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# Quality Characteristics of Noodles Added with Domestic Germinated Barley

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# 발아 보리 및 혼합 복합분을 이용한 국수의 특성

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Abstract

The primary objective of this study is to investigate the quality properties of noodles added with germinated non-waxy (Saesalbori) and waxy (Saechalbori) barley flours at concentrations of 10%, 20% and 30% to wheat flour. The quality characteristics of the samples were assessed for color, cooking characteristics (water absorption, volume increase of noodles and turbidity of cooking water), texture profile analysis (TPA) and sensory evaluation. Regarding the cooking properties of the noodles, adding waxy barley flour did not affect cooking yield and volume increase significantly($p<0.05$), but noodles added with germinated Saesalbori at level of 10% had the lowest values of cooking yield and volume increase. Adding both types of flour increased the turbidity of the noodle soups. There was a common downward trend in $L^*$ and $b^*$ values and upward trend in $a^*$ value when increasing the level of barley used progressively. Adding germinated Saechalbori decreased the hardness, springiness and gumminess of noodles but did not cause any change in cohesiveness significantly while adding germinated Saesalbori decreased all the TPA parameters of the samples. Furthermore, the sensory analysis results showed that cooked noodles with 10% added germinated barley had no significantly different overall acceptance from the control sample, 20% substitution still resulted in acceptable sensory qualities. However treatment with both the substituted flours up to 30% was shown to cause unpleasant sensory qualities of noodles.

Key words : germination, barley, noodle, quality

## Introduction

Barley, ranking fifth among all crops in the world today behind maize, wheat, rice and soybean, has been an important food source in many areas in the world. Besides having high nutritional value, barley also brings health benefits to consumers. Tocols found in barley, including tocophenols and toco-tri-enols are well-known for their antioxidant action (1). The major fiber constituents of barley, β-glucan have been efficient in lowering plasma cholesterol, improving lipid metabolism and reducing glycemic index (2). Barley products are known to reduce cholesterol, blood glucose level and glycemic index (3). Given the health benefits of barley, incorporating barley in food processing should meet the demand of health-conscious customers. Compared to other cereals, barley contains higher protein, inorganic and vitamin contents. However, due to high level of substances adhering to the testa such as pectin, hemicelluloses, viscous indigestible polysaccharides, digestibility of barley is only 65-72% (4). Hence, there is limited use of barley in food or feed. About two-thirds of the barley yield has been used in feed, one-third for malting and only about 2% for food directly (5).

Germination of cereals is a process in which dormant enzymes are activated to supply the sprout and the available nutrients in the seed greatly increase (6). Therefore, germination is considered a good way of improving cereal

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quality. In this study, a new type of germinated barley is introduced (4). In this germination method, embryo turns into a white body, enzymes which hydrolyse fiber polysaccharide in the testa and outer most layer and endosperm are activated, the digestibility of VAW barley reaches 90%. Due to the highest diastatic enzyme among cereals, germinated barley is chosen to be sugar source in brewing. Nevertheless in traditionally germinated barley, one alkaloid substance called hordenine in barley root has been reported to rise blood pressure in human and animals. In this patent, this disadvantage is resolved, hence VAW barley can be considered health-protecting resource, helping to promote barley agriculture. Because digestibility of barley is elevated by the new germination method using no enzyme from external yeast or mold, using no acid, alkaline or any inorganic substances, this method is so-called "no-additive method".

Barley in various forms, has been used in foods in the world. In Russia, Poland, Tibet, Japan and India, pearled barley has been used in the traditional dish preparation (7). Koreans use pearled barley as a rice substitute and for the production of soy paste and soy sauce (8). In Middle Eastern and North African countries, pearled and ground barley is used in soups, flat bread and porridge (9). Barley flour or barley milling fractions are also used in whole grains and fiber-rich foods. Among these foods, the popularity of pasta has grown enormously recently. Pasta is known by many different names of which spaghetti, noodles and macaroni are the most common (10). Noodles, which have been consumed largely in Korea, are usually made from wheat flour, salt and an appropriate amount of water. Recently, standard of living has been increased, consumers are becoming more conscious of the nutritional aspects of food products. There have been many researches on the addition of saboten (11), dandelion (12), apple pomace and soymilk residue (13), pine needle powder (14), mushroom (15), plantain (16), mulberry leaves (17), onion juice (18), chitosan (19), green tea (20) in processing noodle and the effects of using these materials on the properties of the product such as appearance, taste, nutritional value …

In Korea where wheat flour is mainly imported, utilization of domestic flour in manufacture of noodle should be encouraged. The objective of this study is to substitute wheat flour with germinated barleys in order to produce new products of white salted noodles and to investigate the effects of substituting flours on quality characteristics of noodles.

## Materials and methods

### Materials

Barley flours (Saesalbori and Saechalbori) and germinated flours (Saesalbori and Saechalbori VAW barley flours) were obtained from VAW Barley Co (Jeollanamdo, Korea), and wheat flour used was 1st grade strong wheat flour (Korea Flour Mills Co, Ltd.).

### Particle size distribution

Particle size distribution of the flours used were determined with a laser particle size analyser (Mastersizer, Malvern, USA). Flour was suspended in ethanol by means of ultrasound. The instrument output included volume distribution as the fundamental measurement and medians D[v, 0.1], D[v, 0.5] and D[v, 0.9] (i.e. the diameter at which 10%, 50% and 90% of the sample is smaller and the remaining is larger), volume mean diameter D[4,3], ratio of total volume of particles to the total surface area D[3,2].

### Analytical methods

Moisture, ash, lipid and protein content of the flours used were determined following the method of AACC (21). Flour color was determined using a color measurement instrument (Minolta JP/CR-300, Minolta, Japan).

### Total phenolic content

The total phenolic content was determined with the Folin-Ciocalteau method (22). All the flours (200 mg) were extracted with 4 mL acidified methanol (HCl/methanol/water, 1:80:10, v/v/v) at room temperature for 2h. The mixture was centrifuged at 3000 rpm for 10 min using a centrifuge (brushless D.C Motor Centrifuge VS-5500). Aliquot of the supernatant (200μL) was added to 1.5 mL freshly diluted (10-fold) Folin - Ciocalteu reagent. The mixture was allowed to equilibrate for 5 min and then mixed with 1.5 mL of sodium carbonate solution (60 g/L). After incubation at room temperature for 90 min the absorbance of the mixture was read at 725 nm using a UV/VIS Spectrometer (HP-8452, Hewlett Packard, USA). Acidified methanol was used as a blank. The results were expressed as μg of ferulic acid equivalents per gram of flour.

### Free radical scavenging activity (DPPH)

Briefly wheat and barley flours (100 mg) were extracted with 1 mL methanol for 2h and centrifuged at 3000 rpm for 10 min. An aliquot of the supernatant (100 μL) was reacted with 3.9 mL of DPPH solution. Absorbance (A) at 515 nm was measured at t = 0 and t = 30 min against a methanol blank. Free radical scavenging activity was calculated as % discoloration (23).

Free radical scavenging activity (%)=100 x $[1-(A_{t=30\ min} - A_{t=0})]$

### Pasting properties

The pasting properties of the flours were determined using Micro Visco Amylograph (Brabender OHG, Duisburg, Germany). Flour (12 g on 14% moisture basis) was suspended in 100 mL of silver nitrate solution (by displacing 2 mL from 100 mL of water by 2 mL of 10% (w/v) silver nitrate solution (24) and heated in the Viscoamylograph from 30 to 95℃ at a rate of 1.5℃/min, held at 95℃ for 15 min, cooled to 50℃ at a rate of 1.5℃/min. Torque measuring range was 700 cmg. The viscosity was expressed in Brabender Units (BU).

In this experiment, silver nitrate solution was used as an alpha-amylase inhibitor to keep alpha-amylase from reducing the paste viscosity (25, 26).

### Barley noodle preparation

Noodles were prepared using a dough mixer (Model SM 258-10, EGS Stand-Mixer 350, China) and a noodle maker (Model BE-8200, Bethel, Korea). Appropriate volume of distilled water containing 2 g salt (Table 1) was added to 100 of flour and then mixed for 5 min at speed 1. Then the crumbly dough was manually shaped into a rectangular dough. The formed dough was placed into an airtight plastic bag. After 30-minute dough resting time, the dough was passed through the sheeting rolls of the noodle maker. It was then fold and turned 90° and passed 9 times more. The sheet thickness was reduced gradually after being passed through 3 different gaps. Then, the dough sheet was cut into strands (2.62x1.98 $mm^2$ cross section, 15 cm in length).

30 g of noodle was placed in a pan containing 500 mL of boiling distilled water. The noodles were slightly agitated to keep strands from sticking to the pan bottom and sticking together. Noodles were cooked for 9 min, then taken out and rinsed immediately with water at 20℃.

**Table 1. Formula for noodle dough with various level of barley flour**

| Samples | | Wheat flour (g) | Barley flour (g) | Salt water (mL) |
|---|---|---|---|---|
| Wheat | | 100 | 0 | 48 |
| Saesalbori (%) | 10 | 90 | 10 | 50 |
| | 20 | 80 | 20 | 53 |
| | 30 | 70 | 30 | 55 |
| Germinated Saesalbori (%) | 10 | 90 | 10 | 48 |
| | 20 | 80 | 20 | 49 |
| | 30 | 70 | 30 | 49 |
| Saechalbori (%) | 10 | 90 | 10 | 50 |
| | 20 | 80 | 20 | 53 |
| | 30 | 70 | 30 | 54 |
| Germinated Saechalbori (%) | 10 | 90 | 10 | 46 |
| | 20 | 80 | 20 | 45 |
| | 30 | 70 | 30 | 48 |

Saesalbori: ungerminated non-waxy barley; Saechalbori: ungerminated waxy barley; Germinated Saesalbori: germinated non-waxy barley; Germinated Saechalbori: germinated waxy barley

### Cooking properties of noodles

Cooked noodles were cooled with tap water for 30 sec and then drained on a sieve for three minutes. The remaining water was further removed by wipe papers. The drained noodles were weighed.

$$Cooking\,yield(\%) = \frac{m_{cookednoodls} - m_{uncooksdnoodls}}{m_{uncookednoodle}} \times 100$$

250 mL mass cylinder was filled with 150 mL water and then uncooked or cooked noodle was placed in the cylinder. The volume of the noodle was determined from the new water level.

$$Volume \in crease(5) = \frac{V_{cookednoodle}\ V_{uncookednoodle}}{V_{uncookednoodle}} \times 100$$

The turbidity of cooking water was determined by measuring the absorbance at 675 nm.

### Dough and noodle color measurement

Dough and noodle color was measured with a color measurement instrument (Minolta JP/CR-300, Minolta, Japan). $L^*$ (lightness), $a^*$ (redness/greenness) and $b^*$ (yellowness/blueness) values were determined. For dough, measurements were done 5 times at random locations on the surface of the dough sheet before being cut into strands. For cooked noodles, measurements were done 5 times at random locations on the surface for each sample immediately after water was wiped out. For white salted noodles, high $L^*$, moderate $b^*$ are more preferred. Products with extremely high value of $a^*$ are considered deleterious (27).

### Noodle texture profile analysis

Texture characteristics of the cooked noodles were analyzed using a Rheometer (Compac-100II, Sung Scientific Co, Ltd, Tokyo, Japan) and attached software with the instrumental conditions (28) showed in Table 2. Hardness, cohesiveness, springiness, gumminess of the samples were analyzed. The average of each parameter was determined from 10 obtained values.

**Table 2. Intrumental conditions for textural measurements**

| Test type | Mastication test |
|---|---|
| Test mode | Mode 21 |
| Max. force of load cell | 10 kg |
| Table speed | 120 mm/min |
| Adaptor (plunger ) | Round type (diameter 20mm) |
| Distance | 12 mm |

### Cooked noodle sensory evaluation

15 participants engaged in the sensory analysis. The participants evaluated noodle color, texture, elasticity, firmness, taste, flavor and overall acceptance with 5-point scale (1: very bad; 2: rather bad; 3: neither good or bad; 4: rather good; 5: very good).

### Statistic analysis

Experimental results were mentioned as means ± SD. Statistical analysis for One-way ANOVA, $p < 0.05$ (Duncan's multiple range test) was done by the PASW Statistics 18 software.

## Results and discussion

### Particle size distribution

The particle size distribution of both types of flour used are shown in Table 3. The median diameter D[v, 0.1] (i.e. the size at which 10% of the particles by volume are smaller), D[v, 0.5] and D[v,0.9], D are given. The results showed that particle size distribution of wheat flour was unimodal. Barley flours had wider range of particle size and larger volume mean diameter. These results may be due to high ability of barley bran to shatter during milling (29), causing difficulty in producing barley flour free of bran particles (5). The penetrating rate of water into flour is affected by particle size of the flour and their distribution (30). Flour with more relatively fine and evenly distributed particle size is more desirable to acquire optimum mixing, larger particle flours requires more time for water incorporation and resulting in larger dough lumps (30). The results predict that incorporating barley to wheat flour would cause difficulties in making good dough.

**Table 3. Median diameter of different types of flour**

| Sample | Mean diameter (μm) | | | | |
|---|---|---|---|---|---|
| | D (v, 0.1) | D (v, 0.5) | D (v, 0.9) | D [4, 3] | D [3, 2] |
| Wheat | 12.52 | 58.34 | 121.11 | 63.45 | 19.69 |
| Refined Saesalbori | 9.49 | 49.45 | 184.10 | 75.87 | 16.91 |
| Refined Germinated Saesalbori | 5.85 | 48.52 | 230.19 | 89.57 | 12.96 |
| Refined Saechalbori | 5.12 | 60.00 | 230.40 | 92.01 | 11.98 |
| Refined Germinated Saechalbori | 6.22 | 57.63 | 239.33 | 95.36 | 13.36 |

D (v, 0.1), D (v, 0.5), D (v, 0.9) (median of 10, 50 and 90% particle diameter) are the size of particle at which 10%, 50% and 90% of the sample is smaller and 90%, 50% and 10% is larger; D[4, 3]: volume mean diameter; D[3, 2]: ratio of total volume of particles to the total surface area.

### Analytical properties

Analytical properties of the barley flours were given in Table 4. The results showed that there was no significant change after germination in ash, protein, lipid and color of the barley used.

Ash and lipid content of mixture of wheat and barleys at various ratios were calculated using the following equation:

$$\% \text{ Ash (or lipid)} = [A \times (100-b) + B \times b] / 100$$

In which A: ash (or lipid) content of wheat, B: ash (or lipid) content of barley, b: concentration of barley used in mixtures.

Addition of refined ungerminated non-waxy barley at 10, 20 and 30% elevated the content ash of the mixture to 0.45, 0.48 and 0.52% respectively, adding refined germinated non-waxy barley at the above concentrations resulted in ash content of 0.45, 0.50 and 0.54%. Ash content of mixture added with refined ungerminated and germinated waxy barley were 0.46, 0.5, 0.55, 0.47, 0.52 and 0.58%. Due to adverse effect on noodle color, ash content has been considered an important specification in noodle processing (26). Wheat with 1.4% or less ass could be considered an advantage in noodle processing. Superior quality noodle are often processed from flours of 0.4% or less ash. The results of ash content in barley flour acknowledged incorporation of barley flours in wheat up to 30% would still result in acceptable ash content of barley-wheat mixture flour.

Lipid content of mixtures of wheat-refined ungerminated and germinated non-waxy barley at 10, 20 and 30% ranged from 0.71 to 0.82% and 0.72 to 0.85% while those of wheat-refined ungerminated and germinated waxy barley at the concentrations were from 0.67 to 0.70% and 0.70 to 0.79%, respectively. Lu et al (31) showed that excess lipid content (e.g., 2.44 g/100 g flour) resulted in weaken noodle structure due to shortening effect and preventing water absorption of cooked noodles. All mixtures had acceptable lipid content.

These results are in agreement with Paras Sharma et al's results (23). This may be attributed to the fact that the phenolic content are mainly located in cell walls (32).

After germination TPC in refined Saesalbori increased. In germinated barleys, refined Saesalbori and refined Saechalbori had TPC of 1401.49 and 1442.55 μg/g FAE, whole Saesalbori and whole Saechalbori had TPC of 2402.68 and 3997.11 μg/g FAE.

Among all the flours, whole Saechalbori and whole germinated Saechalbori had the highest TPC. Except for refined Saesalbori there is no significant difference between ungerminated and germinated samples.

**Table 4. Analytical properties of barley flours**

| Samples | Moisture (%) | Ash (%) | Protein (%) | Lipid (%) | Colour | | |
|---|---|---|---|---|---|---|---|
| | | | | | $L^*$ | $a^*$ | $b^*$ |
| Wheat | 10.37 ± 0.19 | 0.41 ± 0.01 | 14.40 ± 0.16 | 0.66 ± 0.11 | 93.15 ± 0.93 | -0.81 ± 0.03 | 10.40 ± 0.31 |
| Whole Saesalbori | 9.90 ± 0.14 | 1.56 ± 0.12 | 12.62 ± 0.07 | 2.05 ± 0.06 | 88.01 ± 0.07 | 0.72 ± 0.00 | 9.22 ± 0.01 |
| Whole Germinated Saesalbori | 10.26 ± 0.25 | 1.43 ± 0.01 | 13.29 ± 0.13 | 1.68 ± 0.07 | 88.66 ± 0.08 | 1.31 ± 0.01 | 10.68 ±0.02 |
| Refined Saesalbori | 9.81 ± 0.08 | 0.77 ± 0.03 | 9.87 ±0.06 | 1.20 ±0.03 | 91.18 ± 2.60 | 0.60 ± 0.16 | 9.00 ±0.42 |
| Refined Germinated Saesalbori | 11.54 ± 0.05 | 0.85 ± 0.04 | 10.27 ± 0.06 | 1.28 ± 0.13 | 93.65 ± 0.33 | 0.69 ± 0.02 | 9.97 ± 0.14 |
| Whole Saechalbori | 9.69 ± 0.03 | 1.65 ± 0.01 | 13.40 ± 0.08 | 2.26 ± 0.05 | 88.92 ± 0.19 | 0.48 ± 0.01 | 8.76 ± 0.02 |
| Whole Germinated Saechalbori | 7.12 ± 0.15 | 1.61 ± 0.02 | 13.86 ± 0.13 | 2.02 ± 0.06 | 88.55 ± 0.37 | 0.51 ± 0.02 | 9.81 ± 0.02 |
| Refined Saechalbori | 10.08 ± 0.04 | 0.86 ± 0.01 | 10.88 ± 0.18 | 0.80 ± 0.06 | 89.31 ± 0.71 | 0.25 ± 0.04 | 8.08 ± 0.11 |
| Refined Germinated Saechalbori | 12.27 ± 0.06 | 0.97 ± 0.01 | 10.58 ± 0.09 | 1.10 ± 0.09 | 90.71 ± 1.57 | 0.31 ± 0.03 | 8.86 ± 0.45 |

## Total phenolic content and free radical scavenging activity

Total phenolic content (TPC) of barley flours are given in Fig. 1. The results show that compared to wheat, barley had higher TPC. Whole barley flours had much higher TPC than refined flour group. In ungerminated barleys, refined Saesalbori and refined Saechalbori had TPC of 1083.16 and 1713.41 μg/g FAE while whole Saesalbori and whole Saechalbori had TPC of 2384.85 and 3783.39 μg/g FAE.

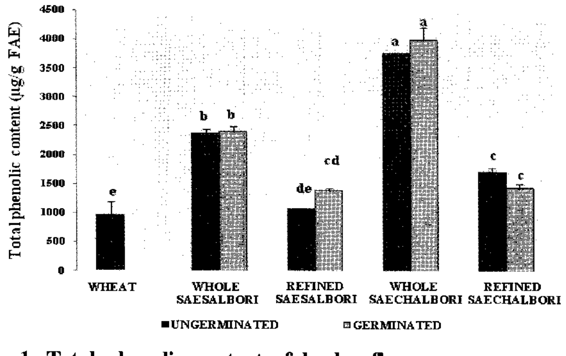


**Fig. 1. Total phenolic content of barley flours.**
Different letters indicate significant difference at $p<0.05$.

In literature, there have been various results of effects of germination on TPC and free radical scavenging activity. Germination increased the polyphenol content and antioxidant activity of lupin seeds (33), but significantly reduced total phenols in studied foxtail millet (34), cereals and legumes (35).

However in our research results, there were no significance changes after germination. This result may be due to the decrease in TPC because of leaching of the substances into the steeping water during soaking and hydrolysis of TPC (34) and the subsequent increase in TPC which could be attributed to the bound phenolic compounds becoming free by the elevated activity of hydrolytic enzyme (36).

Free radical scavenging activity (FRSA,%) of barley flours are given in Fig. 2. Refined germinated Saesalbori had lowest FRSA of 4.83 %. In ungerminated flours, whole Saesalbori and whole Saechalbori had FRSA of 11.98% and 25.82%; refined Saesalbori and refined Saechalbori had FRSA of 6.02% and 9.46%. In both types of barley flours, whole flours had higher free radical scavenging activity than refined flours.

After germination there was increase in free radical scavenging activity found in whole Saesalbori types while there was no significant difference in refined and whole Saechalbori types. Whole germinated Saesalbori and Saechalbori had FRSA of 13.22% and 22.42%, refined germinated Saesalbori and Saechalbori had FRSA of 4.83% and 6.51%. The highest FRSA was found in whole Saechalbori at ungerminated and germinated types, followed by whole germinated Saesalbori.

With higher content of TPC and higher FRSA of germinated barleys compared to those of wheat, addition of barley to noodle would increase functional properties of the product.

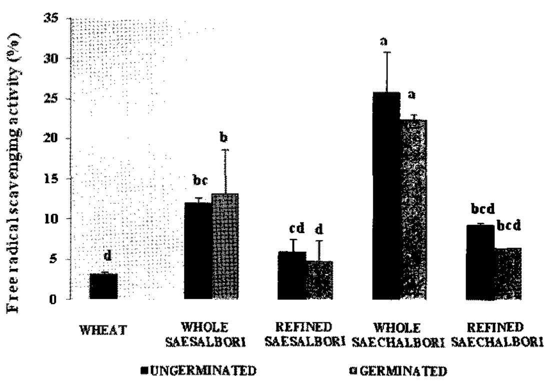


**Fig. 2. Antioxidant activity of barley flours.**
Different letters indicate significant difference at $p<0.05$.

## Pasting properties of barley-wheat composite flours

Pasting properties of composite flour slurries as affected by types and concentrations of barley flours are given in Table 5. Pasting temperature (PT) is the temperature at which the curve leaves the baseline (37). While increasing substituted waxy flours and germinated Saesalbori decreased the PT and PVT values of the slurries, adding Saesalbori up to 30% did not make any significant change in PT and PVT.

Peak viscosity (PV) is a measurement of swelling ability of the starch granules before rupturing (38). While adding Saechalbori decreased peak viscosity of the composite flour, Saesalbori increased PV of the flour. These results are in agreement with Baiks et al's results (39) which have shown increase and decrease in PV of wheat flour added with non-waxy barley and waxy barley, respectively. Increasing germinated Saechalbori and germinated Saesalbori resulted in increase in PV of wheat flour. Low PV would decrease noodle elasticity, appearance (40). Park and Cho (41) also pointed out the relationship between smooth taste and high PV.

Disruption of gelatinized starch granules causes breakdown (BD) of viscosity (42) and setback (SB) is an index of retrogradation tendency of gelatinized starch (43). Adding both types of flour to wheat increased BD and decreased SB values. This suggested that barley composite flour added both types of barley had lower amylose retrogradation than the control flour.

## Quality of cooked noodles

Cooking properties (cooking yield, volume increase and turbidity of soup) of noodles added with barley flours are given in Table 6. Adding Saesalbori up to 30% decreased cooking yield but did not raise volume increase significantly (117.86~141.66%). Cooking yield reflected water absorption capacity of noodles (44). Interestingly, noodle added 10% germinated Saesalbori has lowest cooking yield value of 101.95% while cooking yield of products using the germinated barley flour at 20 and 30% were not significantly lower than the control.

Adding waxy barley did not affect cooking yield and volume increase significantly. In noodles added with germintaed Saechalbori, cooking yield of ranged from 104.65 to 111.90%, volume increases ranged from 125.00 to 134.62%.

Increasing barley level of both types increased turbidity of the cooking water. In non-waxy groups, noodle added with 30% germinated Saesalbori had highest soup turbidity of 0.47 while in waxy groups, noodle added with 30% Saechalbori had highest soup turbidity of 0.40, followed by that of product added with 30% germinated Saechalbori, 0.35.

Turbidity of the soup is caused by solid loss during cooking. High quality noodles should maintain their integrity and have low solid loss during cooking (44). Adding barley flour to the noodle resulted in gluten dilution, hence starch particles could reach out to the cooking water more easily and cause higher turbidity.

## Dough and noodle color

The Hunter colour values (lightness, redness, yellowness) of barley noodles are given in Table 7. In all groups, increasing use of barley flours decreased lightness of both dough and cooked noodles. This may be due to higher phenolic content of barley flours (45). Generally, while lightness decreased with higher content of substituted flours, redness increased and yellowness decreased in all groups. These results are in agreement with Kim et al's results (46) of research on noodle prepared by adding Ge-Geol radish powder.

**Table 5. Pasting properties of composite flour slurries as affected by types and concentrations of barley**

| Samples | | PT (0C) | PVT (0C) | PV (BU) | BD (BU) | SB (BU) |
|---|---|---|---|---|---|---|
| Wheat | | 64.65 ± 0.49$^{a}$ | 91.4 ± 0.14$^{a}$ | 339.00 ± 0.00$^{e}$ | 91.50 ± 7.78$^{e}$ | 189.50 ± 3.54$^{a}$ |
| Saesalbori (%) | 10 | 64.15 ± 0.78$^{a}$ | 91.30 ± 0.00$^{a}$ | 351.00 ± 8.49d$^{e}$ | 114.50± 12.02$^{d}$ | 181.00 ± 4.24$^{ab}$ |
| | 20 | 64.00 ± 0.14$^{a}$ | 90.00 ± 0.14$^{a}$ | 380.50±12.02$^{bc}$ | 141.00 ± 4.24$^{b}$ | 180.50 ± 4.95$^{ab}$ |
| | 30 | 63.60 ± 0.14$^{a}$ | 90.75 ± 0.21$^{a}$ | 396.00 ± 7.07$^{ab}$ | 156.50 ± 0.71$^{a}$ | 177.50 ± 4.95$^{b}$ |
| Germinated Saesalbori (%) | 10 | 63.50 ± 0.42$^{a}$ | 91.15 ± 0.71$^{a}$ | 365.00 ± 5.66$^{cd}$ | 124.00 ± 2.83$^{cd}$ | 180.50 ± 4.95$^{ab}$ |
| | 20 | 61.95 ± 0.92$^{b}$ | 89.85 ± 0.49$^{b}$ | 377.00 ± 0.00$^{c}$ | 137.00 ± 4.24$^{bc}$ | 175.00 ± 1.41$^{b}$ |
| | 30 | 61.90 ± 0.42$^{b}$ | 89.45 ± 0.49$^{b}$ | 402.50 ± 7.78$^{a}$ | 162.50 ± 2.12$^{a}$ | 176.00 ± 1.41$^{b}$ |
| Wheat | | 64.65 ± 0.49$^{a}$ | 91.40 ± 0.14$^{a}$ | 339.00 ± 0.00$^{b}$ | 91.50 ± 7.78$^{d}$ | 189.50 ± 3.54$^{a}$ |
| Saechalbori (%) | 10 | 63.25 ± 0.49$^{b}$ | 90.20 ± 0.57$^{b}$ | 339.50 ± 2.12$^{b}$ | 113.00 ± 1.41$^{c}$ | 172.00 ± 2.83$^{b}$ |
| | 20 | 62.80 ± 0.28$^{bc}$ | 89.20 ± 0.14$^{bc}$ | 329.00 ± 4.24$^{bc}$ | 118.00 ±5.66$^{c}$ | 155.00 ± 1.41$^{d}$ |
| | 30 | 62.15 ± 0.07$^{c}$ | 87.40 ± 0.85$^{d}$ | 320.00 ± 8.49$^{c}$ | 119.00 ± 7.78$^{c}$ | 140.00 ± 1.41$^{f}$ |
| Germinated Sechalbori (%) | 10 | 62.60 ± 0.42$^{bc}$ | 90.05 ± 0.07$^{b}$ | 359.50 ± 3.53$^{a}$ | 126.00± 4.24$^{bc}$ | 175.50 ± 4.95$^{b}$ |
| | 20 | 61.35 ± 0.07$^{d}$ | 89.30 ± 0.28$^{bc}$ | 370.50 ± 4.95$^{a}$ | 146.00 ± 4.24$^{a}$ | 164.00 ± 1.41$^{c}$ |
| | 30 | 59.80 ± 0.00$^{e}$ | 88.25 ± 0.49$^{cd}$ | 368.00 ± 7.07$^{a}$ | 142.00±12.73$^{ab}$ | 147.50 ± 2.12$^{e}$ |

PT: pasting temperature(℃); PVT: peak viscosity temperature(℃); PV: peak viscosity(BU); BD: breakdown(BU);
SB: setback(BU). Different superscripts in a row for a parameter indicate significant difference at $p<0.05$.

**Table 6. Cooking properties of noodles added with different types of barley at various ratios**

| Samples | | Cooking yield (%) | Volume increase (%) | Turbidity of soup ( O.D at 675 nm) |
|---|---|---|---|---|
| Wheat | | 111.45 ± 3.88$^{a}$ | 121.43 ± 0.00$^{b}$ | 0.21 ± 0.00$^{e}$ |
| Saesalbori (%) | 10 | 107.76 ± 3.50$^{abc}$ | 141.66 ± 0.00$^{a}$ | 0.31 ± 0.00$^{b}$ |
| | 20 | 103.75 ± 0.23$^{bc}$ | 126.92 ± 5.44$^{b}$ | 0.27 ± 0.01$^{cd}$ |
| | 30 | 109.95 ± 2.70$^{ab}$ | 117.86 ± 5.05$^{b}$ | 0.24 ± 0.01$^{de}$ |
| Germinated Saesalbori(%) | 10 | 101.95 ± 3.67$^{c}$ | 126.92 ± 5.44$^{b}$ | 0.29 ± 0.00$^{bc}$ |
| | 20 | 111.04 ± 1.89$^{a}$ | 145.83 ± 5.89$^{a}$ | 0.29 ± 0.03$^{bc}$ |
| | 30 | 110.71 ± 1.20$^{a}$ | 145.83 ± 5.89$^{a}$ | 0.47 ± 0.00$^{a}$ |
| Wheat | | 111.45 ± 3.88$^{NS}$ | 121.43 ± 0.00$^{NS}$ | 0.21 ± 0.00$^{e}$ |
| Saechalbori(%) | 10 | 106.75 ± 3.64 | 126.92 ± 5.44 | 0.22 ± 0.00$^{e}$ |
| | 20 | 104.19 ± 6.39 | 130.77 ± 10.88 | 0.25 ± 0.01$^{d}$ |
| | 30 | 112.70 ± 5.68 | 134.62 ± 5.44 | 0.40 ± 0.02$^{a}$ |
| Germinated Saechalbori (%) | 10 | 104.65 ± 2.95 | 130.77 ± 0.00 | 0.34 ± 0.01$^{bc}$ |
| | 20 | 109.52 ± 1.35 | 125.00 ± 5.05 | 0.33 ± 0.01$^{c}$ |
| | 30 | 111.90 ± 2.27 | 134.62 ± 5.44 | 0.35 ± 0.01$^{b}$ |

Different superscripts in a row for a parameter indicate significant difference at $p<0.05$; NS: no significance.

The results show lightness of dough were visibly higher than those of cooked noodles. This also agrees with Jeong et al's results (47) which also found decrease in lightness of noodle added with freeze dried garlic powder. But compared to dough, there was a similar trend of the Hunter color values in noodles when increasing barley.

In non-waxy barley groups, at the same ratios (10, 20 and 30%), lightness of the dough from germinated flour was higher than that from ungerminated flour. Adding Saesalbori and germinated Saesalbori at 10% made no significant decrease in lightness of noodle. Compared to Saesalbori, addition of germinated Saesalbori resulted in more deterioration (higher $a^*$ and lower $b^*$ values). This may be attributed to higher TPC in germinated Saesalbori (1401.49 μg/g FAE) compared to ungerminated Saesalbori (1083.16 μg/g FAE).

**Table 7. Hunter color values of dough and noodle added with different types of barley at various ratios**

| Samples | | Dough | | | Cooked noodle | | |
|---|---|---|---|---|---|---|---|
| | | $L^*$ | $a^*$ | $b^*$ | $L^*$ | $a^*$ | $b^*$ |
| Wheat | | $85.50 \pm 0.21^a$ | $-1.18 \pm 0.02^g$ | $18.51 \pm 0.07^a$ | $79.10 \pm 2.16^a$ | $-2.53 \pm 0.21^f$ | $11.44 \pm 0.50^b$ |
| Saesalbori(%) | 10 | $84.84 \pm 0.15^b$ | $-0.29 \pm 0.05^e$ | $16.48 \pm 0.09^b$ | $75.80 \pm 2.50^a$ | $-1.86 \pm 0.28^e$ | $13.11 \pm 0.89^a$ |
| | 20 | $84.05 \pm 0.35^c$ | $0.17 \pm 0.04^c$ | $15.84 \pm 0.16^c$ | $71.96 \pm 3.99^b$ | $-1.20 \pm 0.21^{bc}$ | $10.80 \pm 0.26^{bc}$ |
| | 30 | $83.29 \pm 0.20^d$ | $0.45 \pm 0.02^a$ | $15.48 \pm 0.15^d$ | $70.53 \pm 1.48^b$ | $-1.05 \pm 0.12^b$ | $9.93 \pm 0.40^c$ |
| Germinated Saesalbori(%) | 10 | $85.19 \pm 0.21^a$ | $-0.42 \pm 0.03^f$ | $16.28 \pm 0.24^b$ | $75.68 \pm 2.45^a$ | $-1.63 \pm 0.11^{de}$ | $10.55 \pm 0.40^{bc}$ |
| | 20 | $84.61 \pm 0.30^b$ | $-0.07 \pm 0.06^d$ | $15.59 \pm 0.11^d$ | $68.42 \pm 4.47^b$ | $-1.37 \pm 0.39^{cd}$ | $9.73 \pm 2.02^c$ |
| | 30 | $83.87 \pm 0.34^c$ | $0.36 \pm 0.08^b$ | $14.94 \pm 0.24^e$ | $68.77 \pm 0.44^b$ | $-0.52 \pm 0.03^a$ | $10.17 \pm 0.06^c$ |
| Wheat | | $85.50 \pm 0.21^a$ | $-1.18 \pm 0.03^e$ | $18.51 \pm 0.07^a$ | $79.10 \pm 2.16^a$ | $-2.53 \pm 0.21^d$ | $11.44 \pm 0.50^b$ |
| Saechalbori(%) | 10 | $84.04 \pm 0.25^b$ | $-0.39 \pm 0.07^d$ | $16.46 \pm 0.16^c$ | $76.55 \pm 2.93^{ab}$ | $-1.78 \pm 0.20^c$ | $10.63 \pm 1.21^b$ |
| | 20 | $84.30 \pm 0.31^b$ | $-0.16 \pm 0.05^c$ | $16.08 \pm 0.15^d$ | $73.01 \pm 3.02^{bc}$ | $-1.69 \pm 0.15^c$ | $11.37 \pm 0.65^b$ |
| | 30 | $84.18 \pm 0.36^b$ | $0.29 \pm 0.09^a$ | $14.27 \pm 0.14^f$ | $69.09 \pm 2.49^d$ | $-1.01 \pm 0.21^a$ | $8.67 \pm 0.58^c$ |
| Germinated Saechalbori(%) | 10 | $85.48 \pm 0.46^a$ | $-0.46 \pm 0.07^d$ | $16.72 \pm 0.22^b$ | $76.30 \pm 2.31^{ab}$ | $-1.64 \pm 0.21^c$ | $12.75 \pm 0.14^a$ |
| | 20 | $85.87 \pm 0.38^a$ | - 0.20 ± 0.07c | $15.74 \pm 0.24^e$ | $74.10 \pm 3.40^{bc}$ | $-1.30 \pm 0.11^b$ | $11.15 \pm 0.42^b$ |
| | 30 | $85.45 \pm 0.40^a$ | $0.00 \pm 0.14^b$ | $15.54 \pm 0.19^e$ | $71.39 \pm 0.70^c$ | $-1.04 \pm 0.07^a$ | $11.41 \pm 0.13^b$ |

$L^*$: degree of lightness (white +100 ↔ 0 black) ± $a^*$: degree of redness/greenness (red +100 ↔ -80 green); ± $b^*$: degree of yellowness/blueness (yellow +70 ↔ -80 blue); Data expressed as Mean ± S.D. Means with different letters are significantly different at $p < 0.05$ by Duncan's multiple rage test.

In germinated Saechalbori groups, lightness of dough was not influenced by wheat-barley ratios but lightness of noodles decreased with increasing concentrations. Lightness of dough added with germinated Saechalbori was higher than that of dough added with Saechalbori. Noodle added with 10% germinated Saechalbori and 10% Saechalbori had highest and lowest yellowness.

## Noodle texture profile analysis

Texture characteristics of cooked noodles by texture analyzer are given in Table 8. As compared to the wheat noodle, barley noodle from both types at 10, 20 and 30% substitution ratios had significantly lower hardness (472.90~372.10 g/cm$^2$ compared to 623.50 g/cm$^2$ in control), which decreased continuously with substitution levels. Downward trend in springiness, cohesiveness and gumminess when increasing use of barley flour was also found. There have been also researches on noodle added with green tea powder (20), freeze dried garlic powder (47), Ge-Geol radish powder (46) showing decrease in hardness with progressive level of added materials.

The dough is considered a gluten matrix filled with starch particles (48). Adding other materials than wheat flour may cause discontinuity in the network and weaken the dough (49). Therefore, decrease in hardness in all groups was expected result.

In non-waxy barley group, noodles added with germinated Saesalbori had higher hardness than those added with ungerminated flour (449.50~427.00 and 424.00~407.4 g/cm$^2$ in germinated and ungerminated type, respectively). Compared to germinated barley noodle, springiness and cohesiveness of ungerminated barley noodle had higher springiness and cohesiveness except for noodles at 10% substitution in which there was no significant difference.

In waxy barley group, noodles added with germinated Saechalbori had lower hardness, springiness and gumminess values than those of noodles added with ungerminated barley flour at the same ratios. Among the groups, noodle added with 30% germinated Saechalbori had lowest hardness, springiness and gumminess. There was no significant difference in cohesiveness among noodles added with waxy barley flours.

## Sensory analysis

Sensory evaluation of cooked barley noodles results are given in Table 9. The results indicate that adding both types of barley flour reduced the sensory scores of the noodles. Compared to instrumental analysis (TPA), the similarities in trend between firmness and TPA hardness, elasticity and TPA springiness when adding barley to noodle were visible.

In non-waxy groups, germinated barley noodles at 10%

**Table 8. Texture characteristics of cooked noodles as affected by types and concentrations of barley flours**

| Samples | | Hardness ($g/cm^2$) | Springiness (%) | Cohesiveness (%) | Gumminess (g) |
|---|---|---|---|---|---|
| Wheat | | 623.50 ± 38.56$^{a}$ | 101.09 ± 1.76$^{a}$ | 85.77 ± 1.28$^{b}$ | 273.14 ± 22.23$^{a}$ |
| Saesalbori(%) | 10 | 423.60 ± 20.61$^{bc}$ | 99.23 ± 1.62$^{b}$ | 85.54 ± 1.25$^{b}$ | 171.43 ± 13.64$^{c}$ |
| | 20 | 424.20 ± 31.99$^{bc}$ | 99.60 ± 2.27$^{ab}$ | 87.24 ± 0.83$^{a}$ | 179.28 ± 14.41$^{c}$ |
| | 30 | 407.40 ± 19.60$^{c}$ | 98.78 ± 1.97$^{b}$ | 85.51 ± 1.68$^{b}$ | 169.49 ± 10.61$^{c}$ |
| Germinated Saesalbori(%) | 10 | 449.50 ± 29.67$^{b}$ | 98.82 ± 1.91$^{b}$ | 83.88 ± 1.27$^{c}$ | 194.86 ±16.27$^{b}$ |
| | 20 | 430.90 ± 23.38$^{bc}$ | 95.74 ± 1.80$^{c}$ | 82.78 ± 1.42$^{c}$ | 170.89 ± 12.41$^{c}$ |
| | 30 | 427.20 ± 7.91$^{bc}$ | 96.38 ± 2.22$^{c}$ | 82.88 ± 1.62$^{c}$ | 178.56 ± 6.51$^{c}$ |
| Wheat | | 623.50 ± 38.56$^{a}$ | 101.09 ± 1.76$^{a}$ | 85.77 ± 1.28$^{NS}$ | 273.14 ± 22.22$^{a}$ |
| Saechalbori(%) | 10 | 472.90 ± 29.92$^{b}$ | 99.66 ± 2.83$^{ab}$ | 85.09 ± 1.48 | 208.76 ± 14.64$^{b}$ |
| | 20 | 408.59 ± 15.73$^{c}$ | 98.73 ± 2.05$^{b}$ | 84.42 ± 1.33 | 159.43 ± 7.61$^{c}$ |
| | 30 | 373.50 ± 42.40$^{d}$ | 99.14 ± 1.81$^{ab}$ | 84.19 ± 4.82 | 137.53 ± 28.99$^{d}$ |
| Germinated Saechalbori(%) | 10 | 396.10 ± 15.34$^{cd}$ | 98.01 ± 2.10$^{b}$ | 85.90 ± 1.22 | 160.26 ± 14.34$^{c}$ |
| | 20 | 391.00 ± 17.49$^{cd}$ | 98.73 ± 2.04$^{b}$ | 84.76 ± 0.68 | 152.94 ± 8.41$^{cd}$ |
| | 30 | 372.10 ± 18.09$^{d}$ | 97.50 ± 2.66$^{b}$ | 85.98 ± 1.88 | 135.64 ± 15.28$^{e}$ |

Different superscripts in a row for a parameter indicate significant difference at $p<0.05$

**Table 9. Sensory analysis of noodles added with different types of barley at various ratios**

| Samples | | Color | Texture | Elasticity | Firmness | Taste | Flavor | Overall acceptance |
|---|---|---|---|---|---|---|---|---|
| Wheat | | 4.07 ± 0.70$^{a}$ | 3.80 ± 1.01$^{ab}$ | 3.73 ± 0.46$^{ab}$ | 3.67 ± 0.82$^{ab}$ | 3.67 ± 0.72$^{a}$ | 3.73 ± 0.88$^{a}$ | 3.87 ± 0.64$^{ab}$ |
| Saesalbori (%) | 10 | 3.93 ± 0.70$^{ab}$ | 3.93 ± 0.46$^{a}$ | 3.73 ± 0.46$^{ab}$ | 3.47 ± 0.74$^{abc}$ | 3.53 ± 0.52$^{a}$ | 3.60 ± 0.63$^{a}$ | 3.87 ± 0.35$^{ab}$ |
| | 20 | 3.40 ± 0.74$^{c}$ | 3.27 ± 0.80$^{bc}$ | 3.60 ± 0.63$^{b}$ | 2.87 ± 0.83$^{cd}$ | 3.13 ± 0.83$^{ab}$ | 3.33 ± 0.82$^{ab}$ | 3.40 ± 0.63$^{b}$ |
| | 30 | 2.67 ± 0.62$^{c}$ | 2.93 ± 0.80$^{cd}$ | 3.00 ± 0.93$^{c}$ | 2.93 ± 0.80$^{cd}$ | 2.87 ± 0.83$^{b}$ | 2.80 ± 0.86$^{b}$ | 2.73 ± 0.88$^{c}$ |
| Germinated Saesalbori (%) | 10 | 4.07 ± 0.70$^{a}$ | 3.87 ± 0.74$^{a}$ | 4.20 ± 0.68$^{a}$ | 4.00 ± 0.76$^{a}$ | 3.53 ± 0.64$^{a}$ | 3.40 ± 0.63$^{ab}$ | 4.13 ± 0.52$^{a}$ |
| | 20 | 3.47 ± 0.64$^{bc}$ | 3.40 ± 0.74$^{abc}$ | 3.67 ± 0.72$^{b}$ | 3.33 ± 0.62$^{bcd}$ | 3.27 ± 0.80$^{ab}$ | 3.27 ± 0.96$^{ab}$ | 3.40 ± 0.63$^{b}$ |
| | 30 | 2.47 ± 0.52$^{c}$ | 2.60 ± 0.51$^{d}$ | 2.60 ± 0.74$^{c}$ | 2.80 ± 0.77$^{d}$ | 2.80 ± 0.56$^{b}$ | 2.80 ± 0.68$^{b}$ | 2.67 ± 0.72$^{c}$ |
| Wheat | | 4.07 ± 0.70$^{a}$ | 3.80 ± 1.01$^{ab}$ | 3.73 ± 0.46$^{ab}$ | 3.67 ± 0.82$^{ab}$ | 3.67 ± 0.72$^{a}$ | 3.73 ± 0.88$^{a}$ | 3.87 ± 0.64$^{a}$ |
| Saechalbori (%) | 10 | 3.33 ± 0.72$^{bc}$ | 3.60 ± 1.06$^{ab}$ | 3.60 ± 1.06$^{ab}$ | 3.33 ± 0.72$^{ab}$ | 3.53 ± 0.99$^{a}$ | 3.60 ± 0.91$^{a}$ | 3.73 ± 0.88$^{ab}$ |
| | 20 | 2.93 ± 0.59$^{cd}$ | 3.13 ± 0.74$^{bc}$ | 3.20 ± 0.94$^{b}$ | 3.13 ± 0.99$^{a}$ | 3.00 ± 1.00$^{ab}$ | 3.07 ± 0.88$^{ab}$ | 3.20 ± 1.01$^{bc}$ |
| | 30 | 2.67 ± 0.62$^{d}$ | 2.60 ± 0.83$^{cd}$ | 2.27 ± 0.80$^{d}$ | 2.40 ± 0.91$^{c}$ | 2.60 ± 0.83$^{b}$ | 2.73 ± 0.8$^{8b}$ | 2.40 ± 0.83$^{d}$ |
| Germinated Saechalbori (%) | 10 | 3.80 ± 0.77$^{ab}$ | 3.87 ± 0.83$^{a}$ | 4.20 ± 0.68$^{a}$ | 3.87 ± 0.64$^{a}$ | 3.67 ± 0.72$^{a}$ | 3.73 ± 0.88$^{a}$ | 3.93 ± 0.46$^{a}$ |
| | 20 | 3.33 ± 0.72$^{bc}$ | 3.60 ± 0.83$^{ab}$ | 3.20 ± 0.77$^{b}$ | 3.07 ± 0.59$^{b}$ | 3.13 ± 0.74$^{ab}$ | 3.13 ± 0.74$^{ab}$ | 3.20 ± 0.68$^{bc}$ |
| | 30 | 2.47 ± 0.74$^{d}$ | 2.40 ± 0.99$^{d}$ | 2.53 ± 0.99$^{c}$ | 2.40 ± 0.73$^{c}$ | 2.73 ± 0.88$^{c}$ | 2.87 ± 0.92$^{b}$ | 2.60 ± 0.91$^{cd}$ |

Different superscripts in a row for a parameter indicate significant difference at $p<0.05$

and 20% has higher scores in color and firmness but similar color and lower score in firmness compared to ungerminated barley noodles. There is no significant difference in taste between noodles from the both types of barley flour. Noodles at level of 20 and 30% germinated barley had no significant difference in overall acceptance from the ungerminated flour noodle samples.

In waxy group, germinated barley noodles had better color (at 10 and 20%) and texture (at all ratios) than ungerminated barley noodles. There is no significant difference in taste and flavor between noodles from ungerminated and germinated barley flours, but germinated barley noodles had lower score in taste at concentration of 30%. Adding germinated barley flour up to 10 and 30% generally resulted in higher overall acceptance score of noodles than that of noodles added with ungerminated flour.

The results showed that using barley flours at 20% would result in acceptable noodles, but using barley up to 30% decreased the sensory charactersitics of the product. Using barley up to 30% should be done along with using additives such as vital gluten to ensure the product quality.

## 요 약

발아 보리쌀을 취반용으로 사용하고 있음에 착안하여서 보리의 이용성 향상을 위해서 새쌀보리와 새찰쌀보리의 발아보리 분말을 밀가루에 첨가한 복합분을 이용한 제면 특성을 조사하였다. 새찰쌀보리 첨가구의 조리면 특성에서 무발아구는 조리 수율과 부피 증가에 영향을 미치지 않았으나 발아 새쌀보리에서는 10% 첨가구가 조리 수율과 부피 증가가 가장 낮았다. 찰보리와 일반보리 모두 혼합량이 증가하면 조리할 때 탁도는 증가하였고, 색도의 명도와 황색도는 감소하나 적색도는 증가하였다. 발아 새찰보리 첨가구의 물성 값에서 경도, 탄성 및 점착성은 감소되었으나 응집성에는 변화가 없었고, 발아 새쌀보리 첨가구에서는 모든 물성 값이 감소되었다. 관능평가에서 10% 발아보리 첨가구의 조리면은 무첨가구와 유의적인 차이가 없었고 20% 첨가구도 우수하였으나 30% 첨가구는 매우 낮게 평가되었다. 발아보리 분말을 20% 혼합한 복한분의 제면에서 조리면의 색도, 탁도 및 관능평가 결과는 제면이 가능한 혼합량으로 판단되었다. 그러나 30% 첨가구는 색상 저하, 탁도 증가, 물성 값 저하 및 관능평가 값 저하로 제면용 혼합량으로 과다한 것으로 판단되었다. 그러나 제면용 첨가제인 글루텐 등을 첨가하면 발아보리 혼합량을 증가시킬 수 있을 것이며 품질도 향상시킬 수 있을 것이다.

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