Effect of germinated grain flours on physicochemical characteristics of rice cakes, *Seolgitteok*

Young-A Kim¹, Su-Jung In¹, and Jeonghae Rho^{1,2,*}

¹Department of Food and Nutrition, Inha University, Incheon 22212, Korea

²Korea Culinary Science Research Institute, Ansan, Gyeonggi 15534, Korea

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*Corresponding Author
Tel/Fax: +82-31-406-2361
E-mail: 216099@inha.ac.kr

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Abstract Minor grains and their germinated shoots such as buckwheat, Job's tears, and mungbean have diverse bioactive functionalities. In this study, the flours of grains and germinated grains were added to Korean rice cakes, known as *Seolgitteok*, and the effects on properties such as starch gelatinization and retrogradation were examined. The dietary fiber content, blue value index, amylogram, texture properties and sensory evaluation of *Seolgitteok* were also investigated. Rice flour amylogram results showed that addition of buckwheat, germinated Job's tears, and mungbean decreased starch setback, and that addition of buckwheat decreased consistency, which are related to slowed retrogradation. Buckwheat, especially when germinated, delayed starch retrogradation, which is one of the main drawbacks of rice cakes. *Seolgitteok* with added germinated buckwheat possessed preferable sensory qualities.

Keywords: germination, rice cake, buckwheat, mungbean, Job's tears

Introduction

Tteok (Korean pronunciation: [tʰʌk]; also spelled ddeock, duk, dduck, dduk, or thuck) is a traditional Korean rice cake made with glutinous or non-glutinous rice flour (1). *Tteok* is largely divided into four categories: steamed, pounded, boiled, and pan-fried. The steamed *tteok*, made by steaming rice flour, is regarded as the oldest and most basic form of *tteok*. '*Seolgitteok*' is a typical steamed *tteok*. *Seolgitteok* has many variations depending on the minor ingredients added; these minor ingredients provide nutrients and *Seolgitteok* is visually appealing, depending on the diverse combination of major and minor ingredients used (2).

Plant seeds germinate when they are provided with appropriate water, oxygen, and temperature. They go through compositional changes during the germination process. For this reason, studies have been conducted to determine methods of increasing bioactive substances by germination (3).

Buckwheat is rich in flavor and has high nutritive value owing to its excellent amino acid composition (4). It is not only a good source of vitamins, but also contains compounds that have medicinal properties such as rutin and quercetin. Studies have reported that buckwheat can prevent various diseases related to hypernutrition in adults such as constipation, high blood pressure, diabetes, and chronic illnesses (5). In the case of buckwheat, germination results in increased levels of rutin, vitamin C, insoluble fibers such as cellulose

and lignin, and antioxidative effects (6).

Job's tears grains are useful as a dietary supplement or substitution food because they are highly nutritious, containing high levels of calcium, iron, and vitamins B₁ and B₂ (7). In Korea, Job's tears have been known to have medicinal effects and have been utilized in oriental medicines, nutritional tonics, and joint medicines, and are said to possess peptic, diuretic, analgesic, and anti-inflammatory properties (8). It has also been reported that Job's tears can reduce tumor growth and lower plasma cholesterol (9).

Featuring a light taste and unique flavor, mungbeans have been widely used as an ingredient in traditional oriental foods. Availability of mungbeans is next to that of soya beans among legumes. It is known that mungbeans have antihypertensive, anti-inflammatory, fever-reducing, and antidotal properties (10). It has been reported that germination increases the content of vitamins and bioactive compounds such as phenolics and flavonoids in mungbeans (11).

Lately, with the growing demand for healthy foods, there has been an increase in studies on rice cakes added with functional ingredients that have health benefits and a suitable taste. There are many studies of *Seolgitteok* with increased functionality by adding minor ingredients such as barley flour, perilla leaf, soybean flour, lotus leaf powder, aloe powder, and raspberry powder (12–17). Meanwhile, there is a growing interest for germinated grains in Asian region, especially in Japan and Korea. As a starch-based food, rice cake has the disadvantage of short storage capacity due to retrogradation.

There have been various studies conducted to address this problem and some of them have attempted to delay retrogradation of rice cakes by adding minor ingredients.

In this study, buckwheat, Job's tears, and mungbeans have been chosen as minor ingredients and added to *Seolgitteok* for their diverse functionality and bioactive substances. In addition, the present study added germinated forms of these grains to *Seolgitteok* in flour form to compare gelatinization, retrogradation, and other properties of the rice cakes by using the grains before and after germination. The present study also tested dietary fiber content, blue value, amylogram, and textural properties of *Seolgitteok* with these novel minor ingredients added, while also conducting sensory evaluation to determine acceptability.

Materials and Methods

Materials of *Seolgitteok* Rice used for this study (variety: *Chucheongmi*, producing area: Icheon-si, Korea) was purchased at a Nonghyup (National Agricultural Cooperative Federation) store. Refined sugar (CJ Corporation, Seoul, Korea) and salt (refined salt that has 88% or greater salinity) were also used. Buckwheat (production area: Geochang-gun, Korea), Job's tears (production area: Geochang-gun, Korea), and mungbeans (variety: *Myeongnokdu*, production area: Geochang-gun, Korea) were purchased from local producers. Buckwheat, Job's tears, and mungbeans were washed three times and hulled before use. After drying under the shade, they were ground.

Germination of grains Buckwheat was thoroughly washed under running tap water, and then was soaked in water for 24 h at room temperature. The pre-soaked buckwheat was spread on a plastic tray with three layers of wet muslin, and was covered with another layer of wet muslin. The buckwheat was germinated for seven days at 10°C while being watered and mixed four times a day (18). Washed Job's tears were soaked in water for 10 h and germinated for four days at 25°C. The method of Koh and Lee (10) was modified to germinate mungbeans. Washed mungbeans were soaked in water in the dark for 6 h. Then, they were watered six times a day and germinated for 24 h at 25°C.

Germinated buckwheat, Job's tears, and mungbeans were freeze-dried for 72 h and then pulverized. They were sifted through a size 20 mesh sieve before use.

Preparation of *Seolgitteok* Rice (200 g) was washed, soaked in water for 8 h, and ground, then sifted through a size 20 mesh sieve. Salt (1.6 g) and sugar (20 g) were mixed in water (30 g), which was then added to the rice flour. Twenty percent of the rice was replaced with germinated or ungerminated buckwheat, Job's tears, or mungbean flour since more than 20% of grain flour failed to form typical *Seolgitteok* texture. Water (1.7 L) was poured into a steamer, and a

pan (53 cm×32 cm×10 cm) with holes for steam to pass through was placed inside. Two layers of muslin were used underneath and top of *Seolgitteok* mix. Samples were steamed for 40 min and cooled down with covered muslin for 1 h. This was used as the day-0 storage sample (19). The samples were sealed and refrigerated at 4°C for 1, 2, or 3 days before examined.

The moisture contents of the *Seolgitteok* samples were in the range of 35.4–36.7% with no significant difference.

Analysis of general composition Moisture content (925.09B), crude protein content (979.09A), crude lipid content (920.39C), and crude ash contents (923.03) of rice, ungerminated grains, and germinated grains were analyzed in accordance with the official AOAC methods (20). Total dietary fiber (TDF) content was quantified in accordance with the method described by Prosky *et al.* (21) registered on AOAC.

Amylogram characteristics Amylograms were obtained by following the method of Juliano *et al.* (22) and using the Brabender Visco/Amylo/Graph. An aqueous 20% suspension of rice flour or rice flour with germinated/ungerminated grain flour (20% substitution of rice flour) was heated from 30 to 95°C at 1.5°C/min, then maintained at 95°C for 15 min before it was cooled to 50°C at the same speed. The following parameters were measured for each suspension: pasting temperature, peak viscosity, cold paste viscosity, breakdown, setback, and consistency.

Color measurements of *Seolgitteok* A colorimeter (JS-555; Color Techno System Co., Tokyo, Japan) was used to measure values of lightness (L), redness (a), and yellowness (b) for freshly made *Seolgitteok*. In addition, the color difference (E) was calculated from $E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$.

Blue value measurements of *Seolgitteok* The method of Gilbert and Spragg (23) was modified to determine the blue values of *Seolgitteok* samples. One gram of sample in 5 mL of distilled water was ground and mixed in 0.5 mL of 1 N NaOH, and then heated for 3 min in boiling water. After adding 0.5 mL of 1 N HCl, 0.08 g of potassium hydrogen tartrate was added to the mixture. Distilled water (45 mL) was poured in the mixture, and then 0.5 mL of iodine solution (10 mg of KI) was added. Distilled water added to reach a final volume of 50 mL. Absorbance was obtained at 680 nm using a UV-visible spectrophotometer (HP 8453; Hewlett Packard, Palo Alto, CA, USA).

Texture of *Seolgitteok* Instrumental textural properties of *Seolgitteok* such as hardness, adhesiveness, cohesiveness, springiness, gumminess, and brittleness were measured using a rheometer (Compac-100; Sun Scientific Co. Ltd., Tokyo, Japan). Sample size was 15 mm×15 mm×15 mm and rheometer conditions were: load cell 2 or 10 kg, deformation 60%, table speed 60 mm/min, and adapter diameter 20.0 mm.

Sensory evaluation of *Seolgitteok* Sensory evaluation was conducted using a 7-point hedonic scale (24) from very undesirable (score 1) to very desirable (score 7). Samples were provided to the panel on a white plastic plate along with some water. Evaluation of graininess (1-very coarse~7-very fine), softness (1-very firm~7-very soft), chewiness (1-very mealy~7-very chewy), and moistness (1-very dry~7-very moist) were performed twice. Ten graduate students from the Department of Food Science and Nutrition at Inha University who had received simple training about *Seolgitteok* served as the sensory panel.

Statistical analysis Using the SAS Package (Statistical Analysis System, version 9.1, SAS Institute Inc., Cary, NC, USA), each test result was processed with analysis of variance, Duncan's multiple range test, and Pearson's correlation analysis (25).

Results and Discussion

Proximate composition Proximate compositions of the rice flour and germinated or ungerminated buckwheat flour, Job's tears flour, and mungbean flour are shown in Table 1. Protein, dietary fiber and ash contents were high in mungbeans, whereas lipid content was high in Job's tears. By germination, total fiber of buckwheat increased and lipid, ash, and total fiber of Job's tears increased. Meanwhile, no significant difference by germination was observed in mungbean.

Amylogram characteristics Amylogram characteristics of *Seolgitteok* preparations are shown in Table 2. Pasting temperature (PT) indicates the temperature when gelatinization of starch structure begins; this parameter is affected by amylose content and molecular associations in the amorphous space of grains (26). Upon heating, a higher PT is obtained when the internal structure of the starch particle is tight, since swelling occurs more slowly. In other words, a lower PT means that gelatinization occurs more easily (27). Compared to rice flour alone, the addition of Job's tears, germinated Job's tears, or germinated mungbeans raised PT, whereas buckwheat and germinated buckwheat lowered PT. In addition, it was found that the

samples with germinated Job's tears and germinated mungbeans had increased PT when compared to their ungerminated counterparts.

Peak viscosity (PV) indicates the highest viscosity when starch particles that have been swelling from heat start to break down and lose their viscosity (26). Compared to the rice flour control group, all the other sample groups added with grain flours (excluding buckwheat) showed a significant decrease in PV. In addition, germinated grain flours showed lower PV values than their ungerminated counterparts. Cold pasting viscosity (CPV), viscosity at the end of cooling, showed similar results to PV.

Breakdown (BD) was obtained by subtracting the value of viscosity maintained for 15 min at 95°C (hot pasting viscosity, HPV) from the PV. It indicates resistance against heat and shear stress and thermal stability (19). Compared to the control sample, all the other groups added with grain flours showed significantly lower BD, meaning decrease in heat resistance. In addition, the samples containing germinated grain flours showed lower BD than their ungerminated counterparts.

Setback (SB), which indicates the retrogradation tendency of starch, was obtained by subtracting PV from CPV. Retrogradation occurs more easily when the SB value is higher (19). Compared to the control group, SB was significantly lower in *Seolgitteok* added with buckwheat, germinated buckwheat, Job's tears, or mungbeans, demonstrating that these grains have the effect of delaying retrogradation. However, the samples added with germinated Job's tears or germinated mungbeans showed significantly higher SB values. Consistency (CT) also relates to the tendency of starch retrogradation. Retrogradation occurs more easily when the consistency value is higher. The value of consistency was obtained by subtracting the CPV value from the HPC value. The consistency after addition of buckwheat was significantly lower than the control group, indicating that buckwheat is effective for delaying retrogradation.

Overall, compared to the *Seolgitteok* with ungerminated grain flour, the *Seolgitteok* with germinated grain flour showed lower PV, CPV, BD, and SB values. These are probably because starch of germinated grain is partially digested for cultivating and growing energy (5). Among the tested grains, germination had the greatest effect on buckwheat. Buckwheat also decreased setback and

Table 1. Proximate composition of rice, grains, and germinated grains

Sample	Proximate composition (% dry basis)			
	Protein	Lipid	Ash	Total fiber
Rice ¹⁾	8.20±0.03 ^{c2)}	1.00±0.05 ^e	0.88±0.03 ^d	5.14±0.04 ^e
Bu	15.7±0.08 ^b	2.89±0.01 ^c	2.37±0.13 ^{bc}	8.09±0.11 ^c
BuG	16.0±0.15 ^b	3.43±0.02 ^c	2.76±0.07 ^b	11.1±0.15 ^b
Jo	14.1±0.03 ^b	6.07±0.12 ^b	1.91±0.03 ^c	6.94±0.10 ^d
JoG	14.3±0.07 ^b	7.07±0.02 ^a	2.83±0.06 ^b	8.82±0.07 ^c
Mu	29.3±0.19 ^a	1.22±0.00 ^d	4.54±0.04 ^a	19.1±0.02 ^a
MuG	28.5±0.15 ^a	1.36±0.01 ^d	4.57±0.03 ^a	18.6±0.09 ^a

¹⁾Rice, rice flour; Bu, buckwheat; BuG, germinated buckwheat; Jo, Job's tears; JoG, germinated Job's tears; Mu, mungbean; and MuG, germinated mungbean

²⁾a-g: Values with the same letters within a column are not significantly different at a level of 0.05 by Duncan's multiple range test.

Table 2. Amylogram characteristics of rice flour and rice flour with grain flours

Sample	PT (°C) ³⁾	PV (BU)	CPV (BU)	BD (BU)	SB (BU)	CT (BU)
Rice ¹⁾	81.4±0.47 ^{c2)}	961±0.7 ^a	849±20.5 ^a	420±0.0 ^a	-112±19.8 ^c	-208±16.9 ^f
RBu	70.5±0.35 ^d	960±0.7 ^a	844±5.7 ^a	368±2.8 ^b	-119±6.4 ^d	-249±4.2 ^g
RBuG	68.6±0.28 ^e	661±0.7 ^b	488±4.2 ^b	204±4.2 ^c	-173±10.6 ^f	-115±14.9 ^e
RJo	84.0±0.57 ^b	595±0.1 ^c	458±2.1 ^c	176±1.4 ^d	-137±9.9 ^e	-48±0.0 ^b
RJoG	88.9±0.28 ^a	466±9.2 ^e	403±7.8 ^d	124±2.8 ^e	-63±9.2 ^b	-62±3.5 ^d
RMu	80.6±0.49 ^c	588±5.0 ^d	402±5.0 ^d	132±7.8 ^e	-186±19.1 ^g	-22±2.1 ^a
RMuG	89.3±0.49 ^a	394±1.4 ^f	391±0.7 ^d	58±2.1 ^f	-3±0.0 ^a	-55±0.7 ^c

¹⁾Rice, rice flour; RBu, rice flour supplemented with 20% buckwheat; RBuG, rice flour supplemented with 20% germinated buckwheat; RJo, rice flour supplemented with 20% Job's tears; RJoG, rice flour supplemented with 20% germinated Job's tears; RMu, rice flour supplemented with 20% mungbean; and RMuG, rice flour supplemented with 20% germinated mungbean

²⁾a-g: Values with the same letters within a column are not significantly different at a level of 0.05 by Duncan's multiple range test.

³⁾PT, pasting temperature; PV, peak viscosity; CPV, cold paste viscosity; BD, breakdown; SB, setback; CT, consistency; BU, brabender units

Table 3. Color and blue values of *Seolgitteok*

Sample	L	a	b	ΔE	Blue value			
					Day-0	Day-1	Day-2	Day-3
Con ¹⁾	83.68±0.11 ^{a2)}	-2.47±0.05 ^f	7.49±0.13 ^f	-	^{A3)} 0.774±0.00 ^d	^B 0.207±0.00 ^g	^C 0.158±0.01 ^d	^D 0.136±0.01 ^c
SBu	76.48±0.16 ^d	0.81±0.02 ^c	11.57±0.16 ^e	8.90±0.08 ^e	^A 0.788±0.00 ^c	^B 0.285±0.00 ^c	^C 0.195±0.00 ^c	^D 0.126±0.01 ^{ed}
SBuG	72.24±0.24 ^e	1.09±0.06 ^b	12.33±0.21 ^d	12.92±0.32 ^d	^A 0.833±0.00 ^a	^B 0.345±0.01 ^a	^C 0.292±0.00 ^a	^D 0.173±0.00 ^a
SJo	78.57±0.18 ^c	-1.60±0.06 ^e	12.02±0.23 ^d	6.88±0.12 ^f	^A 0.776±0.01 ^d	^B 0.249±0.00 ^f	^C 0.188±0.00 ^c	^D 0.129±0.00 ^{cd}
SJoG	57.46±0.34 ^g	4.59±0.05 ^a	18.82±0.33 ^c	30.24±0.35 ^a	^A 0.802±0.00 ^b	^B 0.295±0.00 ^b	^C 0.239±0.00 ^b	^D 0.150±0.00 ^b
SMu	79.82±0.84 ^b	-3.06±0.06 ^g	22.03±0.32 ^a	15.05±0.05 ^c	^A 0.696±0.00 ^f	^B 0.260±0.00 ^e	^C 0.147±0.00 ^e	^D 0.119±0.00 ^e
SMuG	67.82±0.35 ^f	-0.34±0.04 ^d	19.57±0.27 ^b	19.99±0.22 ^b	^A 0.733±0.00 ^e	^B 0.274±0.01 ^d	^C 0.190±0.00 ^c	^D 0.127±0.00 ^{cd}

¹⁾Con, control, *Seolgitteok* with rice; SBu, *Seolgitteok* with 20% buckwheat; SBuG, *Seolgitteok* with 20% germinated buckwheat; SJo, *Seolgitteok* with 20% Job's tears; SJoG, *Seolgitteok* with 20% germinated Job's tears; SMu, *Seolgitteok* with 20% mungbean; and SMuG, *Seolgitteok* with 20% germinated mungbean

²⁾a-g: Values with the same letters within a column are not significantly different at a level of 0.05 by Duncan's multiple range test.

³⁾A-D: Values with the same letters within a row (day-0 to day-3) are not significantly different at a level of 0.05 by Duncan's multiple range test.

consistency, demonstrating the effect of retrogradation delay. Positive correlations were found between BD and CPV ($r=0.5957$, $p<0.05$) and between BD and SB ($r=0.5855$, $p<0.05$). In addition, a positive correlation was observed between moisture content of grains and consistency as seen from the amylograph results ($r=0.6789$, $p<0.05$). The decreased setback cannot be simply explained by the proximate composition. The germinated buckwheat and germinated Job's tear increased fiber while no correlations between total fiber and SB. The retrogradation is inclusive of starch content, amylose ratio, and length of amylose and nonbranched amylopectin. During germination, each starch hydrolytic enzyme of starch in buckwheat, Job's tears and mungbean would produce different types of shortened amylose and amylopectin which needs additional studies later. Though all correlations between values of measurements were examined, the meaningless correlations such as $p>0.05$ are not explained in this article afterwards.

Color of *Seolgitteok* Color of *Seolgitteok* added with grain flours is shown in Table 3. L-value was the highest for the control sample with rice flour alone. The value of lightness significantly decreased when germinated grain flours were added. The value of a was highest in the sample with germinated Job's tears. It was found that the value was higher for *Seolgitteok* samples prepared with germinated flours

than the samples prepared with their ungerminated counterparts.

The value of b was positive in all the sample groups and was significantly elevated in the samples with mungbean flour, whether germinated or ungerminated. As for E, which indicates the overall color difference between the experimental group and the control group (7), the group with germinated Job's tears showed a significantly high value indicating the greatest color deviation from the control group. It was found that *Seolgitteok* prepared with germinated flours had higher E values compared to samples prepared with ungerminated grain flours.

Blue value of *Seolgitteok* Blue value is an index for comparing starch structure, indicating the binding between iodine and linear molecules within starch (23). When retrogradation begins after gelatinization, strong binding occurs between linear starch regions, preventing iodine binding. Hence, a decrease in blue value over the storage period can be interpreted as the progress of retrogradation. Blue value measurements of *Seolgitteok* during storage are shown in Table 3. The day-0 *Seolgitteok*, added with buckwheat flour indicated the highest blue value, and germination further increased the blue value. On day-1, blue value drastically decreased in all the sample groups compared to day-0. Analysis of the change in blue value during the storage period showed that the blue value was

significantly higher in the samples with germinated grain flours, and that the decrease in blue value over time was slower. This indicates that adding germinated grain flours has the effect of delaying retrogradation (28), and that this effect is the most noticeable in the case of germinated buckwheat. This is probably related to the noticeable increase in fiber in buckwheat by germination comparing with Job's tear and mungbean.

Texture of *Seolgitteok* Table 4 shows the hardness of *Seolgitteok* during storage. The *Seolgitteok* with buckwheat flour or Job's tears flour (day-0) showed no difference in hardness when compared to the control group. However, hardness significantly decreased when the *Seolgitteok* was prepared with mungbean flour. In addition, the *Seolgitteok* samples prepared with germinated flours showed decreased hardness compared to the samples containing their ungerminated counterparts.

Hardness of *Seolgitteok* significantly increased over time during storage. Increase in hardness is a general phenomenon observed during retrogradation of starch, resulting from hydrogen bonds forming between starch molecules that have gelatinized (27). Low hardness level or a low increase in hardness can be interpreted as a delay of retrogradation (16). As time passed in storage, lower hardness values were observed in all the samples added with flour in comparison to the control group, demonstrating that retrogradation can be delayed by adding germinated or ungerminated buckwheat, Job's tears, or mungbeans. In addition, the day-2 and day-3 *Seolgitteok* prepared with germinated flours showed decreased hardness when compared to the *Seolgitteok* samples prepared with their ungerminated counterparts. It appears that the contents of dietary fiber, lipids, and proteins, which can affect aspects of gelatinization and retrogradation, increased by adding grain flours, thus decreasing hardness of *Seolgitteok*.

Table 4 also shows adhesiveness of *Seolgitteok* preparations. On day-0, the control group showed low adhesiveness. During storage, adhesiveness values changed from negative to zero in all the samples. By day-3, all the samples indicated adhesiveness value of zero except for the sample with germinated Job's tears, relating to retrogradation of starch gels.

Comparison of cohesiveness and springiness of the *Seolgitteok* samples is shown in Table 4. On day-0, lower cohesiveness was observed in *Seolgitteok* samples prepared with added grain flours than in the *Seolgitteok* made with rice flour alone. The *Seolgitteok* samples with germinated or ungerminated Job's tears and mungbean flour showed significantly decreased cohesiveness compared to the control. Germination of Job's tears resulted in significantly lower cohesiveness compared to ungerminated Job's tears (7). During storage, cohesiveness decreased in all the samples until day-3. When comparing day-2 and day-3 samples, cohesiveness was decreased in all the experimental samples compared to the control sample. Additionally, on day-1 and day-2, the *Seolgitteok* prepared with germinated grain flours showed lower cohesiveness than the

Seolgitteok prepared with the respective ungerminated grain flours.

On day-0, the *Seolgitteok* samples with buckwheat, germinated buckwheat, and Job's tears showed significantly higher springiness values than the control the sample, while samples with germinated mungbeans showed a significantly decreased springiness value. Over time, springiness tended to increase in all the samples.

Gumminess is the tendency to lump and is related to hardness and cohesiveness (29). Table 4 shows gumminess and brittleness of the *Seolgitteok* samples. For the day-0 samples, the gumminess value was significantly lower when buckwheat, germinated buckwheat, and germinated Job's tears were added in comparison to the control group. Gumminess value significantly increased when germinated mungbeans were added. Over time, gumminess of the *Seolgitteok* gradually increased and the preparations with germinated grain flours showed lower gumminess values than those with ungerminated grain flours. For the sample added with buckwheat, a very large increase in gumminess was observed over time; with this sample having higher gumminess values than all the other samples from day-1 forward.

As for brittleness, a lower value indicates a stronger tendency to break and crumble (12). Among the samples from day-0, the *Seolgitteok* prepared with buckwheat had a significantly lower brittleness value than the control group. In addition, brittleness of the *Seolgitteok* samples prepared with germinated buckwheat and germinated Job's tears were significantly lower than the control, while the sample with germinated mungbeans showed significantly increased brittleness. These results were similar to the results from gumminess test. Over time in storage, brittleness gradually increased in all the samples. In general, germination resulted in lower brittleness values when compared to the preparations with ungerminated grain flours.

Hardness, adhesiveness, springiness, gumminess, and brittleness increased over time in storage regardless of grain type or germination, while cohesiveness decreased over time (16). It was found that adding any additional grain flour to the *Seolgitteok* reduces the change in hardness over time, and that germinated grain flours are more effective for this purpose. It was also observed that germinated grain flours and buckwheat reduced changes in brittleness and gumminess over time. Taken together, adding germinated grain flours reduces textural changes of *Seolgitteok* over storage time, and hence is expected to be effective for delaying retrogradation of *Seolgitteok*.

There was a negative correlation between hardness and springiness ($r = -0.7140$, $p < 0.01$) of the *Seolgitteok* indicating that springiness decreases with the progress of retrogradation. A positive correlation was observed between hardness and gumminess ($r = 0.7436$, $p < 0.01$). In addition, a moderately strong negative correlation was observed between adhesiveness and gumminess ($r = -0.6174$, $p < 0.05$).

Negative correlation was found between hardness and CT of amylogram ($r = 0.6309$, $p < 0.05$) whereas adhesiveness and CPV of amylogram were positively correlated ($r = 0.6344$, $p < 0.05$).

Table 4. Texture of *Seolgitteok* during storage at 4°C

Sample	Hardness (g/cm ²)				Adhesiveness (g)			
	day-0	day-1	day-2	day-3	day-0	day-1	day-2	day-3
Con ¹⁾	²⁾ E842±43.7 ^{ab3)}	^D 1521±92.8 ^a	^C 2713±79.4 ^a	^B 3892±6.4 ^a	^B -14.63±0.50 ^d	^A -0.75±0.24 ^b	^A -0.33±0.00 ^e	^A 0.00±0.00 ^a
SBu	^E 817±12.1 ^{ab}	^D 1267±117.9 ^{bc}	^C 1809±11.8 ^b	^B 2790±117.7 ^c	^B -8.33±0.71 ^{bc}	^A -0.58±0.18 ^b	^A -0.25±0.00 ^d	^A 0.00±0.00 ^a
SBuG	^C 759±62.2 ^c	^C 1082±41.3 ^c	^B 1410±14.6 ^c	^A 2087±60.6 ^d	^B -9.25±0.18 ^{bc}	^A -0.83±0.00 ^b	^A -0.08±0.00 ^b	^A 0.00±0.00 ^a
SJo	^E 849±57.3 ^a	^D 1307±9.2 ^{bc}	^C 2461±79.2 ^a	^B 3426±21.3 ^b	^B -10.79±0.15 ^c	^A -0.89±0.00 ^b	^A -0.17±0.00 ^c	^A 0.00±0.00 ^a
SJoG	^E 804±8.0 ^b	^D 1110±48.6 ^{bc}	^C 1434±5.2 ^c	^B 2155±28.6 ^d	^B -8.17±0.00 ^{bc}	^B -3.17±0.00 ^c	^A -0.25±0.00 ^d	^A -0.17±0.00 ^b
SMu	^E 712±35.4 ^d	^D 1344±77.9 ^{ab}	^C 1694±65.1 ^{bc}	^B 2093±12.3 ^d	^B -6.92±0.18 ^{ab}	^A -0.67±0.00 ^b	^A -0.08±0.00 ^b	^A 0.00±0.00 ^a
SMuG	^C 705±27.2 ^d	^B 1204±42.7 ^{bc}	^B 1402±30.7 ^c	^A 1891±51.3 ^d	^B -4.33±0.00 ^a	^A -0.17±0.00 ^a	^A 0.00±0.00 ^a	^A 0.00±0.00 ^a
Sample	Cohesiveness (%)				Springiness (%)			
	day-0	day-1	day-2	day-3	day-0	day-1	day-2	day-3
Con	^A 81.9±1.34 ^a	^B 60.8±0.62 ^a	^C 54.32±1.58 ^a	^{CD} 51.4±0.24 ^a	^C 69.1±1.31 ^c	^B 77.5±0.99 ^b	^B 77.9±1.16 ^{bc}	^{AB} 79.0±0.77 ^b
SBu	^A 80.7±0.33 ^{ab}	^B 54.7±0.86 ^b	^C 45.0±1.76 ^c	^D 40.5±2.09 ^c	^B 75.1±1.14 ^{ab}	^{AB} 76.9±0.55 ^b	^A 80.6±1.89 ^{ab}	^A 80.5±2.03 ^b
SBuG	^A 79.1±0.21 ^{abc}	^B 48.6±0.76 ^c	^C 35.7±2.95 ^e	^C 34.3±0.29 ^d	^C 76.3±1.72 ^a	^{BC} 79.1±1.21 ^{ab}	^{AB} 82.5±1.85 ^a	^A 84.1±1.85 ^a
SJo	^A 78.1±0.19 ^{bc}	^B 57.7±0.80 ^{ab}	^C 50.5±3.11 ^b	^{CD} 49.6±0.64 ^a	^B 72.7±2.81 ^b	^B 81.1±0.08 ^a	^B 80.9±0.40 ^{ab}	^{AB} 83.9±2.38 ^a
SJoG	^A 62.2±0.78 ^e	^B 38.0±0.34 ^d	^B 39.0±0.34 ^{de}	^{BC} 37.5±1.44 ^{cd}	^B 65.7±0.80 ^{cd}	^B 69.3±1.68 ^c	^A 75.6±1.11 ^c	^A 75.1±0.70 ^c
SMu	^A 76.7±0.87 ^{cd}	^B 55.5±2.40 ^b	^C 47.9±0.29 ^{bc}	^C 45.0±0.44 ^b	^C 67.1±1.73 ^{cd}	^B 76.3±1.95 ^b	^{AB} 78.7±0.27 ^{bc}	^{AB} 79.1±2.11 ^b
SMuG	^A 74.2±1.57 ^d	^B 47.7±0.52 ^c	^C 39.6±0.35 ^d	^C 37.6±1.21 ^{cd}	^A 65.4±2.28 ^d	^A 70.1±0.91 ^c	^A 71.3±4.51 ^d	^A 71.5±0.40 ^d
Sample	Gumminess (g)				Brittleness (g)			
	day-0	day-1	day-2	day-3	day-0	day-1	day-2	day-3
Con	^B 249±5.3 ^b	^A 961±42.2 ^a	^A 1029±16.0 ^a	^A 1050±27.1 ^b	^D 203±6.9 ^{ab}	^C 676±21.2 ^b	^B 749±12.4 ^a	^B 764±48.0 ^a
SBu	^E 201±12.2 ^{cd}	^D 597±15.5 ^c	^C 657±32.5 ^{bc}	^B 723±62.8 ^{cd}	^D 156±4.6 ^{cd}	^C 452±14.2 ^d	^{BC} 474±39.8 ^c	^B 506±27.5 ^c
SBuG	^D 178±6.9 ^d	^C 345±37.7 ^e	^B 426±50.9 ^d	^A 496±22.9 ^e	^D 136±13.1 ^d	^C 349±13.1 ^e	^{BC} 374±2.3 ^e	^{AB} 394±32.2 ^e
SJo	^D 232±11.5 ^{bc}	^C 964±12.6 ^a	^{BC} 1182±59.9 ^a	^B 1264±51.8 ^a	^D 176±7.4 ^{bc}	^C 708±42.1 ^a	^C 722±41.6 ^a	^B 789±54.1 ^a
SJoG	^C 183±8.7 ^d	^B 364±9.5 ^e	^A 472±22.2 ^{cd}	^A 509±14.7 ^e	^C 127±7.3 ^d	^B 239±11.5 ^f	^A 354±41.4 ^e	^A 376±17.9 ^e
SMu	^C 260±26.8 ^b	^B 803±11.6 ^b	^{AB} 831±27.6 ^b	^A 842±35.9 ^c	^C 200±5.3 ^{ab}	^B 604±5.9 ^c	^B 640±45.2 ^b	^A 709±53.9 ^b
SMuG	^D 305±4.2 ^a	^C 511±6.8 ^d	^B 612±58.0 ^c	^B 643±49.4 ^{de}	^D 225±8.0 ^a	^C 365±2.6 ^e	^B 431±32.3 ^d	^{AB} 441±21.9 ^d

¹⁾Con, control, *Seolgitteok* with rice; SBu, *Seolgitteok* with 20% buckwheat; SBuG, *Seolgitteok* with 20% germinated buckwheat; SJo, *Seolgitteok* with 20% Job's tears; SJoG, *Seolgitteok* with 20% germinated Job's tears; SMu, *Seolgitteok* with 20% mungbean; and SMuG, *Seolgitteok* with 20% germinated mungbean

²⁾A-E: Values with the same letters within a row (day-0 to day-3) are not significantly different at a level of 0.05 by Duncan's multiple range test.

³⁾a-f: Values with the same letters within a column are not significantly different at a level of 0.05 by Duncan's multiple range test.

A negative correlation was observed between *Seolgitteok* hardness and total dietary fiber content ($r = -0.6155$, $p < 0.05$) when comparing the preparations with various grains. This result is consistent with the findings of Choi and Kim (30), who reported that the addition of dietary fiber significantly decreased hardness of *baekseolgi* (*Seolgitteok* made with rice only) and was found to be effective for delaying retrogradation. Thus, delayed retrogradation can be expected in *Seolgitteok* that contains high dietary fiber. Meanwhile, there was a positive correlation between cohesiveness of *Seolgitteok* and lipid content of grain ($r = 0.9971$, $p < 0.001$), indicating that higher lipid content increased cohesiveness. Positive correlations were also observed between springiness and ash content ($r = 0.8604$, $p < 0.001$) as well as TDF ($r = 0.5280$, $p < 0.05$). A positive correlation was also found between gumminess and TDF ($r = 0.6213$, $p < 0.05$). Blue value was negatively correlated with adhesiveness, indicating that a decrease in blue value increases adhesiveness.

Sensory evaluation Results of sensory evaluation of *Seolgitteok* samples from different storage times are shown in Table 5. *Seolgitteok*

samples stored for more than three days were retrograded to such a degree that they were not suitable for sensory evaluation. Hence, the evaluation was performed with the day-0, day-1, and day-2 samples.

The natural color of *Seolgitteok* is white, but the color of *Seolgitteok* in this study changed due to the inherent color of grains or germinated grains (13). The sensory evaluation panel determined that the natural color of *Seolgitteok* was the most desirable. For all the evaluated samples, there was no difference in color preference between the different storage times. For the *Seolgitteok* with germinated Job's tears and germinated mungbeans, color preference decreased when compared to that of samples prepared with their ungerminated counterparts. The *Seolgitteok* prepared with germinated Job's tears or germinated mungbeans had less desirable flavor than the control group regardless of storage time. The samples with buckwheat or Job's tears showed a significant decrease in flavor preference as storage time increased.

On the day the samples were prepared, there was no significant difference in overall taste preference between the control group and

samples prepared with buckwheat, germinated buckwheat, Job's tears, and germinated Job's tears. The *Seolgitteok* samples prepared with mungbeans, whether germinated or ungerminated, were found to have less desirable taste than that of the other *Seolgitteok* samples. Taste quality of the *Seolgitteok* significantly decreased with increasing storage time. On day-1, the *Seolgitteok* samples with germinated Job's tears, mungbeans, and germinated mungbeans showed significantly less desirable taste than the control group. On day-2, the *Seolgitteok* samples with Job's tears, germinated Job's tears, mungbeans, and germinated mungbeans showed significantly less desirable taste than the control group (15).

Except for the samples prepared with buckwheat, all *Seolgitteok* samples were found to be less preferable to the control group. All the samples became coarse during storage. On day-2, the samples with germinated or ungerminated buckwheat were less coarse than the control group.

As the number of days in storage increased, softness significantly decreased in all the samples. On day-0, the samples prepared with buckwheat, germinated Job's tears, mungbeans, and germinated mungbeans were significantly less soft than the control group. On day-1, there was no significant difference in softness between the control group and the other samples except for the sample prepared

Table 5. Sensory evaluation of *Seolgitteoks* during storage at 4°C

Sample	Color			Flavor		
	Day-0	Day-1	Day-2	Day-0	Day-1	Day-2
Con ¹⁾	^{A2)} 6.15±0.52 ^{a3)}	^A 5.95±0.28 ^a	^A 5.60±0.31 ^a	^A 4.90±0.71 ^{ab}	^A 4.64±0.31 ^a	^A 4.15±0.31 ^a
SBu	^A 5.25±0.43 ^b	^A 4.92±0.26 ^b	^A 4.70±0.24 ^b	^A 5.06±0.39 ^a	^{AB} 4.67±0.76 ^a	^B 4.21±0.43 ^a
SBuG	^A 5.00±0.47 ^b	^A 4.81±0.12 ^b	^A 4.64±0.44 ^b	^A 4.65±1.20 ^{abc}	^A 4.50±0.98 ^{ab}	^A 4.35±0.46 ^a
SJo	^A 5.11±0.37 ^b	^A 4.91±0.33 ^b	^A 4.78±0.40 ^b	^A 5.03±0.42 ^a	^{AB} 4.71±0.81 ^a	^B 4.20±0.39 ^a
SJoG	^A 4.40±0.35 ^c	^A 4.30±0.64 ^{bc}	^A 4.07±0.39 ^c	^A 4.00±0.58 ^{cd}	^A 3.82±0.26 ^c	^A 3.61±0.27 ^b
SMu	^A 5.45±0.51 ^b	^A 4.92±0.21 ^b	^A 4.75±0.18 ^b	^A 4.21±0.40 ^{bc}	^A 3.95±0.29 ^{bc}	^A 4.15±0.37 ^a
SMuG	^A 4.00±0.20 ^c	^A 4.00±0.39 ^c	^A 3.55±0.21 ^d	^A 3.35±0.34 ^d	^A 3.65±0.26 ^c	^A 3.45±0.13 ^b
Sample	Taste			Graininess		
	Day-0	Day-1	Day-2	Day-0	Day-1	Day-2
Con ¹⁾	^A 5.35±0.28 ^a	^{AB} 4.55±0.51 ^a	^B 3.95±0.35 ^a	^A 5.74±0.37 ^a	^B 4.04±0.45 ^{ab}	^C 2.60±0.22 ^{bc}
SBu	^A 5.50±0.27 ^a	^B 4.65±0.42 ^a	^B 4.11±0.41 ^a	^A 5.65±0.34 ^{ab}	^B 4.25±0.44 ^{ab}	^C 3.21±0.26 ^a
SBuG	^A 5.41±0.31 ^a	^B 4.62±0.27 ^a	^B 3.92±0.45 ^a	^A 5.26±0.30 ^c	^B 4.36±0.33 ^a	^C 3.30±0.30 ^a
SJo	^A 5.45±0.35 ^a	^B 4.40±0.51 ^{ab}	^C 3.50±0.36 ^b	^A 5.40±0.44 ^{bc}	^B 3.55±0.23 ^c	^C 2.92±0.49 ^{ab}
SJoG	^A 4.94±0.73 ^{ab}	^B 4.10±0.52 ^b	^C 3.30±0.45 ^{bc}	^A 4.91±0.41 ^d	^B 3.97±0.19 ^b	^C 2.65±0.45 ^{bc}
SMu	^A 3.70±0.17 ^b	^{AB} 3.15±0.40 ^c	^B 3.10±0.31 ^c	^A 4.45±0.33 ^e	^B 2.95±0.17 ^d	^C 2.43±0.26 ^c
SMuG	^A 3.46±0.28 ^b	^A 3.12±0.29 ^c	^A 3.02±0.19 ^c	^A 4.30±0.30 ^e	^B 2.62±0.24 ^d	^B 2.22±0.16 ^c
Sample	Softness			Chewiness		
	Day-0	Day-1	Day-2	Day-0	Day-1	Day-2
Con	^A 5.70±0.33 ^a	^B 3.71±0.54 ^{ab}	^C 2.10±0.60 ^{de}	^A 5.60±0.34 ^a	^B 3.81±0.44 ^a	^C 2.22±0.76 ^a
SBu	^A 5.54±0.45 ^b	^B 3.75±0.63 ^{ab}	^C 2.41±0.45 ^{cd}	^A 4.95±0.43 ^b	^B 3.35±0.55 ^b	^C 2.05±0.45 ^{abc}
SBuG	^A 5.76±0.43 ^a	^B 4.00±0.54 ^a	^C 3.12±0.47 ^a	^A 5.51±0.37 ^a	^B 3.76±0.41 ^a	^C 2.25±0.55 ^a
SJo	^A 5.66±0.33 ^{ab}	^B 3.61±0.64 ^b	^C 2.01±0.55 ^e	^A 5.76±0.38 ^a	^B 3.40±0.61 ^b	^C 1.91±0.77 ^{bc}
SJoG	^A 5.50±0.44 ^b	^B 3.42±0.44 ^b	^C 2.45±0.71 ^c	^A 5.00±0.47 ^b	^B 3.31±0.43 ^b	^C 2.25±0.67 ^a
SMu	^A 4.51±0.39 ^c	^B 3.50±0.37 ^b	^C 2.82±0.65 ^{ab}	^A 3.81±0.44 ^c	^B 3.12±0.62 ^{bc}	^C 2.11±0.63 ^{ab}
SMuG	^A 4.22±0.55 ^c	^B 3.00±0.65 ^c	^B 2.63±0.49 ^{bc}	^A 3.92±0.55 ^c	^B 2.90±0.50 ^c	^C 1.81±0.54 ^c
Sample	Moistness			Preference		
	Day-0	Day-1	Day-2	Day-0	Day-1	Day-2
Con	^A 5.50±0.44 ^a	^B 3.85±0.47 ^a	^C 1.82±0.62 ^{bc}	^A 5.00±0.40 ^a	^B 3.61±0.44 ^a	^C 2.25±0.71 ^{cd}
SBu	^A 5.35±0.35 ^{ab}	^B 3.81±0.54 ^a	^C 1.91±0.73 ^{ab}	^A 4.96±0.52 ^a	^B 3.50±0.55 ^a	^C 2.51±0.55 ^{bc}
SBuG	^A 5.55±0.39 ^a	^B 3.84±0.51 ^a	^C 2.11±0.55 ^a	^A 5.10±0.37 ^a	^B 3.75±0.39 ^a	^C 2.90±0.63 ^a
SJo	^A 5.61±0.41 ^a	^B 3.40±0.43 ^b	^C 1.72±0.66 ^{bc}	^A 4.82±0.39 ^a	^B 3.11±0.55 ^b	^C 2.40±0.44 ^{bc}
SJoG	^A 5.16±0.36 ^b	^B 3.51±0.63 ^{ab}	^C 1.95±0.77 ^{ab}	^A 4.85±0.44 ^a	^B 3.55±0.48 ^a	^C 2.65±0.54 ^{ab}
SMu	^A 3.65±0.41 ^c	^B 2.22±0.49 ^c	^C 1.56±0.72 ^{cd}	^A 3.81±0.60 ^b	^B 3.03±0.61 ^b	^C 2.11±0.47 ^{de}
SMuG	^A 3.82±0.54 ^c	^B 2.10±0.55 ^c	^C 1.40±0.84 ^d	^A 3.40±0.52 ^c	^B 2.81±0.36 ^b	^C 1.92±0.83 ^e

¹⁾Con, control, *Seolgitteok* with rice; SBu, *Seolgitteok* with 20% buckwheat; SBuG, *Seolgitteok* with 20% germinated buckwheat; SJo, *Seolgitteok* with 20% Job's tears; SJoG, *Seolgitteok* with 20% germinated Job's tears; SMu, *Seolgitteok* with 20% mungbean; and SMuG, *Seolgitteok* with 20% germinated mungbean

²⁾A-C: Values with the same letters within a row (day-0 to day-2) are not significantly different at a level of 0.05 by Duncan's multiple range test.

³⁾a-e: Values with the same letters within a column are not significantly different at a level of 0.05 by Duncan's multiple range test.

with germinated mungbeans. On day-2, softness of the *Seolgitteok* samples prepared with germinated buckwheat, germinated Job's tears, mungbeans, and germinated Job's tears was significantly higher than the control, indicating these added grains reduce retrogradation since the softness is mostly related to the retrogradation of *Seolgitteok*.

The *Seolgitteok* prepared with buckwheat, germinated Job's tears, mungbeans, and germinated mungbeans were less chewy than the control group. In all the samples, chewiness significantly decreased as the storage time increased. In other words, the *Seolgitteok* became mealier as the number of days in storage increased.

Moistness significantly decreased in all the samples as storage time increased. On the day the samples were prepared, the samples prepared with germinated or ungerminated mungbeans were the least moist.

Correlations between sensory characteristics were analyzed. Among the sensory characteristics, graininess showed a moderate positive correlation with taste ($r=0.5776$, $p<0.05$) and softness ($r=0.5992$, $p<0.05$). In addition, a positive correlation was found between chewiness and softness ($r=0.5754$, $p<0.05$). In addition, a relatively strong positive correlation was observed between moistness and overall preference ($r=0.7289$, $p<0.01$).

Correlation between sensory characteristics and other quality factors such as general composition, textural characteristics, and gelatinization properties were also analyzed. Higher moisture content of the grain flour added to the *Seolgitteok* was related to a high softness value, showing a strong positive correlation ($r=0.9334$, $p<0.001$). There was a positive correlation between moisture content and chewiness ($r=0.8613$, $p<0.01$) as well as between moistness and overall preference ($r=0.5976$, $p<0.05$). Protein content and chewiness showed a positive correlation ($r=0.5846$, $p<0.05$). Hardness showed positive correlation with graininess and chewiness, and with overall preference ($r=0.8021$, $p<0.01$). Overall preference increased with PT ($r=0.7303$, $p<0.01$) and PV showed a negative correlation with moistness ($r=-0.7973$, $p<0.01$).

According to the results shown above, adding buckwheat, whether germinated or ungerminated, delayed retrogradation, decreased pasting, and improved textural properties of *Seolgitteok*. Germinated buckwheat was particularly effective for delaying retrogradation. The *Seolgitteok* prepared with germinated buckwheat did not show a significant difference from the control group in the sensory evaluation, demonstrating adequate sensory preference. It is reported that buckwheat and buckwheat sprouts are good for constipation, high blood pressure, and diabetes, and possess various biological functions, including antioxidative effects. Since the *Seolgitteok* supplemented with buckwheat delayed retrogradation, buckwheat can be used in a variety of carbohydrate-based products.

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