Food Sci. Preserv., 32(4), 639-649 (2025)
pISSN: 3022-5477, eISSN: 3022-5485

Food Science and Preservation
https://doi.org/10.11002/fsp.2025.32.4.639

Research Article

Quality characteristics and antioxidant activity of cream soup supplemented with shiitake (*Lentinus edodes*) powder

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Abstract This study evaluated the effects of substituting wheat flour with shiitake mushroom powder (25-100%) on the physicochemical and antioxidant properties of cream soup. Compared to the control group, the addition of shiitake mushroom powder led to an increase in the moisture content, crude protein, and crude ash with the highest levels observed in the soup containing 100% shiitake mushroom powder. As the substitution level increased, soluble solids and total acidity rose proportionally, while pH decreased. In contrast, the viscosity of the soup decreased with higher levels of shiitake powder, with the control group showing the highest viscosity. Compared with the control, soups supplemented with shiitake mushroom powder exhibited a gradual decrease in lightness and proportional increases in redness and yellowness with increasing levels of powder. Total polyphenol and flavonoid contents increased proportionally with the amount of shiitake powder added, accompanied by enhanced antioxidant activity, suggesting a strong correlation between bioactive compound content and antioxidant potential. These findings indicate that substituting wheat flour with shiitake mushroom powder in soup preparation can improve its functional properties by enhancing bioactive compound content and antioxidant capacity.

Keywords shiitake mushroom, cream soup, antioxidant potential, polyphenol

Citation: Hwang ES, Son H. Quality characteristics and antioxidant activity of cream soup supplemented with shiitake (*Lentinus edodes*) powder. Food Sci. Preserv., 32(4), 639-649 (2025)

Received: June 07, 2025
Revised: July 23, 2025
Accepted: July 25, 2025

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1. Introduction

Mushrooms, including shiitake mushrooms (*Lentinula edodes*), have been used traditionally for both food and medicinal purposes due to their unique flavors, textures, and pharmacological effects (Kim et al., 2013; Yun et al., 2020). shiitake mushrooms belong to the Pleurotaceae family of the order Agaricales and are basidiomycetes that parasitize broadleaf trees such as oak, chestnut, and beech (Kim et al., 2013). They have been native to Korea, China, and Japan for about 2,000 years and are currently cultivated in East Asia, Europe, North America, and Australia, accounting for approximately 17% of the world's edible mushrooms (Huang et al., 2019; Silva et al., 2007).

Shiitake mushrooms possess a distinctive aroma and texture, attributed to components such as guanylic acid and adenylic acid, which provide a unique umami flavor, and retinol-containing sulfur compounds responsible for their characteristic smell (Hwang and Park, 2005; Yun et al., 2020). They are rich in provitamin D and ergosterol, which support bone health and blood formation (Lim et al., 2022). Furthermore, shiitake mushrooms contain abundant nucleic acids, essential amino acids, and dietary fiber, have low calories, and are known for antioxidant, antibacterial, and anticancer effects. They also help suppress blood sugar increases and contribute to the prevention and treatment of hypertension and arteriosclerosis (Ahmad et al., 2023; Han et al., 2015; Xu et al., 2024). Additionally, their efficacy in tonifying, diuresis, and treatment of conditions such as nephritis, neurasthenia, insomnia, and gastric ulcers has been reported (Jeff et al., 2016; Moon et al., 2018; Zembron-Lacny et al., 2013).

Due to their high moisture content and soft tissue, shiitake mushrooms are commonly distributed in dried form for easier storage. To utilize their physiologically active components, various foods have been developed by mixing dried and powdered shiitake mushrooms with other ingredients. Representative examples include rice cakes with shiitake powder (Cho et al., 2002), muffins (Kim and Joo, 2012), yanggaeng (Yun et al., 2020), tofu (Kim and Yoon, 2024), soybean paste (Hwang, 2009), rice cookies (Kim and Chung, 2017), and pound cakes made with shiitake mushroom concentrate (Lee et al., 2021).

Cream soup is a basic soup prepared by mixing milk and cream with a white roux made from frying flour and butter (Oh, 2006). It is nutritious, soft, and easy to digest, making it suitable for consumption across all ages and genders as a meal replacement or convenience food (MFDS, 2020). Recently, health-functional soups containing mulberry leaves (Park and Lee, 2007), perilla leaves (Kyung, 2022), purple sweet potatoes (Hwang and Kim, 2022), soybean powder (Kim et al., 2016), and lotus root (Hwang and Park, 2024) have been introduced. However, to date, no research has evaluated the feasibility or efficacy of adding shiitake mushroom powder to soup manufacturing.

Therefore, this study manufactured cream soup by substituting 25-100% of wheat flour with freeze-dried shiitake mushroom powder and measured physicochemical quality characteristics, antioxidant contents, and antioxidant activity. The goal was to explore the potential of adding shiitake mushrooms to processed foods such as soups, thereby broadening their utilization and increasing their added value.

2. Materials and methods

2.1. Materials

Shiitake mushrooms were harvested in Jangheung, Jeollanam-do and purchased from an online shopping mall. Wheat flour, butter (CJ Cheiljedang, Suwon, Korea), and salt (Sajo Haepyo, Suwon, Korea) were purchased commercially. Catechin, gallic acid, and polyphenol reagents were purchased from Sigma-Aldrich, and other reagents used for general component analysis and antioxidant activity measurement were purchased from Sigma-Aldrich Chemical Co. (St. Louis, MO, USA) and Junsei Chemical Co., Ltd. (Tokyo, Japan).

2.2. Preparation of shiitake mushroom powder and soup

The shiitake mushrooms were washed cleanly with running tap water, dried, sliced to a thickness of about 3 mm, placed in an aluminum lunch box, frozen at -80°C, and then dried using a freeze dryer (FDU-1200, EYELA, Tokyo, Japan). The freeze-dried shiitake mushrooms were finely ground at high speed in a coffee grinder (PGR 002M, Supreme electric Co. Ltd.), then passed through a No. 20 standard sieve to a size of 850 μm or less and stored at -2 0°C for use in the experiment. The mixing ratio of the soup was manufactured by referring to the method of Hwang and Park (2024) by replacing 25, 50, and 100% of the weight of the flour with shiitake mushroom powder (w/w) through several preliminary experiments (Table 1). After melting the butter in a pan, slowly add wheat flour and shiitake mushroom powder to make a roux, then add water little by little and mix well with a wooden spatula so that the roux and water do not stick or separate. Add sugar and salt to the mixed sample, stir, and boil for 10 min to complete. After cooling the prepared soup to room temperature, measure the viscosity, place the remaining sample in a Lock & Lock container, close the lid, and store in the refrigerator for use in the experiment.

2.3. Proximate composition analysis

The moisture, crude protein, crude fat, and ash contents of soups prepared with different amounts of shiitake mushroom powder, flour, and shiitake mushroom powder used in making soup were analyzed according to the AOAC method (1995). Moisture was quantified by atmospheric pressure heating drying, crude protein by semi-micro Kjeldal method, crude fat by Soxhlet extraction method, and ash by 550°C dry ash method.

2.4. Measurement of available solids, pH, and total acidity

To extract the available solids, pH, and total acidity of the

https://doi.org/10.11002/fsp.2025.32.4.639

Table 1. Formula for cream soup incorporated with different amount of shiitake powder

Ingredients	Shiitake powder (%)[1)]			
	0	25	50	100
Shiitake powder (g)	0	10	20	40
Wheat flour (g)	40	30	20	0
Butter (g)	40	40	40	40
Water (mL)	300	300	300	300
Salt (g)	0.5	0.5	0.5	0.5

[1)]Shiitake powder (25, 50, and 100%) was added based on the total weight of wheat flour.

shiitake mushrooms, flour, and prepared soup used in the preparation of the soup, 30 mL of distilled water was added to 5 g of the sample, and ultrasonic extraction was performed at room temperature for 10 min. The extract was centrifuged at 13,500 ×*g* for 15 min (Mega 17R, Hanil Co.), and the supernatant was collected to measure the sugar content and acidity, respectively, using a saccharometer (JP/PR-201, Atago Co.) and a pH meter (SevenCompactTM PH/Ion S220, Mettler-Toledo). The titratable acidity was measured according to the AOAC method (1995).

2.5. Measurement of viscosity

The viscosity of the soup was measured using a viscometer (Brookfield DV3T, Brookfield AMETEK, Inc.). 200 g of soup adjusted to 60°C was placed in a beaker and measured for 2 min at a speed of 15 rpm using spindle No. 9.

2.6. Color measurement

The color of the soup was measured using a colorimeter (Chrom Meter CR-400, Konica Minolta, Inc.) based on the Hunter Lab system for lightness (L), redness (a), and yellowness (b). The colorimeter was calibrated using a white standard plate (L=97.10, a=0.24, b=1.75).

2.7. Preparation of extracts and analysis of total polyphenol and flavonoid compounds

Extracts were prepared to analyze the total polyphenol and total flavonoid content of soup prepared with shiitake mushroom powder, wheat flour, and shiitake mushroom powder. 70% ethanol equivalent to twice the weight of each sample was added, mixed for 3 min, and extracted using ultrasonic waves for 30 min at room temperature. The extracts were centrifuged at 13,500 ×*g* for 15 min, and the supernatant was diluted to an appropriate concentration and used as a sample for analysis of physiologically active substances.

The total polyphenol content was measured using the Folin-Ciocalteu reagent by the method of Singleton and Rossi (1965), and the total polyphenol content contained in the sample was expressed as gallic acid equivalent (GAE) using the standard curve of gallic acid. The total flavonoid content was measured using Zhishen’s method (1999), and the total flavonoid content in 1 g of sample was calculated using the standard curve of catechin and expressed as catechin equivalent (CE).

2.8. Measurement of antioxidant activity

DPPH radical scavenging activity of soup was measured by the method of Cheung et al. (2003). 100 μL of sample extract and 100 μL of 0.2 mM DPPH solution were mixed and reacted at 37°C for 30 min, and then the absorbance was measured at 515 nm using a microplate reader. The DPPH radical scavenging activity of the sample was expressed as a percentage compared to the control group to which the sample extract was not added.

ABTS radical scavenging activity was measured by the method of Re et al.(1999). 24 h before the experiment, 7.0 mM ABTS and 2.45 mM potassium persulfate were reacted in the dark to form ABTS cations, and then diluted with ethanol until the absorbance value at 735 nm was 0.73±0.03.100 μL of sample extract and 100 μL of ABTS solution with adjusted absorbance were mixed and reacted at 37°C for 30 min, and then the absorbance was measured at 732 nm. The ABTS radical scavenging activity of the sample was expressed as a percentage compared to the control group to which the sample extract was not added.

The reducing power was measured by the method of Oyaizu (1986). 200 mM phosphate buffer (pH 6.6) and 1 mL of 1% potassium ferricyanide were sequentially added to 1 mL of sample extract and reacted in a constant temperature water bath at 50°C for 20 min. After the reaction was completed, 1 mL of 10% TCA solution was added, centrifuged at 13,500 ×*g* for 15 min, and the supernatant was collected. After mixing, distilled water and ferric chloride were sequentially added to 1 mL of the supernatant, and the absorbance was measured at 720 nm. The obtained value was expressed as the reducing power.

2.9. Statistical analysis

All results are expressed as the mean±standard deviation for three replicate experiments. Statistical analysis was performed using R-Studio (Version 3.5.1, Boston, MA, USA) for analysis of variance, and significance was tested using Duncan's multiple range test.

3. Results and discussion

3.1. Proximate composition

The results of general component analysis of soups manufactured with different amounts of shiitake mushroom powder, wheat flour, and shiitake mushroom powder used in making soup are shown in Table 2. The moisture content of shiitake mushroom powder and wheat flour was 14.05% and 11.81%, respectively, indicating that shiitake mushroom powder contained more moisture than wheat flour. In the case of soup, the moisture content of the control group without shiitake mushroom powder was 78.65%, and the moisture content of the soup manufactured with 25-100% shiitake mushroom powder was 79.53-80.33%, indicating that soups manufactured by replacing wheat flour with shiitake mushroom powder 100% contained more moisture than the control group. This may be explained by the moisture content of shiitake mushrooms used in making soup was greater than that of wheat flour.

The crude protein content of the shiitake mushroom powder and wheat flour used in the soup production was 2.30% and 0.67%, respectively, showing a higher content in the shiitake mushroom powder than in the wheat flour. In the case of the manufactured soup, the crude protein content of the control group without the addition of shiitake mushroom powder was 0.50%, and in the soups with the addition of 25-100% of shiitake mushroom powder, it was 0.97-1.34%, showing an increase in proportion to the amount of shiitake mushroom powder added. It has been reported that shiitake mushrooms are the food richest in amino acids among vegetables (Park et al., 2017), and it is thought that the total protein content also increased as the content of shiitake mushrooms added to the soup increased. Cha et al. (2004) analyzed the amino acids contained in shiitake mushrooms using HPLC and found that glycine was the most abundant at 23.7 mg/g, followed by a total of 20 free amino acids including glutamic acid, asparagine, proline, and alanine. The total free amino acids were 71.9 mg/g, of which essential

Table 2. Proximate composition (%) of shiitake powder, wheat flour and cream soup prepared with different amount of shiitake powder

Sample	Measurements			
	Moisture	Crude protein	Crude fat	Crude ash
Shiitake powder	14.05±1.31[1)a2)]	2.30±0.25[a]	0.43±0.01[ns3)]	0.69±0.13[a]
Wheat flour	11.81±0.01[b]	0.67±0.16[b]	0.48±0.20	0.19±0.01[b]
Cream soup with shiitake powder (%)				
0	78.65±0.03[b]	0.50±0.06[d]	2.31±0.28[ns]	0.53±0.07[d]
25	79,53±0.57[ab]	0.97±0.04[c]	2.55±0.27	0.59±0.07[c]
50	79.28±0.18[ab]	1.22±0.07[b]	2.59±0.06	0.69±0.01[b]
100	80.33±0.04[a]	1.34±0.04[a]	2.58±0.06	1.04±0.01[a]

[1)]All values are mean±SD (n=3).
[2)]Means with different superscript letters ([a-d]) in the same column are significantly different (p<0.05) by Duncan's multiple range test.
[3)]ns, not significant.

https://doi.org/10.11002/fsp.2025.32.4.639

amino acids accounted for 12.80%.

The crude fat contents of shiitake mushroom powder and wheat flour used in the soup were 0.43% and 0.48%, respectively, showing that there was no significant difference in the crude fat contents of shiitake mushrooms and wheat flour. The crude fat of the control group without shiitake mushroom powder was 2.31%, and the crude fat of the soup manufactured by adding 25-100% shiitake mushroom powder was 2.55-2.59%, showing no significant differences were observed among the groups of shiitake mushroom powder added. This is thought to be because the same amount of butter was added during the manufacturing process.

The ash content of the soup was the lowest at 0.53% in the control group where no shiitake mushroom powder was added, and increased to 0.59% in the soup with 25% shiitake mushroom powder added compared to the control group. The ash contents of the soups manufactured by adding 50% and 100% shiitake mushroom powder were 0.69% and 1.04%, respectively, confirming that the amount of ash increased in proportion to the shiitake mushroom powder content. The ash contents of the shiitake mushroom powder and wheat flour used in this experiment were 0.69% and 0.19%, respectively, indicating that the shiitake mushroom powder contained more ash than the wheat flour. Accordingly, it is thought that the ash content of the soup with 25-100% shiitake mushroom powder added instead of wheat flour was higher than that of the control group. In a previous study (Cha et al., 2004), the results of analyzing the minerals contained in shiitake mushrooms using an atomic absorption spectrometer showed that sodium content was the highest at 5.04 g/100 g, followed by potassium, calcium, phosphorus, magnesium, iron, zinc, manganese, and copper, which confirmed that shiitake mushrooms contain various minerals.

3.2. pH, total acidity, and soluble solids

The pH, total acidity, soluble solids, and viscosity of soups prepared with different amounts of shiitake mushroom powder are shown in Table 3. The pH of shiitake mushrooms and flour were 5.85 and 6.31, respectively, indicating that the pH of shiitake mushrooms was lower than that of flour. The pH of the soup was highest in the control group without shiitake mushroom powder, measuring 6.10. In soups prepared with 25-100% shiitake mushroom powder, the pH decreased from 5.95 to 5.71, indicating a proportional decrease in pH with increasing amounts of shiitake mushroom powder. The total acidity of shiitake mushrooms and flour was 0.20% and 0.01%, respectively, indicating that the total acidity of shiitake mushrooms was higher than that of flour. In the case of total acidity, it was 0.01% in the control group without added shiitake mushroom powder, and increased in proportion to the amount of shiitake mushroom added, from 0.08 to 0.20% in the soup with 25-100% added shiitake mushroom powder.

In the study by Yun et al. (2020), the pH of the control group without added shiitake mushroom powder was 6.27, and the pH of the yanggaeng with 1-5% added shiitake mushroom powder significantly decreased from 6.17 to 5.74 depending on the amount of shiitake mushroom powder

Table 3. pH, total acidity and soluble solids content of shiitake powder, wheat flour, and cream soup prepared with different amount of shiitake powder

Sample	Measurements		
	pH	Total acidity (%)	Soluble solids content (°Brix)
Shiitake powder	4.50±0.01[1)b2)]	0.35±0.01[a]	31.50±0.01[a]
Wheat flour	6.60±0.01[a]	0.0036±0.01[b]	19.60±0.01[b]
Cream soup with shiitake powder (%)[1)]			
0	6.10±0.01[a]	0.01±0.01[d]	3.90±0.01[d]
25	5.95±0.01[b]	0.08±0.01[c]	6.03±0.06[c]
50	5.87±0.01[c]	0.13±0.01[b]	6.67±0.06[b]
100	5.71±0.01[d]	0.20±0.01[a]	7.67±0.06[a]

1)All values are mean±SD (n=3).
2)Means with different superscript letters (a-d) in the same column are significantly different ($p<0.05$) by Duncan's multiple range test.

added, showing a similar trend to this study. According to a previous study (Seo et al., 1997), the total organic acid content of shiitake mushrooms was 1.4-3.6%, and malic acid, citric acid, and oxalic acid were reported to be particularly abundant. In the study by Gao et al. (2020), the organic acid content of shiitake mushrooms was analyzed by HPLC and it was confirmed that it contained acetic acid (20.64 mg), malic acid (18.81 mg), succinic acid (11.31 mg), fumaric acid (4.23 mg), tartaric acid (2.79 mg), citric acid (2.26 mg), and ascorbic acid (1.80 mg) in that order per 1 g of dry weight. It is thought that the pH decreased and the total acidity increased in proportion to the content of shiitake mushroom powder added to the soup due to the influence of these organic acids contained in shiitake mushrooms.

The soluble solids content of shiitake mushrooms and wheat flour was 0.60 and 0.53 Brix, respectively, confirming that the soluble solids of shiitake mushrooms were higher than those of wheat flour. The soluble solids of the soup manufactured without adding shiitake mushroom powder was 3.90 Brix, and increased to 6.03 Brix in the soup with 25% shiitake mushroom powder added. The soluble solids of the soup manufactured with 50% and 100% shiitake mushroom powder added were 6.67 Brix and 7.67 Brix, respectively, and the content of soluble solids increased as the amount of shiitake mushroom powder added increased. A previous study (Gao et al., 2020) reported that shiitake mushrooms contain soluble sugars and sugar alcohols such as trehalose, mannitol, and arabitol. Therefore, it is thought that the content of soluble solids in the soup increased as the amount of shiitake mushroom powder added increased.

3.3. Viscosity

The viscosity of the soup manufactured by adding 25-100% shiitake mushroom powder decreased in proportion to the amount of shiitake mushroom powder added (Table 4). That is, the viscosity was 8,149.17 centipoise (cP) in the control group without shiitake mushroom powder, and 7,406.40 cP in the soup manufactured by adding 25% shiitake mushroom powder, which was approximately 9.11% less than the control group. The viscosity of the soup manufactured by adding 50% and 100% shiitake mushroom powder was 6,441.67 and 3,530.83 cP, which was 20.95% and 56.67% less than the control group, respectively.

Viscosity is a very important characteristic that determines the fluidity of porridge, and is affected by the amount of rice added, mixing ratio, starch particle size, starch content, amount of water added, cooking time, and temperature, and is inversely proportional to the moisture content (Manohar et al. 1998). In a previous study, when porridge was made by adding chaga mushroom powder (Hwang, 2020) and sesame seed powder (Tae et al., 2016), the viscosity decreased compared to the control group as the amount of these auxiliary ingredients increased, obtaining results similar to this study. The decrease in viscosity due to the increase in the content of auxiliary ingredients when making porridge is a phenomenon that occurs because the content of rice flour relatively decreases as the auxiliary ingredients are added, thereby reducing the gelatinization of rice starch. In addition, it is thought that the starch content is lower than that of rice when making powder such as shiitake mushrooms, so the viscosity does not increase during the process of making soup.

3.4. Color

The color of the soup made by adding shiitake mushroom powder, wheat flour, and shiitake mushroom powder used in making the soup is presented in Table 5. In the case of brightness, the brightness was 94.68 for the wheat flour and 74.33 for the shiitake mushroom powder, showing a higher brightness of the flour, which was closer to white than the shiitake mushroom. The brightness of the soup was the highest at 58.28 in the control group without the addition of shiitake mushroom powder, and the brightness decreased from 57.74 to 45.19 as the shiitake mushroom powder was added from 25 to 100%. The redness was 1.66 for the

Table 4. Viscosity of cream soup prepared with different amount of shiitake powder

Shiitake powder (%)			
0	**25**	**50**	**100**
8,149.17±736.57[1)a2)]	7,406.40±85.13[b]	6,441.67±301.70[cd]	3,530.83±152.03[d]

[1)]All values are mean±SD (n=3).
[2)]Means with different superscript letters ([a-d]) in the same row are significantly different ($p<0.05$) by Duncan's multiple range test.

https://doi.org/10.11002/fsp.2025.32.4.639

Table 5. Color values of shiitake powder, wheat flour and cream soup prepared with different amount of shiitake powder

Sample	Measurements		
	L	a	b
Shiitake powder	74.33±0.25$^{1)b2)}$	1.66±0.02^{a}	8.20±0.21^{a}
Wheat flour	94.68±0.59^{a}	-0.58±0.03^{b}	6.74±0.22^{b}
Cream soup with shiitake powder (%)$^{1)}$			
0	58.28±0.16^{a}	-0.77±0.0^{3}c	3.75±0.05^{c}
25	57.74±0.12^{b}	1.73±0.04^{b}	4.73±0.17^{b}
50	48.66±0.12^{c}	2.25±0.06^{a}	5.12±0.21^{ab}
100	45.19±0.67^{d}	2.35±0.11^{a}	5.18±0.22^{a}

1)All values are mean±SD (n=3).
2)Means with different superscript letters ($^{a-d}$) in the same column are significantly different (p<0.05) by Duncan's multiple range test.

shiitake mushroom powder, which was higher than -0.58 for the wheat flour, and the yellowness was 8.20 for the shiitake mushroom powder, which was higher than 6.74 for the wheat flour. The redness of the manufactured soup was -0.77 in the control group without added shiitake mushroom powder, and 1.73-2.35 in the soup with 25-100% added shiitake mushroom powder, indicating that the redness increased as the amount of shiitake mushroom powder increased. The yellowness was the highest at 3.75 in the control group without added shiitake mushroom powder, and 4.73-5.18 in the soup with 25-100% added shiitake mushroom powder, confirming that the yellowness increased compared to the control group, and the yellowness increased in proportion to the shiitake mushroom powder content.

In a previous study, when freeze-dried shiitake mushroom powder was added at 4-12% instead of wheat flour in the manufacture of cookies (Kim and Chung, 2017) and hot-air-dried shiitake mushroom powder was added at 1-7% compared to rice flour in the manufacture of rice cakes (Cho et al., 2002), the brightness decreased in proportion to the amount of shiitake mushrooms added, while the redness and yellowness increased, showing a similar trend to that of this study. The shiitake mushroom powder is light brown, and when added to processed products, demonstrate decrease the brightness and increase the redness and yellowness compared to the control group.

3.5. Total polyphenol and flavonoid contents

Fig. 1 presents the results of measuring the total polyphenol and total flavonoid contents in the soup formulated with added shiitake mushroom powder. The total polyphenol content of the soup prepared without adding shiitake mushroom powder was 8.52 μg GAE/g, and the total polyphenol content of the soup also increased in proportion to the amount of shiitake mushroom powder added. The soup with 25% shiitake mushroom powder added showed 17.77 μg GAE/g, and the soups with 50% and 100% shiitake mushroom powder added showed 67.47 and 131.18 μg GAE/g, respectively, which was a total polyphenol increase of 2.09-15.40 times compared to the control group without shiitake mushroom powder. In the case of total flavonoid content, the control group without shiitake mushroom powder added showed the lowest at 2.57 μg CE/g, and increased in proportion to the amount of shiitake mushroom powder added. In other words, the total flavonoid content of the soup with 25-100% shiitake mushroom powder added increased to 9.52-33.52 μg CE/g, which was a total flavonoid content increase of 3.70-13.04 times compared to the control group without shiitake mushroom powder added.

In a previous study, in the case of yanggaeng with 1-5% shiitake mushroom powder instead of red bean paste (Yun et al., 2020), the total polyphenol content of the control group was 0.08 mg/mL, but in yanggaeng with 1-5% shiitake mushroom powder, the total polyphenol content increased by 3.25-5.13 times compared to the control group. In addition, in rice cookies manufactured with 4-12% shiitake mushroom powder (Kim and Chung 2017), the total polyphenol content of the control group was the lowest at 9.78 mg GAE/100 g of sample, but as the amount of shiitake mushroom added increased, the total polyphenol content increased to

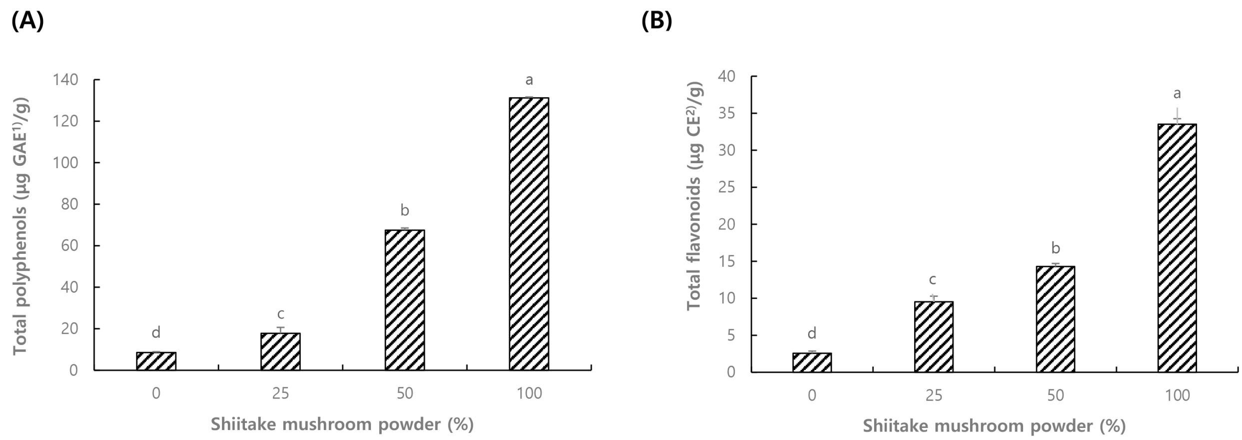

Fig. 1. Total polyphenol (A) and total flavonoid (B) contents of the cream soup prepared with different amount of shiitake mushroom powder. All values are mean±SD (n=3). [1)]GAE, gallic acid equivalent. [2)]CE, catechin equivalent. Means with different superscript letters ([a-d]) in the same row are significantly different ($p<0.05$) by Duncan's multiple range test.

13.51-18.18 mg GAE/100 g, which was 1.38-1.86 times compared to the control group, showing a similar trend to this study.

Shiitake mushrooms contain polyphenol compounds such as catechin, epicatechin, trans-ferulic acid, rosmaric acid, and myricetin, and the polyphenol content is reported to be higher in polar solvent extracts (Bristy et al., 2022; Han et al., 2015). According to a previous study (Han et al., 2015), the ethanol extract showed 2.12 mg GAE/g extract, and the acetone and ethyl acetate extracts showed 1.81 mg and 1.53 mg, respectively. In the case of total flavonoids contained in shiitake mushrooms, the ethyl acetate extract showed 1.18 mg QE/g extract, and the acetone and ethanol extracts showed 1.08 mg and 0.35 mg, respectively. It is reported that shiitake mushrooms contain more non-flavonoid polyphenol compounds, and the main polyphenols are known to exist in the form of phenolic acids (Ferreira et al., 2009).

3.6. Antioxidant activity

The antioxidant activity of the soup was measured and is presented in Fig. 2. The DPPH radical scavenging activity of the manufactured soup was 19.42% in the control group, and increased to 25.06%, 39.25%, and 49.93% in the soups prepared by adding 25, 50, and 100% shiitake mushroom powder, respectively. This represents a 1.29 to 2.57-fold increased DPPH radical scavenging activity compared to the

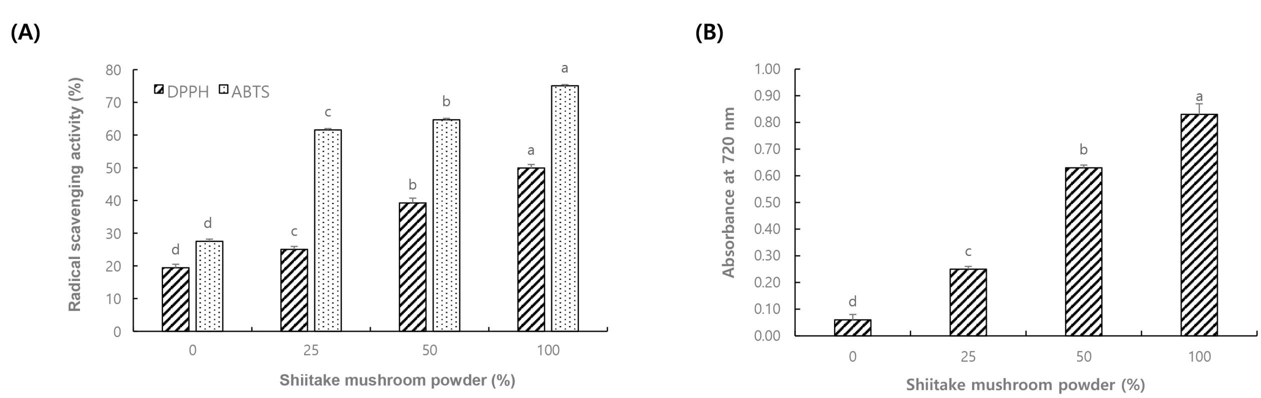

Fig. 2. Antioxidant activities of cream soup prepared with different amount of shiitake mushroom powder, measured by DPPH and ABTS radical scavenging assays (A) and reducing power assay (B). All values are mean±SD (n=3). Means with different superscript letters ([a-d]) on the bars are significantly different ($p<0.05$) by Duncan's multiple range test.

https://doi.org/10.11002/fsp.2025.32.4.639

control. ABTS radical scavenging activity was the lowest at 20.78% in the control group, and increased to 61.58-75.08% as the amount of shiitake mushroom powder added to the soup increased from 25 to 100%, which was a 2.24-2.73-fold increase compared to the control group. The reducing power measured by absorbance at 700 nm was the lowest at 0.06 in the control group without shiitake mushroom powder, and increased from 0.25 to 0.83 as the amount of shiitake mushroom powder added increased from 25 to 100%. Based on the above results, it was confirmed that when the soup was made by adding shiitake mushroom powder, the antioxidant activity increased in proportion to the amount of shiitake mushroom powder added compared to the control group.

In addition to polyphenols and flavonoids contained in shiitake mushrooms, polysaccharides such as lentinan and β-glucan are known to inhibit free radical formation and increase antioxidant enzyme activity (Qian et al., 2018). In a previous study (Lee et al., 2021), when 25-75% shiitake mushroom concentrate was added instead of eggs in the manufacture of pound cake, DPPH and ABTS radical scavenging activities increased in proportion to the added shiitake mushroom concentrate, and increased by 9.00-63.20% and 32.16-55.81%, respectively, compared to the control group to which no shiitake mushroom concentrate was added. In a study by Yun et al. (2020), when 1-5% shiitake mushroom powder was added instead of red bean paste in the manufacture of yanggaeng, DPPH and hydroxyl radical scavenging activities increased compared to the control group, showing a similar trend to this study.

4. Conclusions

This study aimed to explore the functional properties of shiitake mushrooms by substituting wheat flour with freeze-dried shiitake mushroom powder in a cream soup recipe at inclusion levels of 25-100%. The resulting soups were evaluated for physicochemical quality attributes, bioactive compound content, and antioxidant activity. Compared to the control, soups containing shiitake powder exhibited increased moisture content, with the 100% substitution sample showing the highest moisture level. Ash and crude protein contents rose proportionally with increasing levels of shiitake powder. Soluble solids, total acidity, and viscosity increased proportionally, while pH decreased as the amount of shiitake powder increased. Color analysis revealed a proportional decrease in lightness and significant increases in redness and yellowness with higher substitution levels. Total polyphenol and flavonoid contents, along with antioxidant activity, increased proportionally with shiitake powder addition, showing a strong correlation between bioactive compound content and antioxidant capacity. However, full replacement (100%) of wheat flour with shiitake powder resulted in a significant viscosity reduction, approximately 56.67% lower than the control. Therefore, substitution levels of 25-50% are recommended to balance desirable physiological activity and antioxidant benefits with acceptable soup viscosity.

Funding

None.

Acknowledgements

None.

Conflict of interests

The authors declare no potential conflicts of interest.

Author contributions

Conceptualization: Hwang ES. Methodology: Hwang ES, Son H. Formal analysis: Hwang ES, Son H. Validation: Hwang ES. Writing - original draft: Hwang ES. Writing - review & editing: Hwang ES.

Ethics approval

This article does not require IRB/IACUC approval because there are no human and animal participants.

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