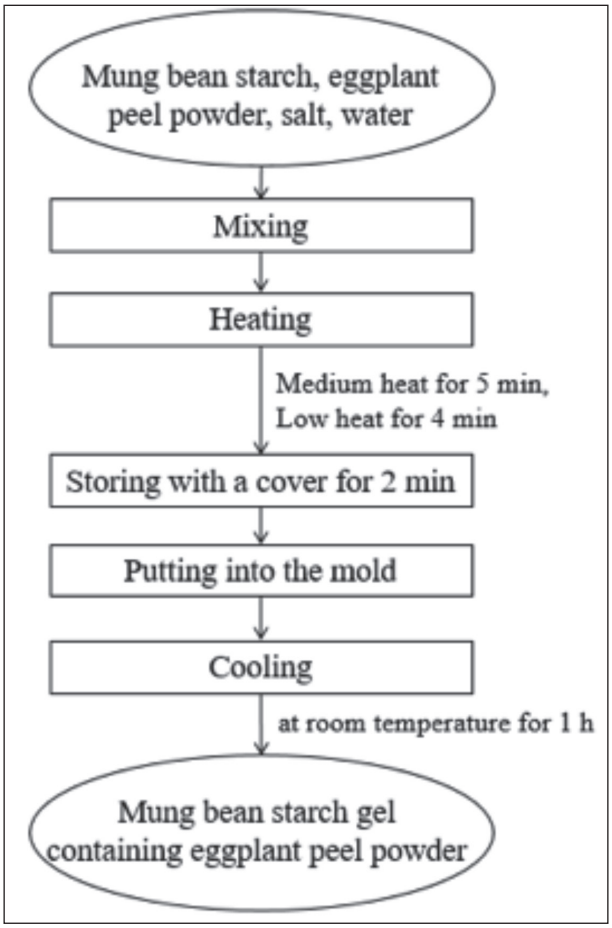

Figure 1. Flow chart of making mung bean starch gels supplemented with eggplant peel powder.

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-Ciocalteau 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-Ciocalteau›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 $IC_{50,}$ which was defined as the concentration of the extract required to inhibit 50% of DPPH radicals. The radical scavenging capacity and IC_{50} were calculated using the following equations:

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

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

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 μL 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 $IC_{50,}$ which was defined as the concentration of the extract required to inhibit 50% of ABTS radicals. The radical scavenging capacity and IC_{50} were calculated in the same manner as described earlier for DPPH-scavenging capacity and IC_{50}.

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 ± 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 ± 0.76	86.33 ± 0.50	85.68 ± 0.68	85.60 ± 0.65	85.43 ± 1.06	2.46^{NS}
pH	$5.95 \pm 0.05^{a3)}$	5.49 ± 0.04^{b}	5.21 ± 0.02^{c}	5.07 ± 0.02^{d}	4.94 ± 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

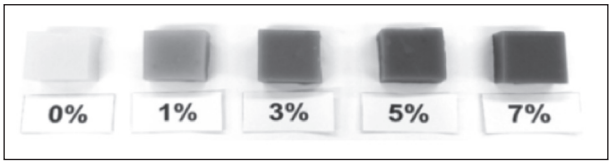

Figure 2. Photograph of mung bean starch gels with different concentrations of eggplant peel powder

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 ± 11.5^{5a}	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^{aC}	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^{cB}	13.93 ± 0.09^{cB}	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^{eA}	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 μg GAE/mg, which is 4.4-fold higher than that of the control (0.05 μg 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 content was obtained in EPP7 (0.20 μg 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 μg/mL), which was 14.3-fold higher than that of EPP7 (21.60 μg/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 μg/mL), followed by EPP5 (162.86 μg/mL), EPP3 (195.59 μg/mL), EPP1 (227.43 μg/mL), and the control (527.05 μg/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	Eggplant peel powder (g/100 g of mung bean starch)[1)]					F-value[2)]
	Control	EPP1	EPP3	EPP5	EPP7	
Total polyphenol (μg GAE/mg)	0.05 ± 0.02[d3)]	0.06 ± 0.01[d]	0.09 ± 0.01[c]	0.12 ± 0.01[b]	0.22 ± 0.01[a]	150.11***
Flavonoid (μg QE/mg)	0.04 ± 0.00[e]	0.08 ± 0.01[d]	0.11 ± 0.00[c]	0.14 ± 0.01[b]	0.20 ± 0.01[a]	546.67***
DPPH (IC50, μg/mL)	309.47 ± 8.20[a]	234.08 ± 16.17[b]	132.07 ± 8.26[c]	51.54 ± 5.14[d]	21.60 ± 0.62[e]	522.45***
ABTS (IC50, μg/mL)	527.05 ± 27.74[a]	227.43 ± 5.90[b]	195.59 ± 10.46[c]	162.86 ± 3.47[d]	111.26 ± 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[a3)]	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.

References

1. Ryu HM, Jeon DK, Kim S-A, Chung H-J. Antioxidant and quality characteristics of mungbean starch gel added with peach seed powder. Korean J Food Preserv 2013; 20(3): 372-8.
2. Joo N, Chun H. Effect of oil addition on texture of mungbean starch gel. Korean J Soc Food Sci 1992; 8(1): 21-5.
3. Lee J, Son ES, Kim AJ. Investigation on Muck (traditional starch jelly) made of typical ingredients such as acorn, mung bean and buckwheat. J Korean Soc Esthet Cosmeceutics 2014; 9(2): 143-56.
4. Sukandar D, Radiastuti N, Muawanah A, Hudaya A. Antioxidant activity from water extract of kecombrang flower (Etlingera elatior) leading to jelly candy formulation. VALENSI 2011; 2(2): 393-8.
5. Joo S-Y, Choi H-Y. Antioxidant activity and quality characteristics of mung bean starch gel prepared with ginkgo nut powder. Korean J Food Culture 2014; 29(1): 84-90.
6. Suh K, Kim K. Quality characteristics of sponge cake added with Helianthus tuberosus powder. J East Asian Soc Dietary Life 2014; 24(1): 126-35.
7. Kim A-J, Jung J-J, Lee M, Joo N, Jung E-K. Quality characteristics of mungbeanmook added with gugija (Lycii fructus) infusion. J Korean Diet Assoc 2012; 18(3): 213-21.
8. Kim A-J, Shin S-M, Joung K-H. Quality characteristics of chungpomook using black ginseng extract. J Korea Acad-Ind Co-op Soc 2011; 12(9): 3994-4000.
9. Nisha P, Nazar PA, Jayamurthy P. A comparative study on antioxidant activities of different varieties of Solanum melongena. Food Chem Toxicol 2009; 47(10): 2640-4.
10. Kyung-Yean B, Sang-Il L, Jeong-Sook K, Doo-Young L, Seoung-Hee O, Soon-Dong K. Antioxidative effects of extracts of various cultivars and different plant parts of eggplant. J East Asian Soc Diet Life 2009; 19(2): 195-201.
11. Jung E-J, Bae M-S, Jo E-K, Jo Y-H, Lee S-C. Antioxidant activity of different parts of eggplant. J Med Plants Res 2011; 5(18): 4610-5.
12. Ji L, Wu J, Gao W, Wei J, Yang J, Guo C. Antioxidant capacity of different fractions of vegetables and correlation with the contents of ascorbic acid, phenolics, and flavonoids. J Food Sci 2011; 76(9): 1257-61.
13. Braga PC, Scalzo RL, Dal Sasso M, Lattuada N, Greco V, Fibiani M. Characterization and antioxidant activity of semi-purified extracts and pure delphinidin-glycosides from eggplant peel (Solanum melongena L.). J Funct Foods 2016; 20: 411-21.
14. Noda Y, Kneyuki T, Igarashi K, Mori A, Packer L. Antioxidant activity of nasunin, an anthocyanin in eggplant peels. Toxicology 2000; 148(2): 119-23.
15. Shen G, Van Kiem P, Cai X-F, Li G, Dat NT, Choi YA, et al. Solanoflavone, a new biflavonol glycoside from Solanum melongena: Seeking for anti-inflammatory components. Arch Pharm Res 2005; 28(6): 657-9.
16. Joshi Y, Goyal B. Anthocyanins: a lead for anticancer drugs. Int J Res Farm Chem 2011; 1(4): 1119-26.
17. Oliveira MdS, Furlong EB. Screening of antifungal and antimycotoxigenic activity of plant phenolic extracts. World Mycotoxin J 2008; 1(2): 139-46.
18. Kwon Y-I, Apostolidis E, Shetty K. In vitro studies of eggplant (Solanum melongena) phenolics as inhibitors of key enzymes relevant for type 2 diabetes and hypertension. Bioresource Technol 2008; 99(8): 2981-8.
19. Jing P, Qian B, Zhao S, Qi X, Ye L, Giusti MM, et al. Effect of glycosylation patterns of Chinese eggplant anthocyanins and other derivatives on antioxidant effectiveness in human colon cell lines. J Food Sci 2015; 172: 183-9.
20. Jo Y-N, Jeong H-R, Jeong J-H, Heo H-J. The skin protecting effects of ethanolic extracts of eggplant peels. Korean J Food Sci Technol 2012; 44(1): 94-9.
21. Choi S-H, Moon S-J, Lee M-K, Ahn J-S. Quality characteristics of Sulgidduk prepared with added freeze dried-eggplant powder. Korean J Food Nutr 2013; 26(3): 421-7.
22. Kusuma D, Santoso F, Prabawati E. Characteristics of soymilk added with dragon fruit and eggplant peel extracts. Jurnal Teknologi dan Industri Pangan 2013; 24(1): 54-9.
23. Hwang E-S, Thi ND. Quality characteristics and antioxidant activities of Cheongpomook added with aronia (Aronia melanocarpa) powder. Korean J Food Cook Sci 2014; 30(2): 161-9.
24. Akay S, Alpak I, Yesil'Celiktas O. Effects of process parameters on supercritical CO2 extraction of total phenols from strawberry (Arbutus unedo L.) fruits: An optimization study. J Sep Sci 2011; 34(15): 1925-31.
25. Woisky RG, Salatino A. Analysis of propolis: some parameters and procedures for chemical quality control. J Apic Res 1998; 37(2): 99-105.
26. Wang K-J, Zhang Y-J, Yang C-R. Antioxidant phenolic compounds from rhizomes of Polygonum paleaceum. J Ethnopharmacol 2005; 96(3): 483-7.
27. Choi Y, Lee S, Chun J, Lee H, Lee J. Influence of heat treatment on the antioxidant activities and polyphenolic compounds of Shiitake (Lentinus edodes) mushroom. Food Chem 2006; 99(2): 381-7.
28. Lu T-M, Lee C-C, Mau J-L, Lin S-D. Quality and antioxidant property of green tea sponge cake. Food Chem 2010; 119(3): 1090-5.
29. Park JH, Kim EM. Changes in the quality characteristics of mung bean starch jelly with white lotus (Nelumbo nucifera) root powder added. Korean J Culinary Res 2010; 16(1): 180-90.
30. Cha Y, Jung Y, Kim J, Youn K. Quality characteristics and antioxidative activity of mung bean starch gels added with carrot, spinach and mulberry juice. J East Asian Soc Dietary Life 2011; 21(1): 46-52.
31. Choi H-Y. Antioxidant activity and quality characteristics of mung bean starch gel prepared with persimmon powder. Korean J Food & Nutr 2013; 26(4): 638-45.
32. Kim A-J, Joung K-H, Shin S-M. Quality characteristics of chungpomook using black garlic extract. J Korea Acad-Ind Co-op Soc 2011; 12(6): 2685-90.
33. Kim A, Lim Y, Kim M, Kim M. Quality characteristics of mungbean starch gels added with green tea powder. J East Asian Soc Dietary Life 2002; 12(2): 135-40.

34. Chung K-M. Molecular structure and lipid in starches for mook. Korean J Food Sci Technol 1991; 23(5): 633-41.
35. Kim H-S, Ahn S-Y. Effect of amylose and amylopectin on the texture of mook. Korean J Hum Ecol 1997; 6(2): 157-66.
36. Na H-S, Kim K, Oh G-S, Kim S-K. Properties of acorn mook with various soaking conditions. Korean J Food Sci Technol 2002; 34(2): 207-12.
37. Kim A-J, Han M-R, Rho J-O. Quality characteristics of cheongpomook prepared with different levels of mungbean powder. Korean J Hum Ecol 2011; 20(6): 1229-37.
38. Son G-O, Lee S-J. Quality characteristics of mungbean starch gel added with Salicornia herbacea L. powder. J East Asian Soc Diet Life 2014; 24(4): 472-80.
39. Choi E, Oh M. Sensory and textural characteristics of mungbean starch gels with soy bean oil and sucrose fatty acid ester during room temperature storage. J Korean Home Eco Asso 2004; 42(2): 213-27.
40. Aruoma OI. Free radicals, oxidative stress, and antioxidants in human health and disease. J Am Oil Chem Soc 1998; 75(2): 199-212.
41. Azuma K, Ohyama A, Ippoushi K, Ichiyanagi T, Takeuchi A, Saito T, et al. Structures and antioxidant activity of anthocyanins in many accessions of eggplant and its related species. J Agr Food Chem 2008; 56(21): 10154-9.
42. Akanitapichat P, Phraibung K, Nuchklang K, Prompitakkul S. Antioxidant and hepatoprotective activities of five eggplant varieties. Food Chem Toxicol 2010; 48(10): 3017-21.

Correspondence:
Young-Soon Kim
Department of Food and Nutrition, Korea University,
Seoul 02841, Republic of Korea
Tel.: +82 2 3290 5638
Fax: +82 2 921 7209
E-mail: kteresa@korea.ac.kr (Y.S. Kim)