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Research Note

Changes in Quality of Dried Rice Cake Using Perforation Process and Drying Methods

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Abstract

Korean sliced rice cakes, or *tteokguk,* are conventionally dried and rehydrated during their preparation. In this study, the effects of the perforation process and various drying methods (e.g., hot-air drying, vacuum drying, low temperature drying, and freeze drying) on the quality characteristics of *tteokguk* (rice cake soup) were evaluated. In the experiment, the rehydration capacity and lightness increased as the pore number increased. The hardness, redness, and yellowness of *tteokguk*, in contrast, tended to decrease as perforations increased. The texture, taste, and overall acceptability scores of *tteokguk* increased as perforations increased. With respect to drying methods, the rehydration capacity was greatest for vacuum drying. The hardness of *tteokguk* was lowest for vacuum drying. The redness, yellowness, pH, and sensory characteristics did not differ significantly among *tteokguk* samples treated through various drying methods. These results suggest that high-quality ready-to-eat Korean sliced rice cakes could be created by perforation and vacuum drying.

Key words: sliced rice cake, perforation, drying method, rehydration capacity, hardness

Introduction

Garaeddeok is the most extensively consumed steam-cooked rice cake in Korea. *Garaeddeok* is a popular item during festivals and is sliced to cook rice pasta soup (*tteokguk*) and stir-fried rice cakes (*tteokbokki*) (Kang et al., 2012). *Tteokguk* has a high nutritional value and demand is increasing (Yoon & Oh, 2014). However, *tteokguk* contains starch, which goes through progressive retrogradation, resulting in the deterioration of texture and flavor (Kim et al., 1996; Son et al., 1997). The retrogradation of starch is affected by various factors, especially moisture and storage conditions (Kum et al., 1995). Previous studies of rice cakes have focused on the effects of additives or cooking methods on retrogradation and quality (Baker & Rayas-Duarte, 1998; Kang et al., 1997; Song & Park, 2003).

The current market focuses on rapidly supplied ready-to-eat *tteokguk* (Bae et al., 2016). *Tteokguk* is dried before delivery to the market and is rehydrated before it is sold to customers (Kim et al., 2013). The swelling of dried food takes more time than drying due to differences in thermal conductivity and diffusion (Lim et al., 1999). Accordingly, the quality of dried food products is strongly affected by the drying and swelling processes. To rehydrate food products, hydrothermal water can be used to transfer heat from the surface to the center of the food. Recently, microwave heating has become popular, as it transfers heat to the center of the food in a uniform manner within a short period of time. However, in the case of ready-to-eat *tteokguk*, rehydration requires a long time. Thus, a technique for uniform swelling in a short period of time is required. The perforation process has been used to shorten the cooking time and increase food quality (Kim et al., 2002). However, this process has only been studied using hamburger patty processing technology.

Therefore, in this study, the effects of the number of perforations on the quality of *tteokguk* were evaluated. The optimal number of perforations to prevent the loss of *tteokguk* quality was determined. Furthermore, various drying methods including hot-air drying, vacuum drying, low-temperature drying, and freeze drying were evaluated to identify a simple method that can be widely implemented in the food industry globally.

Materials and Methods

Manufacturing process for *tteokguk*

Ready-to-eat *tteokguk* was manufactured according to the methods described by Kim et al. (2013). The rice was

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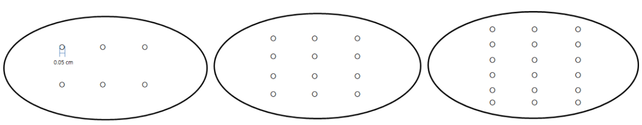
pulverized twice in a roller mill (KM-18, Kyungchang Machine, Seoul, Korea) using wet milling method. To homogenize the particles, the rice flour was filtered through a 20-mesh sieve. *Garaeddeok* was manufactured by re-sifting the rice powder for 20 min on a loose sieve while pouring water over it, followed by 20 min of steaming. The heat was dissipated for an additional 10 min. The steam-cooked rice dough was injected into a juicer (NJE-3570, NUC, Daegu, Korea) to form *garaeddeok*. Then, *garaeddeok* (diameter: 2.8 cm) was cooled at room temperature (25°C) for 3 h. *Garaeddeok* was sliced to make *tteokguk* (thickness: 0.4 cm) and packaged in a 0.2-mm PE film. The moisture content, water activity, and color (Hunter *L*, *a*, *b*) of *tteokguk* were measured.

Perforation process

Pores were formed on the surface of the *tteokguk* after lowering the surface temperature. The pore size of *tteokguk* was 0.05 cm, and the number of pores varied; the control had zero pores and the treatments had 6 pores, 12 pores, and 18 pores. The pore pierced the hole using the 0.05 cm needle, and the position of hole was as follows. The samples were dried using hot-air drying (55°C, CT-FDO42, Coretech, Ansung, Korea).



(6 pores) (12 pores) (18 pores)

Drying methods

Tteokguk with 0.05cm pore size and 18 pore numbers was dried using various methods: hot-air drying (55°C, CT-FDO42, Coretech, Ansung, Korea), vacuum drying (55°C, VFD03, Bocholt, Germany), low-temperature drying (45°C, Sulzle Klein, Niederfischbach, Germany), and freeze-drying (-40°C, DC-41A, Yamato Scientific Co. Ltd., CA, USA). The pores were formed on the surface of the *tteokguk* and dried until the moisture content reached 45%. The physicochemical and sensory properties were then evaluated.

Rehydration capacity

Rehydration experiments were performed by weighing dried samples and immersing them in hot water (100°C) for 3 min. At 0.5-min intervals, the samples were drained over a mesh and quickly blotted gently with paper towels to eliminate the surface water before samples were reweighed. The rehydration capacity, described as the percentage water gain, was calculated from the sample weight difference before and after rehydration.

Hardness

The hardness value of the sliced sample (2 × 2 × 2 cm) was measured using a texture analyzer (TA-XT2*i*, Stable Micro Systems Ltd., Surrey, England). Samples were placed parallel to the center of the plate. A two-bite compression test was used to calculate the hardness (kg) of the sample. The analysis was performed at a maximum load of 2 kg, head speed of 2.0 mm/s, post-speed of 1.0 mm/s, deformation rate of 30%, probe (φ20 mm cylinder probe), distance of 8.0 mm, and force of 5 g.

Color

Using a colorimeter (Chroma Meter, CR 210, Minolta, Osaka, Japan), the surface color of samples was determined. *L*-values (lightness), *a*-values (redness), and *b*-values (yellowness) were measured, and the color values of the calibration plate were as follows: *L* (97.83), *a* (-0.43), and *b* (1.98).

pH

Five grams of sample were homogenized with 50 mL of distilled water at 8,000 rpm using Ultra-Turrax (Model NO. T25, Janken & Kunkel, Staufen, Germany), and pH was measured using a pH meter (Model 340, Mettler-Toledo, Greifensee, Switzerland).

Sensory evaluation

Sensory characteristics were evaluated by selecting 12 panelists. Their preferences were evaluated with respect to the perforation process and drying methods. *Tteokguk* was sliced at a thickness of 0.5 cm. The evaluation was conducted using a 9-point scale in terms of appearance color, flavor, texture, taste, and overall acceptability. The degree of hardness was rated on a scale of 1 to 9, with 1 being very hard and 9 being very moist and soft. The degree of acceptability was also expressed on a scale of 1 to 9, with 1 indicating very bad and 9 indicating very good.

Statistical analyses

Each measurement of a physical characteristic was conducted in triplicate and mean values within the triplicates were obtained for statistical analyses. To determine the significance of the observed differences among the thawing methods, the general linear model (GLM) procedure of Statistics Analytical System (SAS) (version 9.12; SAS Inst., Inc., Cary, NC, USA) was used ($p<0.05$). Duncan's multiple range test ($p<0.05$) was used to determine differences between treatment means.

Results and Discussion

Moisture content, water activity, and color of *tteokguk*

Before *tteokguk* was perforated and dried, the moisture content of *tteokguk* was 48.52%, the water activity was 0.999, and the color (Hunter *L*, *a*, *b*) was 71.85, -1.72, and 5.95, respectively.

Effect of perforation on *tteokguk*

Changes in the physical properties in response to different pore numbers in *tteokguk* are summarized in Table 1. The rehydration capacity increased as the number of perforations increased. In contrast, the hardness of *tteokguk* tended to decrease as the number of perforations increased. The lightness value for the control *tteokguk* was significantly ($p<0.05$) lower values than those for the perforation treatments. The redness value for the control was the greater than those for the perforation treatments. The yellowness of *tteokguk* was lower in perforated samples than in the control. The pH of *tteokguk* did not differ among the perforation treatments ($p>0.05$). The sensory characteristics of *tteokguk* with various pore numbers are shown in Table 2. There was no significant difference in appearance color, and flavor scores between the control and perforation treatments. The texture, taste, and overall acceptability scores increased as the number of pores increased. There is no research on the perforation of starchy foods. Thus, a high number of pores improve the rehydration capacity, hardness, and overall acceptability, controlling for the external features of the *tteokguk.*

Effects of drying methods on *tteokguk*

The physical properties of *tteokguk* treated by different drying methods are shown in Table 3. The rehydration capacity was greatest for samples subjected to vacuum drying. The hardness was greatest for low-temperature drying and was lowest for vacuum drying. The lightness values were significantly greater for hot-air drying than for the other treatments. The redness and yellowness values of *tteokguk* did not differ significantly among samples treated with different drying methods. The pH of *tteokguk* did not differ significantly with respect to the drying method. There were no differences in sensory characteristics (appearance color, flavor, texture, taste, and overall acceptability) among the drying methods. Lim et al. (1999) reported that the effects of drying type on the physical, chemical, and sensory properties of Korean rice cake. They are reported that a significant difference in hardness between microwave and hot air treated rice cake. Choi et al. (2007) reported that the change of quality

Table 1. Physicochemical properties of Korean sliced rice cakes (*tteokguk*) according to the perforation process

	Control	6 holes	12 holes	18 holes
Rehydration capacity	112.54±0.80^{b}	112.83±0.56^{b}	113.35±1.04^{ab}	114.42±0.65^{a}
Hardness (kg)	2.48±0.05^{a}	2.39±0.03^{b}	1.99±0.03^{c}	1.52±0.04^{d}
CIE L^*-values	68.28±1.94^{b}	69.91±1.87^{ab}	70.84±1.15^{a}	71.48±0.68^{a}
CIE a^*-values	-1.47±0.13^{a}	-1.60±0.08^{b}	-1.75±0.10^{bc}	-1.80±0.16^{c}
CIE b^*-values	4.89±0.40^{a}	4.87±0.67^{a}	4.55±0.89^{ab}	4.00±0.51^{b}
pH	5.51±0.02^{a}	5.52±0.02^{a}	5.50±0.02^{a}	5.53±0.03^{a}

All values are means±SD of three replicates
$^{a-d}$Means with different superscripts in the same row are significantly different at $p<0.05$ by Duncan's multiple range test.

Table 2. Sensory characteristics of Korean sliced rice cakes (*tteokguk*) according to the perforation process

	Control	6 holes	12 holes	18 holes
Appearance color	8.32±1.01^{a}	8.28±0.89^{a}	8.27±0.92^{a}	8.31±0.82^{a}
Flavor	8.14±0.92^{a}	8.18±0.74^{a}	8.03±0.39^{a}	8.13±0.97^{a}
Texture	7.84±1.20^{a}	8.00±0.97^{a}	8.14±0.88^{a}	8.37±0.78^{a}
Taste	7.42±0.74^{b}	8.14±0.31^{ab}	8.28±0.67^{a}	8.31±0.82^{a}
Overall acceptability	7.31±0.93^{b}	7.98±0.77^{ab}	8.31±0.74^{a}	8.42±0.98^{a}

All values are means±SD of three replicates
$^{a-c}$Means with different superscripts in the same row are significantly different at $p<0.05$ by Duncan's multiple range test.

Table 3. Physicochemical properties of Korean sliced rice cakes (*tteokguk*) according to drying methods

	HD[1)]	VD	LTD	FD
Rehydration capacity	114.42±0.65[b]	115.42±0.52[a]	114.35±0.42[b]	114.98±0.47[a]
Hardness (kg)	1.52±0.04[a]	1.41±0.04[b]	1.55±0.04[a]	1.47±0.04[ab]
CIE L^*-values	71.48±0.68[a]	70.49±0.21[a]	70.87±0.14[a]	70.29±0.17[b]
CIE a^*-values	-1.80±0.16[a]	-1.78±0.18[a]	-1.72±0.12[a]	-1.77±0.11[a]
CIE b^*-values	4.00±0.51[a]	4.54±0.63[a]	4.05±0.58[a]	4.34±0.72[a]
pH	5.53±0.03[a]	5.52±0.02[a]	5.51±0.03[a]	5.52±0.02[a]

All values are means±SD of three replicates
[a-d]Means with different superscripts in the same row are significantly different at p<0.05 by Duncan's multiple range test.
[1)]HD (hot air dryer, 55°C), VD (vacuum dryer, 55°C), LTD (low temperature dryer, 45°C), and FD (freeze dryer, -40°C).

Table 4. Sensory characteristics of Korean sliced rice cakes (*tteokguk*) according to drying methods

	HD[1)]	VD	LTD	FD
Appearance color	8.31±0.82[a]	8.31±0.72[a]	8.35±0.87[a]	7.98.±0.88[a]
Flavor	8.13±0.97[a]	8.14±0.82[a]	8.10±0.78[a]	8.15±0.96[a]
Texture	8.37±0.78[a]	8.45±0.82[a]	8.17±0.85[a]	8.19±0.71[a]
Taste	8.31±0.82[a]	8.47±0.93[a]	8.31±0.92[a]	8.38±0.87[a]
Overall acceptability	8.42±0.98[a]	8.48±0.72[a]	8.28±0.48[a]	8.32±0.78[a]

All values are means ± standard deviation of three replicates
[a-d]Means with different superscripts in the same row are significantly different at p<0.05 by Duncan's multiple range test.
[1)]HD (hot air dryer, 55°C), VD (vacuum dryer, 55°C), LTD (low temperature dryer, 45°C), and FD (freeze dryer, -40°C).

characteristics of rice flour according to the drying method was not significant. Thus, vacuum drying is optimal for *tteokguk* and ready-to-eat rice cake *tteokguk* can be developed by combining the perforation process with vacuum drying. The sensory characteristics of *tteokguk* with treated by different drying methods are shown in Table 4. There was no significant difference in appearance color, flavor, texture, taste, and overall acceptability scores among the different drying methods. In conclusion, vacuum drying was the suitable drying method for physical properties of *tteokguk*, even though there was no significant difference in the sensory quality of *tteokguk*.

Summary

With increasing the number of pores (pore size 0.05 cm) up to 18 pores, rehydration capacity, lightness, texture, taste, and overall acceptability scores of *tteokguk* increased and hardness, redness, and yellowness of *tteokguk* decreased. Vacuum dried *tteokguk* exhibited higher rehydration capacity and lower hardness of *tteokguk* than hot-air dried, low-temperature dried, and freeze-dried *tteokguk*. These results indicated that perforation process and vacuum drying could obtain high-quality ready-to-eat Korean sliced rice cakes and can be used in the rice cake industry.

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References

Bae JS, Yoo CH, Lee KE. 2016. Effects of extrusion frequency on the quality characteristics of *Ddukgukdduk*. Korean J. Food Cook. Sci. 32: 449-457.

Baker L, Rayas-Duarte P. 1998. Retrogradation of amaranth starch at different storage temperatures and the effects of salt and sugars. Cereal Chem. 75: 308-314.

Choi BK, Park SY, Ha SD, Kum JS, Lee HW, Park JD. 2007. Effec of drying methods of rice flour on growth properties of *Bacillus cereus* and *Enterobacter sakazakii*. Korean J. Food Sci. Tehcnol. 39: 295-298.

Kang HJ, Lee JK, Lim JK. 2012. Quality characteristics of *Topokki Garaedduk* with different moisture ratios. J. Korean Soc. Food Sci. Nutr. 41: 561-565.

Kang KJ, Kim K, Lee SK, Kim SK. 1997. Relationship between molecular structure of acid-hydrolyzed rich starch and retrogradation. Korean J. Food Sci. Technol. 29: 876-881.

Kim JO, Choi CR, Shin MS, Kim SK, Lee SK, Kim WS. 1996. Effects of water content and storage temperature on the aging of rice starch gels. Korean J. Food Sci. Technol. 28: 552-557.

Kim MS, Park JD, Lee HY, Park SS, Kum JS. 2013. Effects of addition of mugwort powder on the quality characteristics of Korean rice cake *tteokgukdduk*. J. Korean Soc. Food Sci. Nutr. 42: 1433-1438.

Kim YH, Kim CJ, Lee ES, Jeong JY, Seo WD. 2002. The effect of perforation process on the cooking characteristics of ground beef patty. 29th KoSFA symposium and annual meeting p.151

Kum JS, Lee CH, Baek KH, Lee SH, Lee HY. 1995. Influence of cultivar on rice starch and cooking properties. Korean J. Food Sci. Technol. 27: 365-369.

Lim JS, Park KJ, Kum JS. 1999. Changes in physicochemical properties of Korean rice cake subjected to microwave-drying. Korean J. Food Sci. Technol. 31: 631-637.

Son HS, Park SO, Hwang HJ, Lim ST. 1997. Effect of oligosaccharide syrup addition on the retrogradation of a Korean rice cake (*Karedduk*). Korean J. Food Sci. Technol. 29: 1213-1221.

Song JC, Park HJ. 2003. Effect of starch degradation enzymes on the retrogradation of a Korean rice cakes. J. Korean Soc. Food Sci. Nutr. 32: 1262-1269.

Yoon SJ, Oh IS. 2014. Usage status of traditional rice cake as a meal substitute and analysis on the selection attributes affecting purchase. Culi. Sci. Hos. Res. 20: 38-53.