49% to 36.59% and significantly decreased upon addition of RCP ($P<0.05$). Similar reduction of moisture content has been observed in sponge cakes containing pine leaf powder (29) and cinnamon powder (30), which can be attributed to the replacement of cake flour by up to 40% RCP with low moisture content, thus increasing total solids content in the formulation.

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 the batter in the baking process (7). If gas escapes, cakes become damaged. Thus, baking loss and its effects on shelf-life are of concern for the structural transformation of cakes (7). The baking loss rate of samples ranged from 11.20 to 14.54% and was increased upon addition of an increasing amount of RCP, with control sample exhibiting the lowest value ($P<0.05$). This implies that an excessive amount of RCP may lead to poor texture quality during baking. A similar trend was also reported for sponge cakes supplemented with pine leaf powder (29) and yacon powder (31).

Cake morphology

Changes in the morphological characteristics of cakes after addition of RCP are shown in Fig. 1. Height significantly decreased upon addition of an increasing amount of RCP ($P<0.05$), as also seen in Fig. 2. This can be attributed to impairment of gas retention by fibrous materials rather than gas formation (32). Similar reduction of loaf height has been observed in muffins containing RCP (26) and pound cakes containing *R. coreanus* concentrate (33).

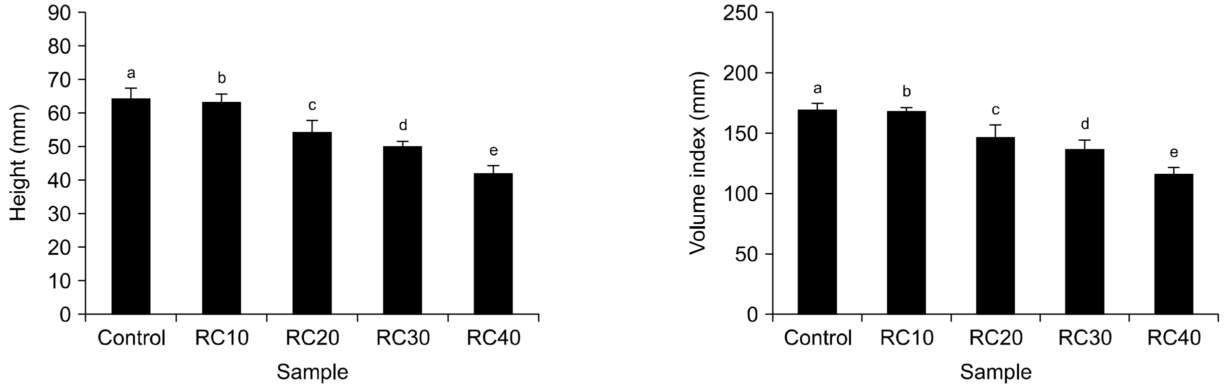
Baking of the control batter resulted in an aerated structure with a significantly higher volume as compared to that of RCP supplemented cakes ($P<0.05$), as indicated by the higher volume index value (Table 1 and Fig. 1). The volume significantly decreased when cake flour was partially replaced by RCP ($P<0.05$), which can be attributed to the improved gas retention capacity of the control batter and a more controlled structure development during baking (34). Reduced expansion of RCP-supplemented sponge cakes could be attributed to decreased batter stability during baking caused by structural changes (35). Similar phenomenon was observed in sponge cakes elaborated with pine leaf powder (29) and banana powder (36).

The symmetry index is a measure of cake peakedness, *i.e.*, the relative height between the central and lateral portions of a cake (37,38). Thus, a peaked cake would have a high symmetry value, whereas a low value results in a flat cake. The symmetry index ranged from 9.66 to

Table 1. Physicochemical properties of sponge cakes prepared with various levels of RCP

Property	Control	RC10	RC20	RC30	RC40
pH	8.23±0.05^a	6.08±0.02^b	4.80±0.01^c	4.34±0.01^d	4.05±0.00^e
Moisture content (%)	36.59±0.10^a	36.20±0.65^a	35.03±0.35^b	32.82±0.62^c	28.49±1.06^d
Baking loss (%)	11.20±0.00^e	13.40±0.01^d	13.77±0.00^c	13.96±0.00^b	14.54±0.01^a
Firmness (N)	1.46±0.08^e	1.59±0.07^d	1.90±0.12^c	2.18±0.13^b	2.43±0.20^a
Color					
L^*	80.10±0.46^a	70.54±0.48^b	66.34±0.45^c	58.74±0.49^d	52.29±0.38^e
a^*	0.61±0.09^e	3.63±0.09^d	8.22±0.38^c	13.14±0.39^b	20.39±0.40^a
b^*	34.64±0.16^a	26.12±0.42^b	23.00±0.42^c	19.77±0.43^d	15.92±0.91^e

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



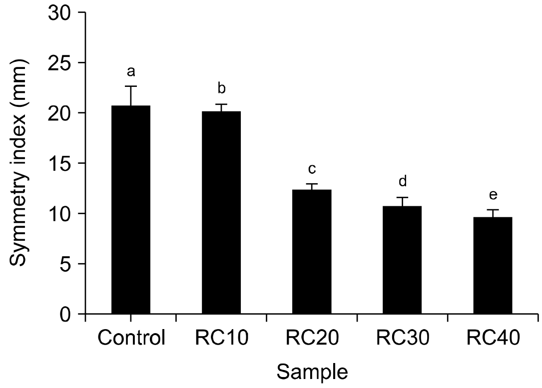


Fig. 1. Morphological characteristics of cakes upon *Rubus coreanus* powder supplementation. Means within the same property without a common letter (a-e) are significantly different according to Duncan's multiple range test ($P<0.05$).

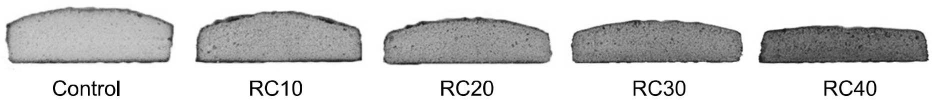


Fig. 2. Cross sections of cake sample upon *Rubus coreanus* powder supplementation.

20.73 and significantly decreased upon addition of RCP ($P<0.05$). All cakes presented positive symmetry indices; negative symmetry values indicate cake volume falling at the end of the baking process (37). Increasing proportions of RCP led to reduction of cake volume and a more flat shape (Fig. 1 and 2). This coincides with the findings of Lee and Lee (29), who performed incorporation of pine leaf powder. In addition, cakes with a low volume index show a low symmetry index. A high symmetry index indicates a peaked cake, which is undesirable, and a low value is also undesirable. Flours with RC20 and RC30 seemed to give similar values to the commercial heat-treated flour.

Texture and color

Of the textural parameters shown in the TPA graph, only firmness was considered as a principal parameter with regard to cake texture. Table 1 shows that addition of an increased amount of RCP from 0 to 40% resulted in a significantly elevated hardness of samples from 1.46 to 2.43 N ($P<0.05$). This increase in hardness can be attributed to differences in cake volume (37,39). The results of the present study coincide with previous reports examining the effects of addition of pin-milled pea flour (6), green tea powder (21), and cinnamon powder (30). In addition, hardening of cakes are attributed to crumb dehydration (40). Despite minimizing moisture transfer from the crust to the environment by packing in polypropylene bags, a slight degree of hardening may have been caused by moisture transfer.

All color data were expressed as CIELAB L^*, a^*, and b^*-values corresponding to lightness, redness, and yellowness, respectively. As shown in Table 1, crumb color of samples was significantly affected by replacement of cake flour with RCP ($P<0.05$). As the level of RCP increased, the L^* and b^*-values decreased while a^*-value increased, indicating a darker, more reddish, and less yellowish color when RCP was added. Crumb color is highly dependent on the raw materials or ingredients used in the formulation since the temperature inside the cakes does not exceed 100°C, meaning that the increase in temperature is not sufficient to produce Maillard or caramelization reactions (37,41). The color observed in the crumb corresponds mainly to the color of RCP. Similar color characteristics have also been detected in other studies in which wholegrain were incorporated into cakes (42).

Sensory findings

Color, flavor, taste, softness, and overall preference of control sponge cakes and RCP-supplemented cakes were evaluated, and the results are presented in Table 2.

Table 2. Sensory characteristics of sponge cakes prepared with various levels of RCP

Attributes	Control	RC10	RC20	RC30	RC40
Color	6.99±1.32[a]	5.15±1.44[c]	5.10±1.27[c]	6.29±1.52[b]	6.81±1.73[a]
Flavor	5.44±1.61[c]	5.93±1.64[bc]	6.05±1.39[b]	6.78±1.46[a]	6.93±1.84[a]
Taste	5.79±1.56[b]	5.88±1.47[b]	6.16±1.45[b]	6.75±1.74[a]	6.05±2.27[b]
Softness	6.44±1.77[b]	5.08±1.81[c]	5.45±1.66[c]	6.77±1.47[ab]	7.03±1.72[a]
Overall preference	5.89±1.58[bc]	5.55±1.58[c]	5.89±1.69[bc]	6.63±1.70[a]	6.25±1.96[ab]

Means within the same row without a common letter (a-c) are significantly different ($P<0.05$).

When evaluated by untrained consumers, statistically significant differences were detected in all of the sensory attributes evaluated ($P<0.05$). With regard to color, control and RC40 were appreciated the most, followed by RC30. RC30 and RC40 received significantly higher preference scores than the other treatments ($P<0.05$), but no significant difference was observed between the two in terms of flavor, softness, or overall preference ($P>0.05$). In addition, cakes elaborated with RC30 received the highest taste preference score ($P<0.05$). On a nine-point hedonic scale, RC30 and RC40 received scores in the range of 6.09∼7.06. Considering RC30 received the highest overall acceptance score of 6.64 and was not significantly different from that of RC40, partial replacement of cake flour with 30∼40% RCP seems satisfactory.

CONCLUSION

A successful and novel formulation of sponge cake production with RCP was developed. Wheat-flour substitution by RCP can be a good alternative because of its functional properties and provide a novel sponge cake to the consumers. The substitution had significant effects on the physicochemical and sensory characteristics of sponge cakes. Sponge cakes formulated with partial replacement of cake flour with 30∼40% RCP received the most acceptable sensory scores. Overall, RCP could be successfully incorporated into cakes and provide sponge cakes with satisfactory consumer acceptance.

AUTHOR DISCLOSURE STATEMENT

The authors declare no conflict of interest.

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