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Properties of Saltine Crackers: Effect of the Addition of *Doenjang* and *Makgeolli*

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ABSTRACT

In this study, we aimed to evaluate the effect of *doenjang* and *makgeolli* addition on the properties of saltine crackers. Saltine crackers of two types were prepared by adding Korean traditional fermented foods *doenjang* and *makgeolli* that made up a final amount of 10% of the weight of wheat flour and substituted an equal quantity of formula water, respectively. The saltiness of the *doenjang* added crackers (DCs) was adjusted to match that of control crackers (CCs). The peak and hot paste viscosities of the *makgeolli* added crackers (MCs) were significantly lower than those of CCs. However, there was no significant difference in the RVA viscosities between DCs and CCs. Fermented doughs of DCs and MCs were lighter and had a lower pH after sheeting and molding when compared to that of CCs. There was no significant difference in the length of baked crackers; however, DCs and MCs were thinner than CCs. The moisture content of DCs was over 7%, which is suboptimal for a cracker. The DCs showed significantly lower scores in terms of crispy texture and savory taste, whereas scored highest in off-flavor upon sensory evaluation. MCs showed the highest score in terms of hardness and scored relatively high in crispness; they did not show significant difference in terms of off-flavor, savory taste, or aftertaste when compared to CCs. From these results, we concluded that the addition of *doenjang* at 10% of wheat flour weight enhanced fermentation; however, it did not impart desirable qualities, such as moisture content, textural properties, and flavor, to crackers. By contrast, the addition of *makgeolli* instead of formula water improved saltine cracker fermentation, moisture content, texture properties, and flavor.

Key words : Saltine cracker, *Doenjang*, *Makgeolli*

Introduction

Crackers have a low moisture content of $<10\%$, allowing them to have good storability due to less degradation by microorganisms, while they also have the advantages of having lower calories and more fat-free taste than cookies that have higher fat content [1]. Depending on how they are made, crackers can be divided into crackers with a chemical leavening agent added, enzyme-added crackers with protease added, and saltine crackers [2]. When making saltine crackers, flour is fermented with yeast and baking soda, a chemical leavening agent, is added. They have low-fat content and a unique flavor from fermentation. Crackers made by adding only chemical leavening agent or by enzyme added method using protease have the advantage of short production time owing to simple production process [2,3].

On the other hand, saltine crackers that undergo a sponge-dough fermentation process for about 24 hours have a lengthy production process, but they have a unique aroma and crisp texture due to the prolonged fermentation process. Sponge fermen-

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tation takes approximately 16 hours, during which time, the dough becomes acidic (pH change from 6 to 4) and the proteins in the dough act as a buffer to relieve the acidification of the dough to a certain degree. During the fermentation process, the actions of the yeast and microorganisms in air generate aromatic organic substances, which produces a unique aroma, while acid generated during the fermentation process increases the acidity of the dough to harden gluten. Hardened gluten tissue enhances the capture ability of gas generated during fermentation and form a structure with good elasticity [1].

Doenjang or *cheonggukjang* with enhanced physiological functionality from the fermentation of soybeans is being added in various foods. When fermented soybeans are added to food, the activities of amylase and protease in soybeans remain, which enhances the physiological function and causes the physical properties of the food to change. Studies have reported on changes in the physical properties of hard wheat flour dough from adding *doenjang* and *cheonggukjang* [4] and volume increase in bread from adding less than 5.0% of *doenjang* powder [5]. In addition, other studies examined the quality characteristics of baked goods by adding *cheonggukjang* to cookies [6,7] and Job's tears *cheonggukjang* added to cookies [8] and pound cake [9].

Makgeolli has a high nutritional value from proteins, dextrin, dietary fibers, vitamins, and organic acids, in addition to high level of lactic acid bacteria content, while it also contains live yeast [10,11]. Adding *makgeolli* to flour or rice powder gives a unique taste and flavor from yeast fermentation, while also contributing to changes in physical properties. *Jeung-pyeon* is a rice cake made by fermenting and steaming *makgeolli*-added rick powder, where the traditional method uses *makgeolli*, but yeast can be added as well [12,13]. When *makgeolli* is added to the fermentation process of sourdough bread, the dough fermentation time is shortened as compared to using yeast alone, while a unique flavor is added to the bread [14]. Studies with the addition of *makgeolli* to baked goods include *makgeolli* ethanol added to dough [15], *makgeolli* pomace used in bread [16], and freeze-dried *makgeolli* powder added to bread [17].

Studies on crackers have reported on various cracker manufacturing methods [18-22], fermentation of saltine cracker dough [23], and physical properties of saltine crackers [19,24]. Meanwhile, when more than 7.5% of traditional Korean fermented food *doenjang* is added to fermented bread, oven spring decreases, and as the amount of *makgeolli* added increases [5], the volume of *jeung-pyun* decreases [13], but there have been no reports on adding traditionally fermented food to saltine crackers. Accordingly, the present study aimed to manufacture saltine crackers with varying quality by adding traditional Korean fermented food to the saltine crackers. *Doenjang* and *makgeolli* were selected as a traditional fermented food, and a preliminary study was conducted to determine the amount to be added so that as much as possible could be added.

Materials and Methods

1. Materials

Commercial bread flour (Samyang Welfood Co., Incheon, Korea), yeast (Instant yeast, Saf-Levure, Marcq, France), and baking soda (Yoo chung food, Daegu, Korea) were purchased from the commercial market. *Doenjang* was obtained from Chungjungone (Sunchang, Korea) once, refrigerated, and used for the entire experiment. *Makgeolli* (Wookooksaeng, Kooksoondang, Hoengseong, Korea) was stored in the refrigerator for two days from the date of manufacture, and after a period of time, it was newly purchased and used.

2. Analysis of pasting properties of flour

The pasting properties of wheat flour were determined according to AACC method 61-02 [25] using a Rapid Visco Analyzer (RVA Tecmaster, Newport Scientific, Warriewood, NSW, Australia). *Doenjang* added 10% of wheat flour weight, and *makgeolli* added the same amount of formula water instead of water. The moisture content of *doenjang* was measured, and the amount of water added was adjusted to the same moisture content as the control. A programmed heating and cooling cycle was used, where the sample was held at 30°C and 40 rpm for 1 h, before heating to 50°C for 1 min and then to 95°C for 3 min 48 s, holding at 95°C for 2 min 30 s, followed by cooling to 50°C over 3.8 min, and then holding at 50°C for 1.4 min. The peak viscosity (PV), hot paste viscosity (HPV) after holding at 95°C, final viscosity at 50°C (cold paste viscosity, CPV), breakdown (BD = PV − HPV), and setback (SB = CPV − PV) were recorded.

3. Preparation of crackers

Preparation and baking of control wheat saltine crackers were performed according to the one-stage fermentation method [20] of cracker making as shown in Table 1. Using a dough mixer (Micro Mixer, National MFG, Lincoln, NE, USA), we

Table 1. Formula of saltine crackers mixed with and without *doenjang* and *makgeolli* (unit: g)

Ingredient	Control cracker	*Doenjang* cracker	*Makgeolli* cracker
Wheat flour	100	100	100
Water	29	25.8	–
Yeast	0.7	0.7	0.7
Sodium bicarbonate	0.45	0.45	0.45
Salt	1.6	1.3	1.6
Shortening	11	11	11
Doenjang	–	10	–
Makgeolli	–	–	29

kneaded the dough for 2 min, scraped off the edges, and repeated the process for 4 min and then for 2 min. The kneaded dough was placed into a beaker covered with cheesecloth, which was then placed in the fermenter (Softmill, Dae Hung Co., Seoul, Korea) for 18 h of fermentation (30±2°C, 85±5 relative humidity). The fermented dough was rolled at 2.5 mm roll interval, and the dough, folded in half, and laminated; this process was repeated five times. After setting the roller (Atlasmotor, Marcato, Italy) interval at 3.0 mm, the dough was rolled three times and placed on the cutting mold (cutter-docker, 50 mm in width, 50 mm in length, 13 holes) to be cut into cracker shapes. Finally, crackers were placed on the baking rack, baked in a Softmill electrically heated deck oven (Dae Hung Co.) at 180°C for 27 min, cooled in a desiccator at 25°C to reduce moisture absorption from the air, and used in the experiments.

The mixing ratio of the dough for *doenjang*-added cracker (DC) with *doenjang* added by 10% of flour weight was adjusted as shown in Table 1. The moisture content in *doenjang* was measured, and the amount of distilled water added was reduced to make sure the moisture content in the dough was equivalent to that of the control cracker (CC). Moreover, considering the salt content in *doenjang*, the amount of salt added was reduced by 0.3 g. The preparation method was the same as the control, but the baking time was shortened to 11 min. The mixing ratio of *makgeolli*-added cracker (MC) was based on an existing cracker mixing ratio, but *makgeolli* was substituted in place of water. The preparation method was the same as the control, but the baking time was shortened to 18 min. At least three batches of all crackers mentioned above were produced.

4. Determination of dough pH

After pasting the dough using the same method to make the crackers according to the mixing ratios (Table 1), 30 g of dough was placed in 30 mL of distilled water and mixed in a mixer (Mini blender, Philips Co., Amsterdam, Netherlands) for 30 sec to create a suspended solution. The pH of the suspended sample was measured using a pH meter (420A Thermo Orion pH meter, Seoul, Korea). The pH of the fermented dough was measured by fermenting the dough made by the same method as the crackers for 18 h and creating a suspended solution by the same method mentioned above.

5. Analysis of cracker physical properties

Before the analysis of moisture content, crackers were crushed with a mortar and pestle. The moisture content of crackers was determined using the AACC-approved Method 44-15A 02 [25] with an infrared moisture analyzer (MB45, Ohaus Co., Parsippany, US). The weight was determined at ambient temperature 2 h after baking. Thickness and width of crackers were measured using a Vernier caliper (Skyndex System 1, Skyndex, LLC, Albuquerque, NM, USA). The width was the average of four edges of the quadrangular cracker, and the thickness was measured 5 mm away from the center of the quadrangular cracker. Data were obtained by averaging measurements from 20 random samples of each cracker.

The hardness and fracturability of crackers were determined using a texture analyzer (TA Express; Texture Technologies Corp., Scarsdale, NY, USA) equipped with a three-point bend rig. The maximum force of was recorded as the hardness and the peak before maximum force to fracture was recorded as the fracturability. The measurement condition of cycle test was compression mode, pre-test speed 2.0 mm/s, trigger force 3 g, test speed 0.5 mm/s, test distance 6 mm.

6. Sensory evaluation

Attribute difference test of crackers was performed by a panel of 15 college students majoring in food and nutrition who were selected and trained. The samples were stored at room temperature in a desiccator. All panel members were given the same four types of samples, which were tested repeated for a total of three times over three days. The evaluation involved the following steps: first, evaluation of hardness after biting the cracker sample with the front teeth; second, evaluation of crispness after biting the cracker sample with the molars and nutty flavor and off-flavor tasted during this process; and third, evaluation of after taste after swallowing the cracker sample. The evaluation sheet used a nine-point scale with higher scores given for stronger traits.

7. Statistical analyses

All of the analyses were repeated at least three times, and statistical analyses were performed using SPSS version 20.0. ANOVA was conducted to determine significant differences among samples and Duncan's multiple range test ($p<0.05$) was used for multiple comparisons.

Results and Discussion

1. Pasting properties of flour

The pasting properties of flour used to make the crackers were as shown in Table 2. Viscosity (PV, HPV, and CPV), which represents the pasting properties of the *makgeolli*-added and *doenjang*-added wheat flour, was lower than the control flour. In particular, the *makgeolli*-added flour showed significantly lower PV and HPV than the control ($p<0.05$). The *doenjang*-added samples did not show significant differences in all measured values for pasting properties, as compared to the control, but they showed a decreasing tendency. A study by Kang et al. [4] also reported that the pasting viscosity was lower in *doenjang*-added or *cheonggukjang*-added powder.

2. pH of the fermented dough

The pH of unfermented dough of the *doenjang*-added and *makgeolli*-added dough showed significant differences ($p<0.05$), but no significant differences when compared to the control dough (Table 3). The pH measured after fermentation was highest in control and decreased significantly in the order of *doenjang*-added and *makgeolli*-added samples. The pH of dough becomes acidic due to organic acids and carbon dioxide generated during the fermentation process [1], where the pH in *doenjang*-added and *makgeolli*-added dough decreased even further. It is believed that such decrease in pH was due to the fact that yeast fermentation was activated by the by sugars, such as glucose and maltose introduced from *doenjang* and *makgeolli* as yeast nutrients [5]. Especially, the involvement of microorganisms introduced from *makgeolli* promoted the more carbon dioxide generation and decreased the pH of dough in the fermentation period.

3. Physical properties of crackers

The measurements of the external size of the crackers, such as weight, length, and thickness were as shown in Table 4. Compared to the control (8.43 g), DC (6.85 g) had lower weight before baking. Such phenomenon can be attributed to the fact that although the doughs were pasted with equivalent moisture content, the extensibility of *doenjang*-added dough increased especially after the fermentation process, and as a result, kneading the dough by same intervals produced a relatively thinner and lighter sheet. Therefore, even after baking, DC, which had the lightest dough before baking, was the lightest. Because this phenomenon appears during fermentation, a preliminary experiment was conducted with fermentation time shortened from 18 to 12 hours. The dough still showed high extensibility and low

Table 2. RVA pasting properties of wheat flour with the addition of *doenjang* and *makgeolli* (unit: RVU)

	Control flour	*Doenjang* added flour	*Makgeolli* added flour
PV[1)]	$227.86\pm8.46^{b2,3)}$	209.25 ± 8.17^{b}	166.53 ± 27.34^{a}
HPV	146.33 ± 7.18^{b}	133.14 ± 14.05^{b}	90.28 ± 12.87^{a}
CPV	245.14 ± 7.93^{a}	222.56 ± 13.96^{a}	203.67 ± 31.17^{a}
BD	81.53 ± 9.33^{a}	76.11 ± 5.88^{a}	76.25 ± 19.48^{a}
SB	98.81 ± 5.79^{a}	89.42 ± 0.38^{a}	113.39 ± 20.80^{a}

[1)]PV: peak viscosity; HPV: hot paste viscosity; CPV: cold paste viscosity; BD: breakdown; SB: setback.
[2)]Mean±SD.
[3)]Within a row, values with different letters are significantly different ($p<0.05$) using Duncan's multiple range test.

Table 3. pH values of dough with the addition of *doenjang* and *makgeolli*

	Control dough	*Doenjang* dough	*Makgeolli* dough
Before fermentation	$6.76\pm0.14^{ab1,2)}$	6.57 ± 0.11^{a}	6.84 ± 0.08^{b}
After fermentation	6.46 ± 0.05^{c}	5.82 ± 0.05^{b}	5.68 ± 0.02^{a}

[1)]Mean±SD.
[2)]Within a row, values with different letters are significantly different ($p<0.05$) using Duncan's multiple range test.

Table 4. Moisture content, weight, and dimension of crackers

	Control cracker	*Doenjang* cracker	*Makgeolli* cracker
Weight (g) before baking	$8.43\pm0.41^{b1,2)}$	6.85 ± 0.86^{a}	8.57 ± 0.63^{b}
Weight (g) after baking	6.13 ± 0.20^{b}	5.32 ± 0.78^{a}	6.54 ± 0.29^{c}
Weight loss (%/g)[3)]	27.3 ± 0.14^{c}	22.3 ± 0.23^{a}	23.7 ± 0.10^{b}
Moisture contents (%)	2.35 ± 0.60^{a}	7.32 ± 0.61^{b}	3.61 ± 1.28^{a}
Length (mm)	45.74 ± 2.65^{a}	45.99 ± 3.65^{a}	46.38 ± 2.51^{a}
Thickness (mm)	7.15 ± 1.61^{b}	6.33 ± 0.87^{a}	6.22 ± 1.13^{a}

[1)]Mean±SD.
[2)]Within a row, values with different letters are significantly different ($p<0.05$) using Duncan's multiple range test.
[3)]Weight loss (%/g) = (weight before baking-weight after baking) × 100/weight before baking

volume expansion, while the tissue became harder after baking. Therefore, since shortening the fermentation time did not have a positive effect on the quality of *doenjang*-added dough, the fermentation time was set to be the same as the control.

For moisture loss rate during baking, when the difference between the weight before and after baking was calculated as a percentage relative to 1 g of weight before baking, the control showed the significantly ($p<0.05$) highest loss rate of 27.3%. The reason why the weight of crackers decreases after baking is because volatile substances and moisture in fermented product evaporate during baking. It is believed that by adding *makgeolli* or *doenjang* to the dough during the fermentation process, hydrophilic substances, such as sugars and peptides produced from fermentation, bonded with moisture in the dough to show less evaporation than the control. Such results confirmed that moisture content was significantly ($p<0.05$) highest in DC (7.32%), while MC (3.61%) showed higher moisture content than CC (2.35%), although the difference was not significant. In particular, the moisture content in DC was ≥7%, which was much higher than the typical moisture content of around 2.5% for crackers [26], and thus, not desirable for crackers.

There were no significant differences in the length of the cracker samples. Therefore, it is believed that there are no differences based on spread during baking, unlike cookies. The thickness was significantly ($p<0.05$) thinner in DC and MC than CC. Concerning the differences in thickness, it is believed that the most likely cause is the thickness of the sheet being thin before baking due to increased extensibility of the dough after fermentation, as mentioned earlier. Also, it is also believed that *doenjang* and *makgeolli* interfered with the formation of flour gluten network structure, which reduced the amount of increase in volume after fermentation [5,27]. Such results were also reported in another study, in which, oven spring decreased rapidly when *doenjang* was added by more than 7.5% [5] and a study on *jeung-pyeon*, in which, adding more *makgeolli* resulted in greater reduction in volume [13].

4. Textural properties of cracker

The analysis results on the mechanical properties of crackers are shown in Table 5. Hardness and fracturability, which are two values that represent the physical properties of crackers, showed significant ($p<0.05$) differences in the order of DC< MC< CC. It is believed that the reason why hardness was lower in DC or MC than CC was due to the phenomenon that appears from less gluten formation when the moisture content is high. Generally, fracturability can have two meanings; crispness and hardness. Just as in a study on sugar alcohol-added cookies [28], the present study penetrated the product with a blade that is shaped similar to front teeth to measure the product breaking after a single attempt, and thus the meaning is similar to the latter. Such results were also confirmed in another study, in which the strength of noodles decreased when *doenjang* powder was added [27], and another study, in which, the hardness of bread decreased when *doenjang* was added [5]. Based on the results above, it was confirmed that DC and MC fracture less and are softer than CC.

5. Sensory properties of crackers

The sensory evaluation results were as shown in Table 6. The hardness of crackers appeared in the order of DC<CC<MC. These results were inconsistent with the results shown in Table 5, where hardness was measured mechanically. In the mechanical measurement, CC showed the highest hardness value, whereas, in the sensory evaluation, MC showed the highest hardness value. It is believed that the members of the panel may have felt that MC was harder than CC due to MC with a thin thickness, as shown in Table 4, had less rise due to well-formed gluten tissue than CC which formed layers after fermentation. The crispness of crackers appeared in the order of DC<MC<CC. Relative to MC and CC, DC showed very low crispness.

Table 5. Texture properties of crackers with the addition of *doenjang* and *makgeolli*

	Control cracker	*Doenjang* cracker	*Makgeolli* cracker
Hardness (kg)	5.89±1.44[c1,2)]	4.05±0.43[a]	4.93±1.35[b]
Fracturability (kg)	4.28±1.55[b]	2.69±1.04[a]	3.20±1.19[a]

[1)]Mean±SD.
[2)]Within a row, values with different letters are significantly different ($p<0.05$) using Duncan's multiple range test.

Table 6. Mean sensory evaluation score of sensory attributes of crackers with the addition of *doenjang* and *makgeolli*

	Control cracker	*Doenjang* cracker	*Makgeolli* cracker
Hardness	6.20±1.13[b1,2)]	2.36±1.11[c]	7.10±0.95[a]
Crispiness	6.67±1.05[a]	1.68±0.76[c]	5.60±1.42[b]
Nutty taste	6.10±1.32[a]	3.98±1.96[c]	5.39±1.20[b]
Off-flavor	3.45±1.86[b]	6.37±1.92[a]	4.14±1.89[b]
After taste	5.10±1.57[a]	5.23±1.87[a]	5.08±1.51[a]

[1)]Mean±SD.
[2)]Within a row, values with different letters are significantly different ($p<0.05$) using Duncan's multiple range test.

In the evaluation of taste and flavor of crackers, nutty taste appeared in the order of DC < MC < CC. Concerning off taste, there was no significant ($p < 0.05$) difference between MC and CC, which confirmed that there was no unique alcohol smell from adding *makgeolli*. However, since DC showed a significant difference against CC, it was confirmed that the unique off taste of *doenjang* was present in the crackers. There were no significant differences between the samples for after taste that remained after eating the crackers. Therefore, it is believed that adding *doenjang* or *makgeolli* does not leave any specific after taste.

Conclusion

In the present study, crackers were prepared by adding traditional Korean fermented food *doenjang* (10%) or *makgeolli* (instead of water in the dough) to the basic ingredients of saltine crackers. Adding *makgeolli* resulted in a significant ($p < 0.05$) decrease in PV and HPV of flour, whereas adding *doenjang* resulted in decreased viscosity, but with no statistical significance. Adding *doenjang* or *makgeolli* affected the fermentation process to cause a significant decrease in dough pH. In this study, both *doenjang* and *makgeolli* which contained low molecular weight sugar produced during fermentation were used as yeast nutrients in cracker dough to promote fermentation. However, the difference between *doenjang* and *makgeolli* is that since the *doenjang* was a heated treated commercial product, the microorganisms of the *doenjang* were inactivated and had no further effect on the fermentation process of the crackers. On the other hand, microorganisms of raw *makgeolli* without heat treatment was involved in the dough fermentation process of cracker.

Although there were no significant differences in cracker length, DC was thinner and lighter than CC. CC had the highest weight loss rate during the baking process, which is believed to be the result of increased levels of sugars and amino acids from mixing *makgeolli* or *doenjang* or the fermentation process bonding with moisture to reduce evaporation. Consequently, moisture content in cracker was higher than CC and it also affected the texture to cause the crackers to be less crisp. In particular, adding *doenjang* resulted in moisture content being ≥7%, which caused the crackers to be soft and lack crispness. DC showed the lowest values in the evaluation of crispness and nutty taste while showing the highest value for off taste. On the other hand, MC was harder and crisper than DC, while showing no significant differences in off taste and after taste as compared to CC. The results in the present study showed that adding 10% *doenjang* to crackers resulted in higher moisture content, less crispness, and nutty taste, and more off taste, making the product quality not desirable. Therefore, additional studies are needed on reducing the amount of *doenjang* added or on pre-treatment of *doenjang* to control the physical properties of dough and reduce off taste to increase the amount of *doenjang* add to above 10%. On the other hand, crackers with an equal amount of *makgeolli* in place of water needed in dough showed no significant ($p < 0.05$) difference in moisture content, as compared to CC. Moreover, although MC showed less crispness and nutty taste than CC, there were no significant differences in off taste and after taste. Therefore, *makgeolli* may be useful as an additive for saltine crackers.

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