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Physicochemical and sensory evaluation of wheat cookies supplemented with burdock powder

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우엉 분말을 첨가한 쿠키의 물리화학적 및 관능적 평가

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Abstract

Burdock powder (BP) has shown diverse functional activities; thus, it seems a good way to increase its consumption by incorporating BP into suitable food products such as cookies. Studies were carried out on cookies prepared by incorporating BP (2%, 4%, 6%, and 8%) into wheat flour. The cookie dough and cookies were evaluated for their physical, chemical, and sensory characteristics. The pH and density of cookie doughs ranged from 6.70-6.85 and 1.19-1.21, respectively, with no remarkable differences. Moisture content and spread factor of cookies appeared to increase with higher content of BP in the formulation but did not show significant differences (p>0.05). For color values of cookie surface, L*, a*, and b*-values significantly decreased as a result of BP substitution (p<0.05). The cookies became crispier as indicated by the reduction in the breaking strength value from 26.71 to 17.83 N. 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 higher substitution of BP, and they were well correlated. Hedonic sensory results indicated that cookies supplemented with 2% BP received the most favorable acceptance scores for all sensory attributes evaluated. Overall, cookies with BP could be developed with improved physicochemical qualities as well as consumer acceptability.

Key words : burdock powder, wheat cookie, physicochemical properties, consumer acceptance, antioxidant properties

Introduction

Burdock (*Arctium lappa* L.) belongs to *Asteraceae*, a family featuring plants such as chicory, Jerusalem artichoke, and yacon (1), and is a popular vegetable in many Asian countries. Its root is commonly consumed as a nutritious and healthy food and used in folk medicine for the treatment of infectious diseases (2), such as gout, hypertension, hepatitis, arteriosclerosis, and other inflammatory disorders (3). Furthermore, it has been reported to posses antimicrobial activity (2), body weight management effect (4), and free radical scavenging activities (5).

Bakery products such as cookies, breads, doughnuts, and bagels are gaining more interests and popularities because of their pleasant sensation and sweet flavor. In fact, they are widely accepted and consumed in large quantities around the world (6); therefore, they can be used as a convenient supplementation vehicle for nutritional improvement (7). The consumers are more demanding for health-oriented products since their eating habits and behavior have changed (8). Bakeries can provide a refreshing alternatives and it is of great importance to develop new types of ready-to-eat convenience foods that provide health benefits. Cookies have been suggested as a good way to use composite flours, and

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provide a good source of energy (9) and refreshment.

Rapidly growing concerns about healthy diets and increased demand for the use of new natural food ingredients, especially in cookies, have led us to investigate wheat-based products with value-added ingredients. Over the years, several studies have been reported on improved nutritive value of cookies supplemented with various types of powder replaced the wheat flour. Burdock powder has been successfully incorporated into bread (10), castella (11), non-glutinous dasik (12), glutinous dasik (13), and cookie (14). There is little information on the incorporation of burdock powder (BP) in cookies except for study reported by Kim et al. (14) who prepared cookies with 0-30% BP. However, our preliminary study indicated that their incorporation rate seemed too high since some sensory panels expressed unpleasant flavors when BP was incorporated more than 6%.

Therefore, the objectives of this research were to make cookies with 0%, 2%, 4%, 6%, and 8% BP substituted for wheat flour in order to evaluate the effects of BP on cookie qualities and consumer acceptances as a result of supplementation. The antioxidant properties of cookies were also determined.

Materials and Methods

Materials

BP was procured from Garunara (Seoul, Korea), and wheat flour (soft flour, CJ Cheiljedang, Yangsan, Korea), white sugar (CJ Cheiljedang, Seoul, Korea), salt-free butter (Seoul Dairy Coop., Seoul, Korea), and eggs were purchased from a local market.

Cookie formulation and preparation

The standard cookies' recipe consisted of 200 g (100%) of flour (white wheat flour as a control), 90 g salt-free butter, 100 g white granulated sugar, and 50 g egg. The composite flour cookies were prepared from various combinations of wheat flour, and BP in ratio of 100:0, 98:2, 96:4, 94:6, and 92:8, respectively. Butter, sugar, and eggs were creamed with a kitchen mixer (5K5SS, KitchenAid Inc., St. Joseph, MI, USA) at speed 2 for 3 min with scraping down every minute. Wheat flour and appropriate amount of BP were then added and mixed at speed 1 for 3 min. Dough was placed in a 4℃ refrigerator for 30 min before sheeting. To prepare cookies, the dough was slightly flattened with palm of the hand, sheeted with a roller to a uniform thickness of 4 mm and cut into circular shapes of 5 cm diameter. The dough pieces were then placed on a baking tray with baking paper and baked at 170℃ for 10 min in a preheated oven (KXS-4G+H, Salvia industrial S.A., Lezo, Spain). Baked cookies were removed from the oven and cooled down for 1 h, weighed, packed in sealed plastic bags and stored for 24 h at ambient temperature before analyses were conducted. The test cookie samples prepared with 0%, 2%, 4%, 6%, and 8% BP substituted for wheat flour were designated as the control, BP2, BP4, BP6, and BP8, respectively.

Physicochemical analysis of cookie dough and cookies

A dough sample (5 g) was mixed with 45 mL of distilled water and vortexed for 1 min. The mixture was held at ambient temperature for 1 h 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). Dough density measurements were performed in a 50 mL mass cylinder by water displacement.

Moisture content of cookies was obtained by drying a specific amount (5 g) of sample to a constant weight at 105℃ in an oven (FOL-2, Jeio Tech Co., Daejeon, Korea), and the results were reported on a wet basis (w.b.). Cookie spread factor was determined according to the AACC Method 10-50D (15). Diameter was measured with a vernier caliper by laying down six cookies edge to edge. The diameter of six cookies was measured again after rotating each cookie to 90o and then the average value of cookie diameter was calculated. Six cookies were stacked on each other and their thickness was measured. Cookies were restacked in random order and thickness was measured again and then the average value of cookie thickness was calculated. Spread factor of cookies was calculated by dividing the average diameter of cookies by average cookie thickness.

Hardness of the baked cookies was measured using a texture analyzer (LRXPlus, Lloyd Instrument Limited, Fareham, Hampshire, UK) in a compression mode via 3-point bending test using 3-point bending rig, trigger force of 0.049 N, and load cell of 100 N. The textural studies were conducted at test speed of 1.0 mm/s, distance 10 mm and the distance between the two bottom supports was adjusted to 40 mm. The peak value of fracture force (maximum) was recorded as hardness at a point when the cookies were broken into two major pieces (16). The peak force to snap the cookies was reported as fracture force in N. Surface color measurement of BP cookies on the basis of CIE L*, a*, b* color system was carried out using a Chromameter (CM-600d, Minolta Co., Osaka, Japan).

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 (17) 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 $ABTS^{+}\bullet$ radical scavenging activity was determined according to the method used by Re et al. (18) with slight modifications. The $ABTS^{+}\bullet$ 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 h. Before use, $ABTS^{+}\bullet$ solution was diluted with methanol to obtain an absorbance of 1.1 at 734 nm. Subsequently, 3 mL of $ABTS^{+}\bullet$ 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

Cookies were subjected to sensory evaluation using fifty untrained volunteer panelists (25 males and 25 females, aged from 21 to 26), drawn within the University community. Cookies were evaluated for consumer acceptance of color, flavor, softness, taste, and overall acceptance. The ratings were carried on a 9-point Hedonic scale ranging from 9-(like extremely) to 1-(dislike extremely). Orders of serving were completely randomized. 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 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 handlethe samples and questionnaire, and evaluation time was not constrained. No specific compensation was given to the participants.

This study was approved by the Daegu University Institutional Review Board (IRB # 1040621-201703-HR-015-02).

Statistical analysis

Each measurement was conducted triplicate, except for pH (n=5), moisture content (n=6), color (n=9), hardness (n=15), and sensory evaluation (n=50). 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.

Table 1. Physicochemical characteristics of cookie dough and cookies containing different levels of burdock powder

Sample	Property		BP content (%)				
			0	2	4	6	8
Cookie dough	pH		6.85±0.01[a1)]	6.82±0.01[b]	6.78±0.01[c]	6.75±0.01[d]	6.70±0.01[e]
	Density (kg/L)		1.20±0.01[a]	1.20±0.01[a]	1.20±0.02[a]	1.19±0.01[a]	1.21±0.01[a]
Cookies	Moisture content (%, w.b.)		2.31±0.16[a]	2.33±0.30[a]	2.36±0.16[a]	2.60±0.26[a]	2.64±0.50[a]
	Spread factor		8.66±0.12[a]	8.85±0.09[a]	8.96±0.08[a]	9.08±0.10[a]	9.18±0.07[a]
	Hardness (N)		26.71±1.20[a]	25.17±1.04[b]	23.13±1.40[c]	20.65±1.50[d]	17.83±0.96[e]
	Color	L*	61.52±0.10[a]	56.35±0.15[b]	53.31±0.18[c]	50.88±0.95[d]	48.25±0.65[e]
		a*	6.67±0.18[a]	6.48±0.10[ab]	6.35±0.12[abc]	6.11±0.04[bc]	5.90±0.06[c]
		b*	31.48±0.02[a]	28.96±0.12[b]	28.62±0.14[b]	26.64±0.30[c]	26.42±0.67[c]

[1)]Means within the same row with a different letter are significantly different (p<0.05).

Results and Discussion

Physicochemical characteristics of cookie dough and cookies

Table 1 describes the physicochemical characterization of cookie dough and cookies supplemented with different levels of BP. The pH ranged from 6.70 to 6.85 and significantly decreased upon addition of BP ($p<0.05$). Nonetheless, only minor changes were observed. Thus, it seems that BP supplementation could result in the production with cookies of little lower pH. Similar reduction of pH was observed for castella incorporated with BP probably due to the organic acids included in BP powder supplemented (11). The pH of BP was 6.33 in this study.

Density of cookie dough appeared to remain stable (1.19-1.21 kg/L) upon addition of BP and no significant differences were found among them ($p>0.05$). When the dough density is low, cookie hardness increases; on the other hand, baked cookies become smaller and more fragile if the dough density is high (19). This indicates that supplementation of BP in cookie formulation did not have an adverse effect on physical quality value of the product. Similar findings were reported for cookies incorporated with *Pleurotus eryngii* powder (20), *Codonopsis lanceolata* (21), and cinnamon powder (22).

Physical characteristics of cookies

The moisture content of cookies ranged from 2.31 to 2.64% (w.b.) and appeared to increase upon addition of BP. This can be explained by an affinity effect between BP sample and moisture (23) and this would increase the moisture content of cookies with higher amount of BP. Similar trends were also reported for cookies supplemented with *Hovenia dulcis* fruit powder (8) and rice cookies with yacon powder (24).

As the substitution level of white wheat flour increased, the spread factor increased from 8.66 to 9.18. Similar trend and values were reported for the cookies containing 0-8% *Hovenia dulcis* fruit powder (8). The incorporation of BP might induce lowering dough viscosity (25); thus, the spread factor was increased, as the spread factor is highly correlated negatively to the dough viscosity (26). Singh et al. (27) reported that the spread ratio increased as non-wheat protein content increased, and it was also noted that Non-wheat protein exhibited greater water retentions than gluten, resulting in affecting cookie spread during baking (28). The increase in spread factor by adding BP in this study could be attributed to the decrease in total gluten content and also the increase in protein content (29).

The hardness of the cookies containing BP was significantly ($p<0.05$) lower than the control. The incorporation of increasing levels of BP remarkably decreased the cookies' hardness changing from 26.71 N at 0% of replacement to 17.83 N at 8% of substitution. The values of hardness for BP cookies were found in range with values of hardness found by others (8). The lower amount of gluten formed due to less amount of white wheat flour existed in the formulation (30) might explain the decreasing hardness values of BP substitution in the cookies. Similar observations have been described by Park et al. (8) for cookies incorporated with *Hovenia dulcis* fruit powder, and Lee and Choi (31) for yacon cookies.

All color data were expressed as CIELAB L*, a*, and b*-values corresponding to lightness, redness, and yellowness, respectively. It was observed that the cookies became darker in color as evident from lower L* values of the BP cookies in comparison to control cookies. L* value decreased as the concentration of BP in the blend increased ($p<0.05$). Adding BP resulted in decreases in both redness (a*) and yellowness (b*) compared to the control, which could be attributed to the color changes being brought by the BP replacing at different levels the wheat flour. These results were in accordance with the findings reported for cookies supplemented with *Taraxacum coreanum* powder (32), and bread (10), non-glutinous rice dasik (12), and glutinous rice dasik (13) incorporated with BP. Surface color generated during baking process probably due to non-enzymatic browning (Maillard reactions) between reducing sugars and amino acids, and starch dextrinization and sugar caramelization which are induced by heating also played the role in color formation in cookies during baking process (33).

Free radical scavenging activities

Antioxidants compounds are known to prevent, delay or retard rancidity development or other flavor deterioration in foods or capable of protecting the oxidative damage in the human body (34). The BP supplemented cookies exhibited higher antioxidant activities compared to whole wheat flour cookies ($p<0.05$) (Fig. 1). The usage of BP in the cookie formulation enhanced antioxidant activities, and the effectiveness of antioxidant properties were as follows in ascending order: control < BP2 < BP4 < BP6 < BP8. Highest DPPH activity was exhibited by cookies containing 8% BP (21.42%). The results show that BP supplementation greatly enhanced antioxidant properties of the cookies due to

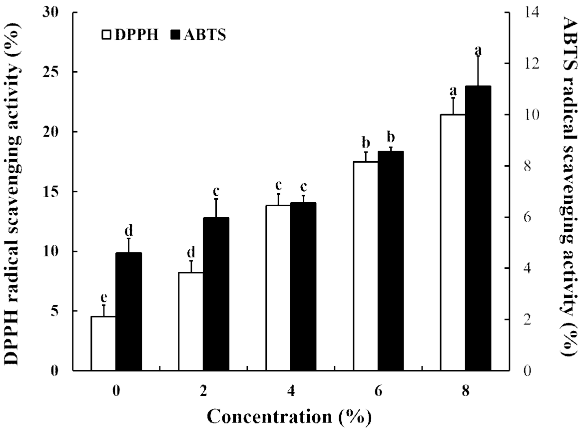

Fig. 1. DPPH and ABTS radical scavenging activities of cookies with different levels of burdock powder.

Means with in the same activity with a different letter are significantly different (p<0.05).

incorporation of phenolic compounds, which have been reported to possess antioxidant activity (5). ABTS also followed a similar trend to DPPH activity and the data also confirm a positive correlation between two antioxidant capacities. Cookies supplemented with Amaranth flour (35) and *Hovenia dulcis* fruit powder (8) showed a similar increase in the antioxidant activities. Baking has also been reported to increase the antioxidant activity of cookies (35); this increase in antioxidant activity could be attributed to the formation of dark (brown) color pigments during the baking process, which have been reported to have antioxidant activity (36).

Sensory characteristics of cookies

Incorporation of BP in wheat flour significantly influenced all the sensory characteristics of cookies evaluated (p<0.05) (Table 2). The highest surface color score was achieved by cookies prepared from blend containing BP at 2% level; however, further BP addition lowered the surface color scores. The scores for softness and taste also decreased when BP was incorporated at over 2% level. The scores for flavor decreased as the level of BP increased from 2% to 8% level (p<0.05), showing a similar trend with color, softness, and taste sensory attributes. It is noted that flavor preference score for control was not significantly different from that of BP2 (p>0.05). BP2 received the highest overall acceptance score but further increase in BP incorporation over 2% significantly lowered the score (p<0.05). On a nine-point hedonic scale, BP2 received scores in the range of 6.34-7.12, which is very acceptable. The data showed that the BP cookies improved the sensory attributes with the best scores for the BP2. Considering BP2 received the highest overall acceptance score of 7.12, partial replacement of 2% BP in cookie formulation seems satisfactory. In a study reported by Tae et al. (10), it was observed that BP can be incorporated in bread as a partial replacement up to 5% of wheat flour without negatively affecting the physical and sensory quality. Chung et al. (12) recommended 3% replacement of BP when making non-glutinous rice dasik.

요 약

우엉 분말(BP)은 여러 기능적 활성을 나타내고 있고, 쿠키와 같은 간편식품에 활용하면 소비진작에 도움이 될 것으로 판단되어, 우엉 분말의 첨가량을 0-8%로 달리하여 제조한 쿠키의 물리·화학적 품질, 항산화 활성 및 소비자 기호도를 비교하였다. 쿠키반죽의 pH와 밀도는 BP의 첨가량에 현저한 영향을 받지 않는 것으로 나타났다. 쿠키의 수분함량과 퍼짐성 지수는 BP의 첨가량이 증가함에 따라 유의적 차이 없는 증가경향을 보였다(p>0.05). 쿠키표면의 명도(L*), 적색도(a*) 및 황색도(b*) 그리고 경도는 BP의 첨가량이 증가할수록 유의적으로 감소하였다(p<0.05). 항산화 활성을 나타내는 전자공여능과 ABTS 라디칼 소거능 활성은 BP를 첨가할수록 유의적으로 증가하는 경향이 나타났다(p<0.05). 소비자 기호도 결과 2% 첨가군이 전체적 기호도를 포함한 모든 평가항목에서 유의적으로 높게 평가되어, 관능품질과 건강기능성 효과 등을 고려할 때 소비자의 기호

Table 2. Consumer acceptances of cookies containing different levels of burdock powder

Attributes	BP content (%)				
	0	2	4	6	8
Color	6.36±1.32$^{b1)}$	6.98±1.39^{a}	5.72±1.37^{c}	4.80±1.44^{d}	4.48±1.67^{d}
Flavor	6.38±1.51^{ab}	6.62±1.70^{a}	5.92±1.56^{b}	4.84±1.46^{c}	4.56±1.63^{c}
Taste	6.18±1.51^{b}	6.90±1.36^{a}	5.66±1.53^{b}	4.58±1.57^{c}	3.94±1.62^{d}
Softness	5.30±1.65^{b}	6.34±1.76^{a}	5.56±1.59^{b}	5.32±1.56^{b}	5.28±1.81^{b}
Overall acceptance	5.98±1.42^{b}	7.12±1.46^{a}	5.84±1.45^{b}	4.60±1.38^{c}	4.16±1.34^{c}

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

를 충족시키기 위한 최적 첨가비율은 2%가 가장 적합한 것으로 판단된다.

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