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연구논문

약용버섯(꽃송이버섯) 분말의 첨가가 밀가루 반죽과 빵의 품질에 미치는 영향

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Effects of Dried Medicinal Mushroom (*Sparassis crispa*) Powder on Wheat Flour Dough and Bread Properties

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Abstract: The effects of medicinal mushroom (*Sparassis crispa*) powder supplementation on the rheological property of dough and the quality of bread were investigated. Naturally dried *S. crispa* powders (NDSCP) and freeze-dried ones (FDSCP) were prepared. Farinograph profiles of dough showed that mushroom powder addition at levels higher than 1% led to reduced dough stability suggested by decreased development time and increased weakness. The incorporation of *S. crispa* powders was significantly (p<0.05) lower compared to other mushrooms which might be attributed to its high content of beta-glucan. FDSCP was chosen over NDSCP because of its fragrant flavor which could be ascribed to the preservation of volatile polyphenol components. The quality of FDSCP bread was evaluated with respect to specific volume, texture, color, and organoleptic qualities. The specific volume of bread with *S. crispa* powder decreased compared to the control, while textural properties, such as hardness, chewiness, and gumminess, were enhanced. Sensory evaluation showed that 0.3% FDSCP incorporation presented the highest bread quality. With its daily consumption, *S. crispa* supplemented bread can provide consumers with multiple health benefits.

Keywords: *Sparassis crispa*, Bread, Dough characteristic, Texture profile, Sensory evaluation

1. INTRODUCTION

Bread has been an important constituent of the diet of people across the globe for thousands of years. Specialty breads are becoming increasingly popular among consumers because of their nutritional value, antioxidant properties, flavor, and color attributes [1]. Recently many functional ingredients, including buckwheat [2], inulin [3], turmeric [4], and omija [5] have been incorporated into bread, providing beneficial effects to the health of consumers. In addition, several medicinal mushroom powders from both mycelia and fruiting bodies have been explored as valuable sources of supplements for new breads [6,7]. However, there are currently no reports of practically commercialized bread supplemented with medicinal mushroom powder being marketed.

Mushrooms have been consumed as food and medicine since ancient times due to their enormous health benefits. They contain high levels of protein, carbohydrate, fiber, vitamins, and minerals, and are low in calories, sodium, fat, and cholesterol

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[8,9]. *Sparassis crispa* is a culinary and medicinal mushroom, commonly called the cauliflower mushroom in English, Hanabiratake in Japanese, and Ggotsongyi (meaning "blossom") in Korean [10]. *S. crispa* is a brown-rot fungus that primarily grows on the stumps of coniferous trees and is widely distributed throughout the North Temperate Zone [11]. Currently, this mushroom is very popular among consumers because it has sweet, tender, and rich flavor [12]. The fruiting bodies of *S. crispa* have been reported to exhibit excellent effects for enhancing cytokine synthesis and preventing human diseases, such as gastric ulceration, oesophageal cancer, hypertension, and diabetes [11-14]. With its immune benefits for people especially the elderly, the incorporation of *S. crispa* into the formulation of bread would be of great interest. *S. crispa* powder bread is now under pre-market assessment and we believe that it will become popular in local market.

The objectives of this study were to substitute different levels of wheat flour with two types of *S. crispa* powders to make bread, and to investigate the influence of mushroom on the rheological properties of dough and the quality of the bread produced. The samples were evaluated by farinograph profiling, and by reference to specific volume, texture, color, and organoleptic qualities.

2. MATERIALS AND METHODS

2.1. Preparation of *S. crispa* powder

Fruiting bodies of *S. crispa* were collected from the Forest Resources Research Institute at Naju, Jeonnam, Korea. The powder of *S. crispa* was prepared and homogenized in a Waring blender (Waring Laboratory Science, Torrington, CT, USA) by two drying methods: (1) naturally dried *S. crispa* powder (NDSCP) at room temperature for 96 h, and (2) freeze-dried *S. crispa* powder (FDSCP) at -20°C for 72 h utilizing freeze dryer FD 12008 (IlShinBioBase, Seoul, Korea).

2.2. Bread formulation

The bread recipe consisted of wheat flour (Beksul Bread 45, Korea), 2% compressed yeast (w/w, wheat flour basis), 0.2% yeast food, 6% sugar, 4% shortening, 3% skim milk powder, 2% salt, and water (up to the optimum consistency of 500 Brabender Units). Different concentrations of *S. crispa* powder (0-4% by weight) were substituted to the formulation.

2.3. Bread making process

Bread was made using a straight dough method according to Lin *et al.* [15]. Firstly, compressed yeast was dissolved in warm water at 35°C and added to the dry ingredients for shortening, and then, the mixture was blended for 5 min. After complete mixing, the dough was placed in an incubator (Daeyung Bakery Machinery Co., Seoul, Korea) for two-step fermentation. The first fermentation was carried out at 27°C and 75% relative humidity for 1 h. The dough was divided into portions of similar weights, and each portion was shaped and placed in an incubator for second fermentation at 38°C and 85% relative humidity for 1 h. The bread was baked at 200°C for 45 min in an electric oven (FDO-7104, Electric Deck Oven, Daeyung Bakery Machinery Co., Seoul, Korea). The baked product was cooled to room temperature for 1 h. The whole bread was used for further analysis.

2.4. Dough characteristics

Farinograph measurements were made on 300 g of wheat flour using Farinograph®-AT (C.W. Brabender, South Hackensack, NJ, USA) [16]. Extraction of wheat proteins from the dough with *S. crispa* powder was performed as follows: After 15 min of the farinograph test, the dough was freeze-dried. Then 10 g of frozen-dried dough was mixed with 100 mL of 1% sodium dodecyl sulfate (SDS) and shaken overnight at room temperature. After centrifugation, the supernatant fractions were dialyzed against water and freeze-dried. Parameters measured were water absorption, dough development time (DDT), dough stability, and degree of weakening.

2.5. Measurement of bread quality

Breads supplemented with *S. crispa* powder were weighed. The length, width, and height of the loaves were measured using a fixed ruler. The volume of the bread was measured using the rapeseed displacement method, and the specific volume was calculated.

2.6. Color measurement

Surface color of breadcrumbs was measured using a handheld CR-310 colorimeter (Minolta Corp., Ramsey, NJ, USA). L*, a*, and b* values were recorded. The L* value represents the lightness component on the surface, and the values range from 0 (dark) to 100 (light), while a* and b* values represent chromatic components of redness (positive values) to greenness (negative values), and blueness (positive values) to yellowness (negative values), respectively. The L*, a*, and b* values of a white standard tile used as a reference were 97.83, 0.02, and 1.79, respectively.

2.7. Textural profile analysis

Texture profile analysis (TPA) was carried out 1 h after final baking, in four replications on separate samples, using a model Lloyd TA+ texture analyzer (AMETEK, Largo, FL, USA), with a 30 mm cylinder probe and according to the method: pre-test speed of 2 mm/s, test speed of 2 mm/s, post speed of 2 mm/s, and compression distance of 50%. Firmness, chewiness, cohesiveness, and springiness were calculated from the texture profiling curves from the analyzer.

2.8. Sensory evaluation

Bread quality was tested by 80 untrained panelists within 24 h of baking. The panel consisted of 35 males and 45 females between 21 and 48 years old. Each subject tested five samples (3×3×1 cm each), and their preferences on texture, flavor, taste, color, and overall acceptance were assessed based on the nine-point hedonic scale, which ranges from 1 (dislike extremely) to 9 (like extremely). Samples were placed on white plates and identified with random three-digit numbers. The panelists evaluated the samples in a testing area and were instructed to rinse their mouths with water between samples to minimize any residual effect.

2.9. Statistical analyses

Analysis of variance was performed on the data obtained at different stages of manufacture in accordance with SPSS for

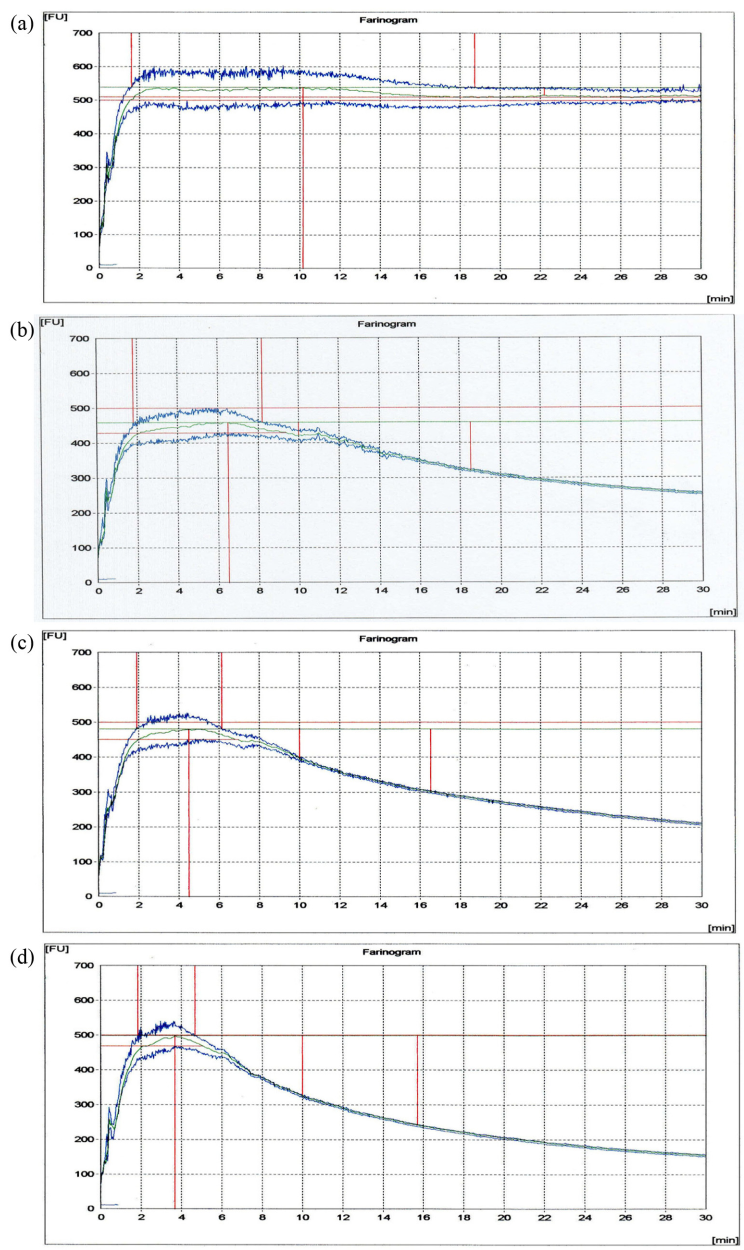

Fig. 1. Farinograph profiles of dough prepared using frozen dried *S. crispa* powder (FDSCP) at 0, 1%, 2%, and 4% and wheat flour.

Table 1. Physicochemical properties of dough prepared using frozen dried *S. crispa* powder (FDSCP) at 0, 1%, 2%, and 4% and wheat flour

Sample	FDSCP 0	FDSCP 1%	FDSCP 2%	FDSCP 4%
Water content (%)	12.9±1.5	12.7±1.6	12.9±1.7	12.6±1.4
Water absorption (%)	57.5±3.2	59.0±3.4	59.0±3.3	59.5±3.6
Development time (min)	10.2±0.5	6.5±0.6	4.5±0.5	3.7±0.6
Stability (min)	17.1±0.6	6.4±0.5	4.2±0.6	2.8±0.5
Weakness (BU)	23±2.6	138±11.3	179±12.1	257±12.4
Farinograph quality number (FQN)	300±27.2	94±8.9	70±7.2	51±6.8

Each value is expressed as mean±SD (n=3) and means having different letter superscripts within a same row are significantly different (p<0.05).

Windows, version 12.0 (IBM, Seoul, Korea). Properties of the bread supplemented with *S. crispa* powder were subjected to analyses of variance using one-way ANOVA. Differences between means were separated using Duncan's multiple range test.

3. RESULTS AND DISCUSSION

3.1. Dough properties

The incorporation of FDSCP at 0, 1%, 2%, and 4% levels gave rise to differences in the dough physicochemical properties such as Farinograph quality and dough stability as presented in Fig. 1 and Table 1. It was observed that the addition of FDSCP caused a slight increase in water absorption compared to the wheat flour control, which was 59.0%, 59.0%, and 59.5% with an FDSCP level of 1%, 2%, and 4%, respectively, while the control was 57.5%. This observation was consistent with previous findings [6,7] in which both fruiting body and mycelium powders were used. Factors affecting water absorption are the protein (gluten) and starch contents, and absorption tends to increase when the protein and starch are damaged. Rosell *et al.* [17] reported that differences in water absorption were mainly caused by the greater number of hydroxyl groups existing in the fiber structures, allowing more water interaction through hydrogen bonding.

DDT is the amount of time between first addition of water and the development of the dough to maximum viscosity. With *S. crispa* powder substitution, the DDT decreased from 10.2 min for the control to 6.5, 4.2, and 2.8 min with 1%, 2%, and 4% FDSCP addition, respectively (Table 1). The weakening degree observed for the dough increased from 23 Brabender Units (BU) for the control to 138, 179, and 257 BU in 1%, 2%, and 4% sample, respectively. Similar results were found with NDSCP-supplemented wheat flour (data not shown).

As concluded from the dough physicochemical properties, the incorporation of *S. crispa* powder at levels higher of 2% and 4% resulted in a dramatic decrease in dough strength and stability, which would lead to poor bread quality. As established by many reports, the beta-glucan content of *S. crispa* is more than 40% of the dry weight of the fruiting bodies which is highest in mushrooms found for now [12-13,18]. Therefore, the supplementation levels were limited under 1% (0, 0.3%, 0.5%, and 0.8%) for further study.

3.2. Bread quality with *S. crispa* powder supplementation

The bread volume and specific volume of FDSCP breads were presented in Table 2. The volume of bread gradually decreased with the addition of *S. crispa* powder. As shown in Fig. 2, the volume shrinkage with 0.3% and 0.5% FDSCP was similar in range compared with the control, while 0.8% FDSCP reduced to only 64% of the control in volume. The internal area of the FDSCP loaves exhibited an obvious cross-linking structure when viewed under a microscope (data not shown). It has been reported that *S. crispa* composes many components and pro-

Table 2. Quality indicators of bread supplemented with frozen dried *S. crispa* powder (FDSCP) at 0, 0.3%, 0.5%, and 0.8%

Sample	FDSCP 0	FDSCP 0.3%	FDSCP 0.5%	FDSCP 0.8%
Dough weight (g)	339.5±2.1	337.6±2.3	335.1±1.8	337.8±2.7
Bread volume (mL)	1335.4±18.4	1115.9±11.6	1085.5±13.1	837.6±10.3
Specific volume (mL/g)	3.9±0.2	3.3±0.1	3.2±0.1	2.5±0.1
Hunter's color value (crumb)				
L* (crumb)	74.50±2.03	69.54±2.99	69.93±2.98	66.30±3.00
L* (crust)	57.22±3.00	53.77±3.92	59.49±4.04	58.51±4.84
a* (crumb)	-1.93±1.22	-1.90±0.73	-2.04±1.18	-2.34±1.51
a* (crust)	8.11±1.00	7.73±0.85	4.75±1.94	4.08±2.32
b* (crumb)	8.11±0.10	7.89±0.14	8.56±0.19	9.27±0.20
b* (crust)	21.06±2.01	18.47±4.09	20.62±2.03	20.30±1.90

Each value is expressed as mean±SD (n=3) and means having different letter superscripts within a same row are significantly different (p<0.05).

Fig. 2. Dough property, external appearance and cut loaves of bread supplemented with frozen dried *S. crispa* powder (FDSCP) at 0, 0.3%, 0.5%, and 0.8%.

teins, such as lectin which was shown to inhibit both bacteria (*Staphylococcus* and *Pseudomonas* sp.) and fungi (*Candida* and *Fusarium* sp.) [19,20]. Thus the incorporation of *S. crispa* powder to wheat flour could hinder the growth and fermentation of yeast in the dough. Also the mushroom powder might inhibit the formation of gluten during dough making which then result in reduced volume [21]. Another possible explanation could be attributed to the protease secreted by the mushroom, which can digest the wheat proteins and damage the bread structure [22,23].

NDSCP supplementation was also evaluated for its effects on bread properties, and resulted in similar specific volume under 1% supplementation, while increased supplementation caused more apparent shrinking (data not shown). However, the flavor of NDSCP bread was more rarefied than FDSCP bread due to lower antioxidant property of NDSCP which may be ascribed to the loss of volatile polyphenol components during preparation [24]. FDSCP, on the other hand, appeared high radical scavenging activity (IC_{50} of 186.24 μg/mL measured by DPPH and 269.57 μg/mL by ABTS) and total polyphenol contents (2.7789 μg/mg) (data not shown). Thus FDSCP was chosen over NDSCP.

3.3. Color characteristics

Color is a major criterion affecting the quality of the final product. The bread made with *S. crispa* powder showed a difference in color compared with the control. The slight improvement in color was interpreted as an intense color and was dependent on the supplementation level with mushroom powder. For both crumb and crust, there was a minor decrease in L* and a* values, and an increase in b* values compared with the control group, which indicates a tendency toward dark and brown caused by the addition of mushroom powder (Table 2). These results were in agreement with those obtained by other researchers [25,26].

3.4. Texture profile analysis of FDSCP bread

Texture characteristics of FDSCP bread are presented in Table 3. Hardness is commonly used as an index of bread quality, and its change is frequently accompanied by a change in resilience

Table 3. Texture characteristics of bread supplemented with frozen dried *S. crispa* powder (FDSCP) at 0, 0.3%, 0.5%, and 0.8%

Sample	FDSCP 0	FDSCP 0.3%	FDSCP 0.5%	FDSCP 0.8%
Hardness (gw)	161.61±0.90	171.89±23.66	219.80±38.80	360.95±34.67
Adhesiveness	-0.99±0.63	-4.353±0.60	-4.06±0.73	-5.76±3.25
Springiness	0.93±0.00	0.92±0.01	0.91±0.01	0.88±0.02
Cohesiveness	0.82±0.02	0.80±0.01	0.80±0.01	0.74±0.04
Gumminess (gw)	133.21±2.98	136.94±20.80	165.84±29.20	267.25±16.15
Chewiness (gw)	124.25±2.98	126.05±19.52	150.03±24.97	234.31±16.69
Resilience	0.43±0.02	0.39±0.01	0.36±0.02	0.33±0.01

Each value is expressed as mean±SD (*n*=3) and means having different letter superscripts within a same row are significantly different (p<0.05).

Table 4. Sensory characteristics of bread supplemented with frozen dried *S. crispa* powder (FDSCP) at 0, 0.3%, 0.5%, and 0.8%

Sample	FDSCP 0	FDSCP 0.3%	FDSCP 0.5%	FDSCP 0.8%
Texture	0.58±1.65	1.32±1.15	0.87±1.38	-0.28±1.27
Flavor	0.73±1.33	0.88±1.15	0.42±1.37	0.13±1.52
Taste	0.13±1.34	1.02±1.24	0.58±1.39	0.12±1.50
Color	0.93±1.51	1.27±1.27	0.28±1.12	0.43±1.43
Overall eating quality	0.43±1.27	1.27±1.35	0.58±1.31	-0.08±1.36

Each value is expressed as mean±SD (n=3) and means having different letter superscripts within a same row are significantly different (p<0.05).

[27]. The hardness of the bread increases with the addition of *S. crispa* powder to 0.5%, then decreases at 0.8%. The different bread samples had uniform weights and the increase in hardness is mainly attributed to the reduced moisture content and loaf volume with the addition of mushroom powder [4]. The increase in crumb hardness can also be related to an increase in loaf density [28]. The mushroom powder interacts with the protein in wheat flour and thereby affects the uniform structure in FDSCP bread.

Adhesiveness represents the work necessary to pull the food away from a surface, and springiness is associated with the number of air bubbles incorporated into the bread during mixing [29]. Cohesiveness quantifies the internal resistance of the food structure. Briefly, cohesiveness is the ability of a material to stick to itself, gumminess is determined by hardness multiplied by cohesiveness, and chewiness is determined by gumminess multiplied by springiness. Thus, chewiness represents the amount of energy needed to disintegrate a food for swallowing. Resilience is the percentage of recoverable energy as the first compression is relieved, and is a dimensionless ratio. Texture profiling analysis showed an increase in gumminess and chewiness for FDSCP bread corresponding to the FDSCP supplementation level. However, there is a decrease in adhesiveness, springiness, cohesiveness, and resilience. In general, the quality of the bread decreases as the FDSCP amount increases, and the addition of 0.3% resulted in the lowest drop in bread quality.

3.5. Sensory evaluation

The effects of *S. crispa* powder supplementation on the sensory characteristics of bread are presented in Table 4. With an increase in the level of FDSCP in the formulation, the sensory scores for texture, flavor, taste, color, and overall eating quality of bread increased up to 0.3% supplementation, and then decreased. Generally, plain white bread was more acceptable since the starch-based food in Korea is rice instead of bread [30]. It was concluded that 0.3% supplementation with mushroom powder does not interfere with the original color of the bread made with wheat, since the color of *S. crispa* powder was light yellow. The taste and overall acceptability of breads with 0.3% FDSCP had the highest approval score. The results for sensory characteristics indicate that a partial replacement of wheat flour with up to 0.5% FDSCP in breads gives satisfactory overall consumer acceptability. However, breads which contain over 0.8% FDSCP are rated comparatively lower, which may be due to excessive amounts of volatiles and phenolic compounds that negatively affect the taste of food [31,32].

The results indicate that incorporating 0.3% *S. crispa* powder into bread formulation is acceptable and leads to the highest bread quality. The addition amount under 1% is much lower compared to around 5% of other mushrooms which might be caused by high concentration of beta-glucan [7,14]. *S. crispa* has been proven with various pharmacological activities including antitumor activity and antihypertensive and antidiabetic effects in mice model [33,34]. Although health benefit and antioxidant activity of this bread was not included in this study, it could be suggested with potential effects based on other reports of *S. crispa* showing such antioxidant activity and health property. Therefore, the addition of mushroom powder to bread would both be economically viable and provide consumers with the alleged beneficial properties.

4. CONCLUSION

It is concluded that *S. crispa* powders contribute a valuable supplement for developing bread with enhanced functional properties. The supplementation of 0.3% freeze-dried *S. crispa* powder (FDSCP) into bread formulation was optimal for improving the sensory quality and antioxidant potential of bread. FDSCP bread has already been commercialized by local company and is getting popular in market. People can make their homemade biscuits or cookies with *S. crispa* powder supplemented for more health and better taste.

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