

Quality characteristics and antioxidant activities of mung bean starch gel containing eggplant (*Solarium melongena* L.) peel powder

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Summary. Eggplant is a good source of dietary fiber, minerals, and vitamins and has been reported to show antibacterial, anticancer, and antitumor effects. Eggplant peel is richer in the antioxidant anthocyanin than is its flesh. In this study, mung bean starch gels containing different concentrations of freeze-dried eggplant peel powder (EPP) – control (0% EPP), EPP1 (1% EPP), EPP3 (3% EPP), EPP5 (5% EPP), and EPP7 (7% EPP) – were prepared to examine their quality characteristics and antioxidant activities. The pH significantly decreased with increasing content of EPP, and EPP7 showed the lowest pH value (4.94). With the addition of EPP, *L* (lightness) decreased, while *a* (redness) and *b* (yellowness) increased. In texture analysis, hardness and chewiness of the mung bean starch gels decreased as the EPP content increased, while the springiness and fracturability did not significantly differ between control and other starch gels containing EPP. Syneresis increased during the storage period. On the 5th day, syneresis of EPP7 was the lowest (13.49%), while that of the control was the highest (17.37%). Total polyphenol and flavonoid contents, 2, 2'-azino-bis-3-ethylbenzothiazoline-6-sulphonic acid (ABTS) radical, and 2, 2'-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activities significantly increased with increments in the content of EPP. In sensory evaluation, using a 7-point scaling method, EPP5 showed the highest sensory preference scores in color, flavor, springiness, and overall acceptability. The results of this study suggest that mung bean starch gel prepared with 5% EPP is the most suitable product based on its quality characteristics and antioxidant activity.

Key words: antioxidant property, eggplant peel, mung bean starch gel, quality characteristics, sensory evaluation

Introduction

Starch gel, a traditional Korean food, is made by the following process. First, starch and water are mixed, and then heated until a viscous material is created. The mixture is allowed to cool to form a gel. Starch gels are traditionally made as *dotorimuk* (acorn starch gel), *memilmuk* (buckwheat starch gel), and *cheongpomuk* (mung bean starch gel) (1). Mung bean starch gel has unique properties, such as a high gel forming ability compared to a low starch content, a smooth surface,

high elasticity, and softness (2). Due to its unique properties, mung bean starch gel looks similar to conventional jelly/gelatin, but differs significantly from jelly in terms of other qualities. As a carbohydrate food source, mung bean starch gel is low in calories (37 kcal per 100 g mung bean starch gel) (1). In addition, mung bean contains vitexin, triacontanol, β -sitosterol, and stigmasterol, which have been reported to reduce fat accumulation (3). Recently, mung bean starch gel has emerged as a low-calorie diet product. On the other hand, jelly consists of gelatin (an incomplete protein)

and is rich in calorie content due to the large amounts of sugar added during the production process (4, 5).

Lately, the relationship between diet and diseases, such as cerebrovascular disease, heart disease, diabetes, etc., has received much attention (6). There is a great demand for low-calorie foods supplemented with natural ingredients that are beneficial to health. In response to consumer demand, recent studies have examined the qualitative properties of mung bean starch gel supplemented with functional food materials that are considered to have health benefits, such as ginkgo nut powder (5), peach seed powder (1), *gugija* infusion (7), and black ginseng extract (8).

Eggplant (*Solanum melongena* L.), an annual plant belonging to the *Solanaceae* family, was first domesticated in India and is widely cultivated throughout the torrid and temperate zones in South Korea. Eggplant contains considerable amounts of minerals, vitamins, and polyphenols, which have strong antioxidant properties (9). Additionally, eggplant is also a rich source of dietary fiber (9). In particular, eggplant peel has better antioxidant activity than eggplant flesh, as more anthocyanins are present in eggplant peel (10–12). Delphinidin-3-rutinoside (D3R) and nasunin (NAS) are the principal components of anthocyanins in eggplant peel (13). Nasunin has the strongest antioxidant activity among the anthocyanins (14). Several studies have demonstrated that eggplant peel has medicinal benefits due to its anti-inflammatory, anti-cancer, and antibiotic effects, and can be used for treating type 2 diabetes and lowering blood pressure (15–18). Furthermore, eggplant peel is also reported to protect cells from DNA damage and helps to maintain healthy skin (19, 20). Eggplant is used as a natural supplement

in *sulgidduk* (rice cake) (21) and soy milk (22); however, it has rarely been used as a commercial natural food supplement.

In order to assess the consumer demand for functional health foods, mung bean starch gels supplemented with eggplant peel were prepared with different ratios of freeze-dried EPP. The aim of this study was to evaluate the quality characteristics, antioxidant activity, and sensory properties of mung bean starch gels supplemented with the optimal concentration of EPP.

Materials and methods

Materials

Eggplants (Gwangju, Gyeonggi, Korea) were purchased in September 2015 and its peels were obtained using a peeler, freeze-dried using freeze dryer (FD8508, Ilshin Bio Co. LTD., Gyeonggi, Korea), ground using a high speed grinder (CRT-04, Hungchuan Machinery Enterprise, Taipei, Taiwan), and passed through a 40 mesh sieve. Mung bean starch and refined salt were purchased from Chung-En F&B (Gyeonggi-do, Korea) and CJ Cheiljedang Co. Ltd. (Seoul, Korea), respectively.

Preparation of mung bean starch gel

Mung bean starch gel was prepared using Hwang & Nhuan's manufacturing method with slight modifications (23). The mixture ratios are presented in Table 1. A schematic representation of the preparation process for mung bean starch gels is shown in Fig. 1. EPP was added in concentrations of 0% (control), 1%, 3%, 5%, and 7%, based on the mung bean starch weight.

Table 1. Formulation for mung bean starch gel containing different concentrations of eggplant peel powder.

Ingredients	Mung bean starch gel ¹⁾				
	Control	EPP1	EPP3	EPP5	EPP7
Mung bean starch	100	99	97	95	93
Eggplant peel powder	0	1	3	5	7
Water	800	800	800	800	800
Salt	4	4	4	4	4

¹⁾ Control, EPP1, EPP3, EPP5, and EPP7 were prepared with 0%, 1%, 3%, 5%, and 7% replacement of mung bean starch with eggplant peel powder, respectively.

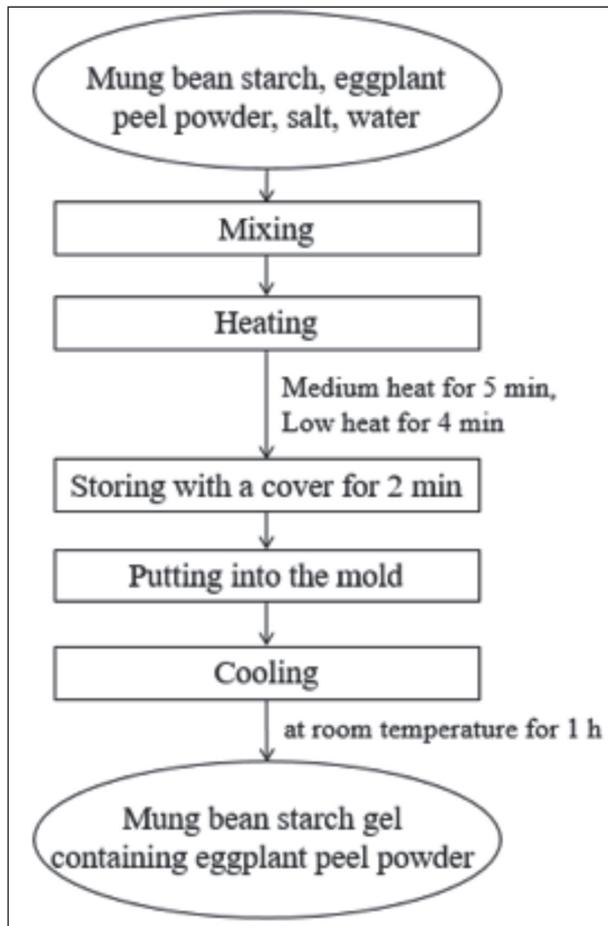


Figure 1. Flow chart of making mung bean starch gels supplemented with eggplant peel powder.

All other materials were added in the same amounts to all formulations. Each formulation was made by first mixing mung bean starch, EPP, and salt, and then adding 800 g of water. The mixture was constantly stirred over a medium heat for 5 min, followed by a low heat for 4 min. It was then left to stand without heating for 2 min, poured into a mold (12 × 19 × 5 cm), and cooled at 25°C for 60 min.

Determination of moisture content

The moisture content of mung bean starch gel was measured in triplicate using a moisture analyzer (MB35, OHAUS, Zurich, Switzerland). An amount of 0.5 g mung bean starch gel was placed in an aluminum dish at 105°C and continuously weighed until a constant weight was obtained for all samples. The

moisture content was calculated by using the following equation:

$$\text{Moisture content (\%)} = \frac{\text{wet weight} - \text{weight after drying}}{\text{wet weight}} \times 100$$

Determination of pH

Ten grams of mung bean starch gel sample was mixed with 90 mL of distilled water. Each mixture was homogenized using a high pressure homogenizer (Unidrive 1000D, Ingenieurburo CAT M. Zipperer GmbH, Staufen, Germany) for 1 min, and then left to stand for 30 min at 25°C. The pH of the mung bean starch gel was measured in triplicate using a pH meter (SP-701, Suntex Instruments Co. Ltd., Taipei, Taiwan)

Color measurement

The surface color of the mung bean starch gel was measured with a chromameter (CR-400, Konica Minolta, Osaka, Japan). *L* (lightness), *a* (redness), and *b* (yellowness) values were measured in triplicate. A white tile (*L*: 94.20, *a*: 0.46, *b*: 2.35) was used for calibration. The total color difference (ΔE) was calculated and compared with each sample, as follows:

$$\Delta E = \sqrt{(L_{\text{sample}} - L_{\text{standard}})^2 + (a_{\text{sample}} - a_{\text{standard}})^2 + (b_{\text{sample}} - b_{\text{standard}})^2}$$

Texture profile analysis (TPA)

The gel samples were cut into a fixed size (4 × 4 × 2 cm). The texture values of the eggplant peel–mung bean starch gel were measured in triplicate using a rheometer (Compac-100II, Sun Scientific Co., Tokyo, Japan). TPA values were determined by means of the two-bite compression test. Hardness, springiness, co-

Table 2. Operating conditions for rheometer.

Type	TPA (Texture Profile Analysis) test
Cylinder probe	No.11
Sample size	4 × 4 × 2 cm
Table speed	60 mm/min
Distance	50%
Max. weight	10 kg

hesiveness, chewiness, adhesiveness, and fracturability were calculated by the TPA curve. The operating conditions of rheometer are given in Table 2.

Syneresis during storage

Mung bean starch gel sample was placed in a petri dish and stored for 5 days at 4°C. The sample was weighed in triplicate every 24 h and syneresis was calculated using the following equation:

$$\text{Syneresis (\%)} = \frac{\text{weight of water separated}}{\text{weight of gel}} \times 100$$

Evaluation of antioxidant activity

Preparation of mung bean starch gel extracts

Each sample of mung bean starch gel was freeze-dried, powdered, and passed through a 40 mesh sieve. Ten milliliters of distilled water was added to 1 g of mung bean starch gel powder and extracted for 24 h at 25°C in a shaking incubator (Universal 32R, Hettich, Tuttlingen, Germany). The sample extract was centrifuged at 4°C and 3,000 rpm for 10 min and filtered through a filter paper (Whatman no. 1, GE Healthcare, Little Chalfont, UK).

Determination of total polyphenol content

The total polyphenol content of mung bean starch was analyzed by the Folin-Ciocalteu method with some modifications (24). Ten microliters of the starch gel extract was added into a test tube containing 790 µL of distilled water. Then, 50 µL of 0.9 mol/L Folin-Ciocalteu's reagent (cat. # 96703-8130, Junsei Chemical Co., Ltd, Tokyo, Japan) was added and stirred vigorously by vortexing. Finally, 150 µL of 20% sodium carbonate solution (cat. # 1.93211.0500, Merck, Germany) was added, stirred vigorously, and left to stand in the dark at 25°C for 2 h. The absorbance was measured in triplicate at 700 nm using a spectrophotometer (Infinite 200PRO, Tecan, Männedorf, Switzerland). Gallic acid (cat. # 8.42649.0025, Merck, Germany) was used as the standard. The results were expressed as µg gallic acid equivalent (GAE) per mg of mung bean starch gel (dry basis).

Determination of total flavonoid content

The total flavonoid content in the mung bean starch gel extracts was determined by the aluminum

chloride colorimetric procedure (25). Five hundred microliters of the extract was mixed with 500 µL of 2% aluminum chloride methanolic solution (cat. # 9G4082, Junsei Chemical Co., Ltd, Japan) and vigorously stirred by vortexing. It was left to stand in the dark at 25°C for 15 min, after which the absorbance was measured in triplicate at 450 nm using a spectrophotometer. Quercetin (cat. # 117-39-5, Sigma, St Louis, MO, USA) was used as the standard. The results were expressed as µg quercetin equivalent (QE) per mg of mung bean starch gel (dry basis).

Evaluation of antioxidant activity through DPPH radical scavenging activity

The DPPH radical scavenging capacity of the extract was measured as described previously (26), with slight modifications. Each extract was diluted with distilled water to obtain five different concentrations (20–100 mg/mL). Each diluted extract (100 µL) was mixed with 100 µL of 0.2 mM DPPH solution (cat. # 1898-66-4, Sigma, St Louis, MO, USA), and vigorously stirred by vortexing. It was left to stand in the dark at 25°C for 30 min. The absorbance was measured at 520 nm using a spectrophotometer. The results were presented as IC₅₀, which was defined as the concentration of the extract required to inhibit 50% of DPPH radicals. The radical scavenging capacity and IC₅₀ were calculated using the following equations:

$$\text{Radical scavenging capacity (\%)} = \left[1 - \left(\frac{\text{O.D of Sample}}{\text{O.D of Control}} \right) \right] \times 100$$

$$\text{IC}_{50} (\mu\text{g/mL}) = \frac{50 - b}{a}$$

where a is a slope and b is the y-intercept in a radical scavenging capacity–concentration line graph. All calculations were carried out in triplicate.

Evaluation of antioxidant activity as determined by ABTS radical scavenging activity

ABTS radical scavenging activity was measured according to the method of Choi *et al.* (27), with slight modifications. Briefly, ABTS radical cation was produced by adding 7.4 mM ABTS (cat. # 30931-67-0, Sigma, St Louis, MO, USA) to 2.45 mM potassium persulfate solution (cat. # 7727-21-1, Sigma, St Louis, MO, USA), and

the mixture was left to stand in the dark at 25°C for 12 h. The blue–green ABTS radical cation was diluted with distilled water until absorbance of 1.47 at 414 nm was reached. Ten microliters of the extract was added to 200 μ L of diluted ABTS radical solution. The decrease in absorbance was monitored at 414 nm after 60 min. The ABTS radical scavenging activity was expressed as IC₅₀, which was defined as the concentration of the extract required to inhibit 50% of ABTS radicals. The radical scavenging capacity and IC₅₀ were calculated in the same manner as described earlier for DPPH-scavenging capacity and IC₅₀.

Sensory evaluation

Twenty trained panelists were selected. Each mung bean starch gel sample was cut into a fixed size (1 × 1 × 1 cm) and each cut sample was marked with random 3-digit numbers. The panelists evaluated mung bean starch gel samples for color, flavor, moisture, taste, springiness, and overall acceptability on a 7-point scale ranging from very desirable (7) to very undesirable (1). The panelists rinsed their mouths before tasting each sample to minimize any residual effects (28).

Statistical analyses

All measurements were determined in triplicate. The results were analyzed by one-way ANOVA using SPSS statistical program (ver. 12.0, SPSS, Chicago, IL, USA), and the data were expressed as the mean values and standard deviation (mean \pm SD). Significant differences were analyzed by Duncan's multiple range test ($p < 0.05$).

Results and discussion

Moisture content in mung bean starch gels

Changes in the moisture content of mung bean starch gel supplemented with EPP are shown in Table

3. The control had a moisture content of 87.08% and the gel samples with EPP showed a moisture content in the range of 85.43%–86.33%. The moisture content in mung bean starch gels decreased slightly with the addition of EPP, and it was not significantly different from the control. A similar result was also observed in a study by Hwang and Thi (23), in which the moisture content of mung bean starch gel containing aronia powder was slightly decreased as the level of the added flour increased, although it was not significantly different from the control (to which no aronia powder was added). The moisture content values are also similar to the results of a study by Park and Kim (29), in which the moisture content of mung bean starch gel with added white lotus root powder was in the range of 86.78%–88.58%. However, it differed from the results of a study by Cha *et al.* (30), in which the moisture content of mung bean starch gel supplemented with carrot, spinach, and mulberry juice had higher moisture content values (in the range of 90.60%–90.90%). The differences in moisture content in mung bean starch gel was possibly due to various factors, such as the ingredients, the amount of water added, or the heating time.

pH characteristics of mung bean starch gels

Table 3 shows the effect of adding eggplant peel to mung bean starch gels on pH values. The pH decreased significantly with increasing amounts of EPP ($p < 0.001$). Furthermore, the pH of EPP7 had the lowest pH value (4.94; $p < 0.001$). The pH of EPP was 4.53, and the control had a pH of 5.95. Therefore, the decrease in pH in the mung bean starch gels can be attributed to the added EPP, which lowers pH value. However study by Choi (31) was different with our results. It showed that the pH values of mung bean starch gel increased (in the range of 3.80–4.48) with

Table 3. Moisture content and pH of mung bean starch gels containing different concentrations of eggplant peel powder.

Content	Mung bean starch gel ¹⁾					F-value ²⁾
	Control	EPP1	EPP3	EPP5	EPP7	
Moisture (%)	87.08 \pm 0.76	86.33 \pm 0.50	85.68 \pm 0.68	85.60 \pm 0.65	85.43 \pm 1.06	2.46 ^{NS}
pH	5.95 \pm 0.05 ^{a3)}	5.49 \pm 0.04 ^b	5.21 \pm 0.02 ^c	5.07 \pm 0.02 ^d	4.94 \pm 0.02 ^e	447.22 ^{***}

¹⁾ See the legend of the Table 1; ²⁾ The F-value corresponds to a significant effect of the eggplant peel powder (NS represents Not Significant, *** $p < 0.001$); ³⁾ Different letters in the same row indicate statistically significant difference.

the addition of persimmon powder (pH of persimmon powder was 6.03). Therefore, the pH of mung bean starch gel can be influenced by the pH of the natural supplement/ingredient that is added.

Color properties of mung bean starch gels

The color characteristics of the eggplant peel–mung bean starch gel samples are shown in Table 4. The cross-section photographs of eggplant peel–mung bean starch gel are shown in Fig. 2. With the addition of EPP, lightness (*L*) decreased. Furthermore, the control showed the highest *L* value of 44.54 ($p < 0.01$). This result is similar to those of studies on mung bean starch gel supplemented with different amounts of black garlic extract (32) and green tea powder (33). Redness (*a*) and yellowness (*b*) significantly increased as the EPP content increased ($p < 0.001$). Our results are consistent with the results of the study by Choi *et al.* (21), in which the lightness of *sulgidduck* decreased, while redness and yellowness increased with the addition of eggplant powder. The overall color difference in EPP7 was the highest (57.63) and there were no significant differences between EPP1, EPP3, and EPP5. In a study by Choi (31), the color values of mung bean starch gel were attributed to the color and type of ingredients added. Similarly, in the present study, the color values of mung bean starch gel can be attributed to the anthocyanin pigments in EPP.

Texture analysis

Table 5 shows the effect of EPP on the texture properties of mung bean starch gel. The hardness of mung bean starch gel significantly decreased with

increasing amounts of EPP substitution ($p < 0.001$). In the initial stages, gelation of the starch depends on amylose, which leaks into the water upon heating. Subsequently, gelation depends on the remaining amylopectin in starch. It has been reported that the hardness of mung bean starch gel increases with amylose levels, as determined using starch iodine tests (34, 35). In addition, Na *et al.* (36) have found a decrease in the hardness of mung bean starch gel with increasing levels of non-starch components, such as tannin and dietary fiber. Cha *et al.* (30) have also suggested that the hardness of mung bean starch gels decreased with addition of carrot, spinach, and mulberry juice, due to the pigments and phytochemicals in carrot, spinach, and mulberry juice, which inhibit the gelation and retrogradation in starch gels. Thus, the decrease in hardness observed in this study could be due to the tannin, dietary fiber and pigment present in EPP, which inhibited gelation. Previous studies have also reported similar results (29, 37). Springiness was not significantly different between the control and starch gels containing EPP, which is similar to the results of the study by Son *et al.* (38), in which springiness was not significantly different between the control and hamcho powder-added gels. The chewiness of the mung

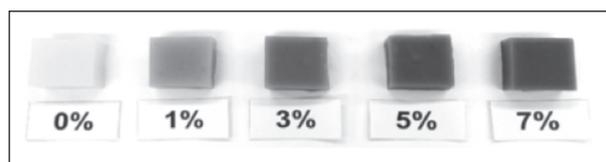


Figure 2. Photograph of mung bean starch gels with different concentrations of eggplant peel powder

Table 4. Color values of mung bean starch gels containing different amounts of eggplant peel powder.

Color values	Mung bean starch gel ¹⁾					F-value ²⁾
	Control	EPP1	EPP3	EPP5	EPP7	
L ³⁾	44.54 ± 2.42 ^{a6)}	40.70 ± 0.74 ^b	40.44 ± 1.86 ^b	39.86 ± 1.44 ^b	36.60 ± 0.18 ^c	10.04 ^{**}
a ⁴⁾	-0.47 ± 0.23 ^c	-0.81 ± 0.10 ^d	-0.47 ± 0.11 ^c	0.06 ± 0.01 ^b	0.39 ± 0.01 ^a	47.88 ^{***}
b ⁵⁾	-6.65 ± 0.86 ^c	-2.27 ± 0.13 ^d	1.26 ± 0.15 ^c	2.40 ± 0.18 ^b	4.43 ± 0.09 ^a	349.75 ^{***}
E	50.48 ± 2.54 ^c	53.71 ± 0.75 ^b	53.78 ± 1.86 ^b	54.34 ± 1.44 ^b	57.63 ± 0.18 ^a	7.73 ^{**}

¹⁾ See the legend of the Table 1; ²⁾ The Large F-value corresponds to a significant effect of the eggplant peel powder (** $p < 0.01$, *** $p < 0.001$);

³⁾ Degree of lightness (black 0 ↔ +100 white); ⁴⁾ Degree of redness (green -80 ↔ +100 red); ⁵⁾ Degree of yellowness (blue -80 ↔ +70 yellow);

⁶⁾ Different letters in the same row indicate statistically significant difference.

Table 5. Texture characteristics of mung bean starch gels containing different amounts of eggplant peel powder.

Texture characteristics	Mung bean starch gel ¹⁾					F-value ²⁾
	Control	EPP1	EPP3	EPP5	EPP7	
Hardness (kg/cm ²)	225.47 ± 4.64 ^{a3)}	202.00 ± 6.11 ^b	204.40 ± 8.48 ^b	186.17 ± 5.33 ^c	164.70 ± 2.56 ^d	46.40 ^{***}
Springiness (%)	101.07 ± 1.07	100.46 ± 2.01	99.59 ± 12.87	98.52 ± 1.40	95.05 ± 6.19	0.40NS
Cohesiveness (%)	54.80 ± 0.68 ^a	52.17 ± 2.69 ^a	48.03 ± 1.54 ^b	46.78 ± 3.57 ^b	55.80 ± 0.78 ^a	10.29 ^{**}
Chewiness (g)	449.93 ± 18.95 ^a	370.18 ± 10.10 ^b	356.32 ± 15.14 ^{bc}	340.32 ± 39.12 ^{bc}	327.05 ± 12.40 ^c	14.68 ^{***}
Fracturability (kg)	43.91 ± 0.73	37.92 ± 0.78	35.38 ± 9.82	35.05 ± 2.94	31.40 ± 1.88	2.94 NS
Adhesiveness (g)	-46.67 ± 5.77 ^a	-40.00 ± 17.32 ^a	-96.67 ± 15.28 ^b	-50.00 ± 10.00 ^a	-56.67 ± 11.55 ^a	9.44 ^{**}

¹⁾ See the legend of the Table 1; ²⁾ The F-value corresponds to a significant effect of the eggplant peel powder (NS represents Not Significant, ** $p < 0.01$, *** $p < 0.001$); ³⁾ Different letters in the same row indicate statistically significant difference.

bean starch gel significantly decreased with increasing amounts of EPP ($p < 0.001$). This is consistent with the results of a study by Park and Kim (29), in which the chewiness of the mung bean starch gel with added white lotus root powder significantly decreased as the level of white lotus root powder increased. Fracturability of samples was not significantly different among any of the mung bean starch gel formulations.

Syneresis during storage

Syneresis represents the structural stability of the starch gel and is affected by the kind and amount of substance added, the number of soaking days, mineral levels, storage temperature, and storage time. The syneresis during the storage of mung bean starch gel in

this study is shown in Table 6. After 5 days of storage, syneresis significantly decreased as the EPP content increased ($p < 0.001$). The control gels had the highest syneresis value (17.37%) and EPP7 had the lowest value (13.49%). This is believed to be due to the phenolic compounds in EPP that decreases contraction, leading to a stable structure of the starch gel. Syneresis of all the samples significantly increased as the storage time increased ($p < 0.001$). This is because contraction occurs in the structure of the starch gel and retrogradation of starch occurs during storage at 4°C. This is similar to the results of studies by Hwang and Thi (23) and Park and Kim (29). It has been reported that syneresis of starch gels was higher during storage at 4°C than that at 25°C, because the lower stor-

Table 6. Syneresis of mung bean starch gels with different amounts of eggplant peel powder during storage at 4°C.

Storage period (day)	Mung bean starch gel ¹⁾					F-value ²⁾
	Control	EPP1	EPP3	EPP5	EPP7	
0	0 ± 0.00 ^{F3)}	0 ± 0.00 ^F	0 ± 0.00 ^F	0 ± 0.00 ^F	0 ± 0.00 ^E	-
1	4.86 ± 0.19 ^{d4)E}	4.93 ± 0.35 ^{cdE}	5.46 ± 0.34 ^{bcE}	5.85 ± 0.03 ^{abE}	6.03 ± 0.40 ^{ad}	9.65 ^{**}
2	11.23 ± 0.31 ^D	10.61 ± 0.40 ^D	10.87 ± 0.33 ^D	10.75 ± 0.05 ^D	10.64 ± 0.29 ^C	2.08 ^{NS}
3	14.57 ± 0.14 ^{cC}	13.84 ± 0.44 ^{bc}	13.11 ± 0.11 ^{cC}	12.89 ± 0.17 ^{cC}	12.31 ± 0.34 ^{Bd}	31.44 ^{***}
4	16.33 ± 0.13 ^{ab}	15.38 ± 0.33 ^{bb}	14.12 ± 0.15 ^{bB}	13.93 ± 0.09 ^{bB}	13.08 ± 0.25 ^{dA}	112.77 ^{***}
5	17.37 ± 0.16 ^{aA}	16.29 ± 0.35 ^{ba}	14.84 ± 0.05 ^{cA}	14.44 ± 0.10 ^{dA}	13.49 ± 0.23 ^{cA}	165.99 ^{***}
F-value	4404.10 ^{***}	1074.45 ^{***}	2396.82 ^{***}	11486.08 ^{***}	1060.60 ^{***}	

¹⁾ See the legend of the Table 1; ²⁾ The F-value corresponds to a significant effect of the eggplant peel powder (NS represents Not Significant, ** $p < 0.01$, *** $p < 0.001$); ³⁾ Different letters in the same column indicate statistically significant difference; ⁴⁾ Different letters in the same row indicate statistically significant difference.

age temperature increased the retrogradation of starch and increased the contraction level in the structure of the starch gel (39). Na *et al.* (36) have shown that the syneresis of starch gels increased with an increasing number of soaking days. Additionally, Son and Lee have demonstrated that minerals, including salt, in the mung bean starch gel affect water-binding stability, which can slow down the water segregation (38).

Total polyphenol and flavonoid content

The total polyphenol and flavonoid contents of mung bean starch gel containing EPP are shown in Table 7. The total polyphenol content significantly increased with increasing amounts of EPP in the mung bean starch gels ($p < 0.001$). The polyphenol content of EPP7 was 0.22 $\mu\text{g GAE/mg}$, which is 4.4-fold higher than that of the control (0.05 $\mu\text{g GAE/mg}$). Ji *et al.* (12) have reported that eggplant peel contains 90.65 mg phenolics per 100 g fresh weight. Therefore, the change in polyphenol content is expected to be due to the addition of EPP. This data is similar to the results of the study by Son and Lee (38). According to Aruoma, phenolic compounds have various functions, such as preventing lipid oxidation and scavenging free radicals, indicating that the addition of EPP, which is rich in phenolic compounds, can delay the retrogradation of starch (40).

The total flavonoid content significantly increased with increasing amounts of EPP in the mung bean starch gels ($p < 0.001$). The highest total flavonoid con-

tent was obtained in EPP7 (0.20 $\mu\text{g QE/mg}$). This is consistent with the results of the study by Hwang and Thi (23). Polyphenol include flavonoids and other phenolic compounds. However, the value of polyphenol contents in the samples a little higher than or similar to the value of flavonoid contents in this study. This is because standard materials were different.

Antioxidant activities

The DPPH and ABTS radical scavenging activities of mung bean starch gels containing EPP are shown in Table 7. The IC_{50} value, which was defined as the concentration of the sample required to inhibit 50% of free radicals (DPPH and ABTS, respectively), significantly decreased with increasing amounts of EPP in the mung bean starch gels, according to the DPPH assay ($p < 0.001$). The IC_{50} value of the control showed the highest value (309.47 $\mu\text{g/mL}$), which was 14.3-fold higher than that of EPP7 (21.60 $\mu\text{g/mL}$). This finding shows that the DPPH radical scavenging activity of mung bean starch gels increased significantly with increasing amounts of EPP. This result is similar to those of studies by Choi *et al.* (21) and Choi (31).

Similar to the DPPH radical scavenging activity, the IC_{50} value significantly decreased with increasing amounts of EPP, according to the ABTS assay ($p < 0.001$). EPP7 possessed the strongest scavenging activity of ABTS (111.26 $\mu\text{g/mL}$), followed by EPP5 (162.86 $\mu\text{g/mL}$), EPP3 (195.59 $\mu\text{g/mL}$), EPP1 (227.43 $\mu\text{g/mL}$), and the control (527.05 $\mu\text{g/mL}$). Azuma *et al.*

Table 7. Total polyphenol and flavonoid levels and DPPH-radical and ABTS-radical scavenging effects of mung bean starch gels containing different amounts of eggplant peel powder.

Content	Mung bean starch gel ¹⁾					F-value ²⁾
	Control	EPP1	EPP3	EPP5	EPP7	
Total polyphenol ($\mu\text{g GAE/mg}$)	0.05 \pm 0.02 ³⁾	0.06 \pm 0.01 ^d	0.09 \pm 0.01 ^c	0.12 \pm 0.01 ^b	0.22 \pm 0.01 ^a	150.11***
Flavonoid ($\mu\text{g QE/mg}$)	0.04 \pm 0.00 ^c	0.08 \pm 0.01 ^d	0.11 \pm 0.00 ^e	0.14 \pm 0.01 ^b	0.20 \pm 0.01 ^a	546.67***
DPPH (IC_{50} , $\mu\text{g/mL}$)	309.47 \pm 8.20 ^a	234.08 \pm 16.17 ^b	132.07 \pm 8.26 ^c	51.54 \pm 5.14 ^d	21.60 \pm 0.62 ^e	522.45***
ABTS (IC_{50} , $\mu\text{g/mL}$)	527.05 \pm 27.74 ^a	227.43 \pm 5.90 ^b	195.59 \pm 10.46 ^c	162.86 \pm 3.47 ^d	111.26 \pm 4.53 ^e	423.73***

¹⁾ See the legend of the Table 1; ²⁾ The F-value corresponds to a significant effect of the eggplant peel powder (***) $p < 0.001$; ³⁾ Different letters in the same row indicate statistically significant difference

Table 8. Sensory preference scores for mung bean starch gels with different amounts of eggplant peel powder.

Sensory preference scores	Mung bean starch gel ¹⁾					F-value ²⁾
	Control	EPP1	EPP3	EPP5	EPP7	
Color	4.45 ± 1.70 ³⁾	2.95 ± 1.19 ^b	4.60 ± 1.73 ^a	5.40 ± 1.14 ^a	5.00 ± 1.52 ^a	7.95 ^{***}
Flavor	4.00 ± 1.59 ^{abc}	3.75 ± 1.02 ^{bc}	4.55 ± 1.32 ^{ab}	4.80 ± 1.54 ^a	3.55 ± 1.39 ^c	2.92 [*]
Taste	3.75 ± 1.52	4.35 ± 1.14	3.90 ± 1.62	4.30 ± 1.59	3.40 ± 1.98	1.24 ^{NS}
Moisture	4.65 ± 1.39	4.55 ± 1.28	4.45 ± 1.43	4.65 ± 1.14	4.50 ± 2.04	0.07 ^{NS}
Springiness	3.15 ± 1.50 ^c	3.90 ± 1.21 ^{bc}	4.45 ± 1.39 ^{ab}	4.55 ± 1.43 ^{ab}	4.95 ± 1.32 ^a	5.14 ^{**}
Overall acceptability	4.00 ± 0.97 ^b	4.25 ± 0.72 ^{ab}	4.35 ± 0.75 ^{ab}	4.75 ± 0.91 ^a	3.95 ± 0.83 ^b	2.92 [*]

¹⁾ See the legend of the Table 1; ²⁾ The F-value corresponds to a significant effect of the eggplant peel powder (^{NS} represents Not Significant, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$); ³⁾ Different letters in the same row indicate statistically significant difference.

(41) and Akanitapichat *et al.* (42) have reported that eggplant possesses strong antioxidant activity. Therefore, our data suggest that adding EPP to mung bean starch gels enhance the antioxidant activity of the gels.

Sensory evaluation

To measure product acceptability, a 7-point hedonic scale, which provides both reliable and valid results, were used (28). The sensory evaluation results of the eggplant peel–mung bean starch gel samples are shown in Table 8. EPP1 recorded the lowest color score of 2.95, but the control, EPP3, EPP5, and EPP7 did not differ significantly. EPP5 had the highest flavor score of 4.80, and EPP7 had the lowest flavor score of 3.55. This might be attributed to the strong unpleasant flavor of EPP, which was probably found to be unsatisfactory by the panelists when 7% eggplant peel powder was added. No statistically significant differences were found in the taste and moisture among the control and the EPP-added gels. As increasing amounts of eggplant peel powder were added, the springiness scores significantly increased ($p < 0.01$). Overall acceptability was in the following order: EPP5 (4.75) > EPP3 (4.35) > EPP1 (4.25) > control (4.00) > EPP7 (3.95). The results are similar to those of mung bean starch gels containing persimmon powder, in which overall acceptability scores increased as the persimmon powder content increased (similar to the increase from EPP1 to EPP7 in our study); however, gels containing 9% supplement received decreased scores (31). Thus, the sensory evaluation results pointed out that the mung bean starch gel containing 5% EPP is satisfactory.

Conclusion

In this study, eggplant peel, as a natural potential functional food ingredient, was added to prepare mung bean starch gels and the quality characteristics and antioxidant properties were investigated. The moisture content of the mung bean starch gels containing various amounts of EPP were not significantly different. The pH significantly decreased with increasing amounts of EPP. With the addition of EPP, the *L* value decreased, while *a* and *b* values increased. In texture analysis, increased substitution of EPP led to a decrease in hardness and chewiness, while springiness and fracturability did not change significantly. Syneresis increased during the storage period, and syneresis of EPP7 had the lowest value on the 5th day. Total polyphenol and flavonoid contents, and DPPH and ABTS radical scavenging activities significantly increased with increasing amounts of EPP. From the sensory evaluation results, EPP5 showed the highest sensory preference scores. In conclusion, mung bean starch gel prepared with the addition of 5% EPP could improve the quality characteristics, sensory quality, and antioxidant properties of mung bean starch gels.

Acknowledgements

This research was supported by Korea University Grant (K1605391), and grateful acknowledgements.

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