Effects of Various Steeping Periods on Physical and Sensory Characteristics of *Yukwa* (Korean Rice Snack)

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ABSTRACT

This experiment was conducted to investigate the effect of various steeping periods on the physical and sensory properties of *yukwa*, which is a traditional Korean oil-puffed snack made of waxy rice, using milled waxy rices (cv. Shinsunchalbyeo) steeped for 0, 1, 3, 6, 9, 12, and 15 days. As the steeping period changed from 0 to 15 days, the cross-sectional area and expansion ratio of *yukwa* evaluated by image analysis significantly increased from 226 to 437 mm^2 and from 805 to 1,874%, respectively. Conversely, the ratio of length to height and density of *yukwa* significantly decreased with an increase in steeping period duration. The Hunter *a* value of *yukwa* tended to increase, whereas *b* value tended to decrease, as steeping period increased. Among the mechanical textural parameters, hardness was greatly affected by the steeping period range, with values ranging from 1,358 to 25,514 dyne/cm^2. Sensory results showed that sour aroma, color uniformity, and original flavor tended to increase, but hardness, crispiness, color roughness, oil flavor, and oil aroma tended to decrease in *yukwa* with the longer steeping period. From these observations, it can be concluded that the steeping period of waxy rice has an influence on the physical and sensory properties of *yukwa*.

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Yukwa is a traditional Korean oil-puffed snack made of waxy rice (*Oryza sativa*). It has long been eaten as a popular snack due to its soft texture and unique taste, and there has been a 10-fold increase in its production during the last 10 years in Korea. In traditional *yukwa* processing, milled waxy rice is steeped for 2 to 14 days (Lee and Maeng 1987) and then washed, drained, and crushed by mill into a fine powder. After steaming, the waxy rice dough is kneaded and pounded for aeration and then is cooled, cut into small pieces, and dried. These dried small pieces (*bandegi*) are fried through two consecutive deep-frying processes and coated with honey and puffed or roasted cereal grits. The resulting *yukwa* product is quite different from western and other Asian rice-based snacks in the aspects of texture and taste.

Generally, the objective of steeping or soaking is to hydrate the waxy grain sufficiently to enable it to be gelatinized on subsequent heating (Juliano 1985). *Arare or okaki*, Japanese traditional baked snacks similar to *yukwa*, usually are prepared from milled waxy rice soaked for 16 to 20 hr in water (to 38% wb moisture content) at <20°C (Li and Luh 1980). *Arare* or *okaki* have a hard, rough texture in comparison with *yukwa*. In contrast, *yukwa* is made from milled waxy rice steeped for long time periods, ranging from 2 to 14 days, which is an extraordinary lengthy period for hydration.

The qualities of *yukwa* depend entirely on the processing conditions, such as the steeping period of the waxy rice in the water, milling method, conditions of pounding, drying, frying, and so on (Shin et al 1989; Park et al 2000). In particular, the steeping period of waxy rice in water is supposed to be related to texture and volume expansion, which are the most important characteristics of a snack such as *yukwa* (Kim and Yoshimatsu 1984). However, both the reasons for the lengthy steeping time and the effect of steeping period on the physical and sensory characteristics of *yukwa* have yet to be clearly defined.

This study was done to determine the effects of the long steeping process on the physical and sensory characteristics of *yukwa* and to provide basic data for producing high quality *yukwa*.

MATERIALS AND METHODS

Preparation of *Yukwa*

Milled waxy rice (cv. Shinsunchalbyeo) was steeped for 0, 1, 3, 6, 9, 12, and 15 days in water at 20–25°C and then washed, drained, and crushed by rollers (KyungChang Machine Works, Korea) into a fine powder. After steaming at 100°C for 30 min, the resulting powder was kneaded at 250 rpm for 5 min using a screw kneader (KyungChang Machine Works). The kneaded dough was pressed into a sheet 5 mm thick using a rolling machine and dried by hot air at 60–65°C for 2 hr. Using a cutting machine (KyungChang Machine Works), the dried sheet was cut into small pieces, each with an average dimension of 30 × 8.5 × 3.0 mm, and dried again by hot air at 60–65°C for 2 hr. These small dried pieces (called *bandegi*) were fried in two consecutive deep-frying pans. The frying time and temperature were 1.5 min at 100 ± 5°C in the first pan and 1.5 min at 165 ± 5°C in the second pan. These fried *yukwa* were used for all experiments without coating with starch syrup and puffed or roasted cereal grits on the surface.

Expansion Parameters and Density

The expansion parameters related to *yukwa* were evaluated by computerized image analysis. A computer vision system, consisting of a 0.66 in. one-chip color CCD camera (model TMC-74, PULNiX) and a personal computer equipped with a color frame grabber (model Oculus-TCX, Coreco), was used to measure the dimensions of the *yukwa*. A color image was acquired through a lens system with an 11- to 110-mm zoom lens and a close-up lens of diopter +2. In this vision system, the *x*-axis and *y*-axis scale factors for calibration were 0.4045 and 0.4098 mm/pixel, respectively. The algorithms for image analysis were coded by C interpreter language in Visilog (ver. 4.1.5; Noesis Vision). The expansion parameters, including cross-sectional area, longitudinal-cut area, ratio of length to height, and expansion ratio, were calculated from a view of the whole and the cross-section of 20 samples. The volumes of *yukwa* and *bandegi* were calculated using a geometric formula based on a cylindrical shape for *yukwa* and a rectangular shape for *bandegi*. The expansion ratio was obtained by dividing the volume of *yukwa* by the volume of the *bandegi* and multiplying by 100. The density of each *yukwa* was calculated from weight measured on an analytical balance and volume determined by image analysis.

Instrumental Measurements

Color of the *yukwa* was measured with a color difference meter (Color JC801; Color Techno System Co., Tokyo) to get Hunter *L* (lightness), *a* (redness), and *b* (yellowness) values. The instrument was standardized with a white tile (C/2, $L = 98.63$, $a = 0.19$, $b = -0.67$).

Texture analysis was performed on the samples using a rheometer (Compac-100; Sun Scientific Co., Tokyo). The conditions for measurements were a maximum weight of 2 kg and a speed of 240 mm/min using a cutting-type probe number nine. The 10 sam-

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ples for each testing group were measured and data were analyzed by a randomized block design.

Sensory Evaluation

Seven panelists who had been trained over a period of two weeks evaluated the sensory properties of the samples. During their training, the panelists were informed about the purpose of the test, and selected descriptive terms and references. Definitions and evaluation methods of each sensory attributes were developed by the panelists. The references provided during the training session were the *yukwa* made from waxy rice steeped for three and 12 days.

Panelists evaluated samples according to the balanced incomplete block design and each sample was evaluated 20 times in a total of five sessions. The panelists evaluated each attribute with four specimens per test using 15-cm unstructured line scales, with the left end for very low intensity and right end for very high intensity. The attributes evaluated were sour aroma, oily aroma, color uniformity, color roughness, original *yukwa* flavor, oily flavor, hardness, crispness, and adhesiveness.

Statistical Analysis

Analysis of variance (ANOVA) was performed to test the differences among treatments (SAS Institute, Cary, NC). When a significant difference was found among treatments, Duncan's multiple range tests were performed to determine the differences among the mean values.

RESULTS AND DISCUSSION

Expansion Parameters and Density

A typical view of cross-sectioned and whole *yukwa* made from milled waxy rice steeped for 0–15 days is shown in Fig. 1. The degree of volume expansion as well as the size of cross-sectioned and whole *yukwa* substantially increased as the steeping duration of milled waxy rice increased from 0 to 15 days.

The effect of the various steeping periods of milled waxy rice on expansion parameters and density of *yukwa* is presented in Table I. The cross-sectional area of *yukwa*, an indication of radial expansion, significantly increased as the steeping period of the milled waxy rice was increased from 6 to 15 days. The longitudinal-cut area of *yukwa*, a measurement of longitudinal expansion, also showed the increasing trend in proportion with the steeping period of the milled waxy rice. The ratio of length to height of the *yukwa* tended to decrease with an increase in the steeping period, indicating that the effect of the steeping period on radial expansion is greater than that of longitudinal expansion of the *yukwa*. With an increase in steeping duration, the density of *yukwa* significantly decreased. The expansion ratio (obtained by dividing the volume of *yukwa* by the volume of the *bandegi* and multiplying by 100) increased steadily as the steeping duration increased from 6 to 15 days. The expansion ratio of samples with 15 days of steeping showed a 2.3-fold increase compared with 0 days of steeping. Thus, there is a strong relationship between long-period steeping of milled waxy rice and the expansion parameters and density of *yukwa.*

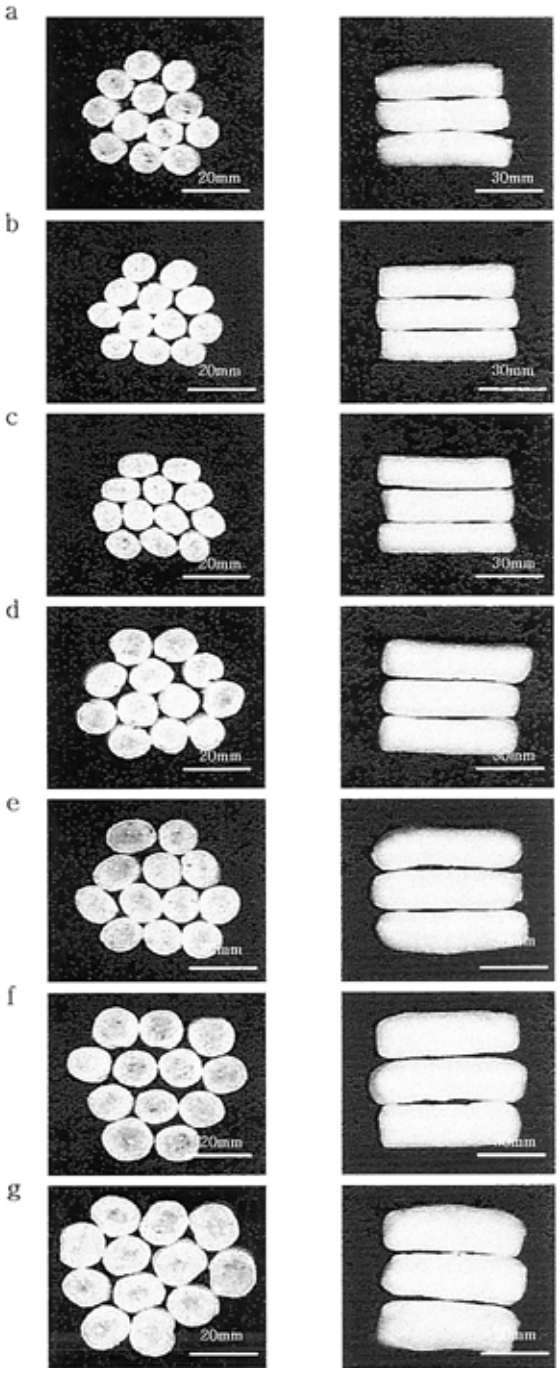

Fig. 1. Cross-sections of (left) and whole (right) *yukwa* (Korean oil-puffed snack) made from waxy rice steeped for 0, 1, 3, 6, 9, 12, and 15 days (**a–g**, respectively).

TABLE I
Effects of Steeping Periods (days) of Waxy Rice on Expansion Parameters and Density Using Image Analysis[a]

Days	Cross-Sectional Area (mm^2)	Longitudinal-Cut Area (mm^2)	Length/Height	Density (g/cm^3)	Expansion Ratio (%)[b]
0	226d	942e	4.10b	0.16a	805d
1	211d	1,017d	4.40a	0.17a	764d
3	210d	969de	4.35a	0.16a	721d
6	298c	1,142c	3.97bc	0.13b	1,171c
9	311c	1,163bc	3.91c	0.13b	1,238c
12	357b	1,209b	3.72d	0.13b	1,468b
15	437a	1,290a	3.48e	0.12c	1,874a

[a] Each value is the average of 20 replicates. Values followed by the same letter in the same column are not significantly different ($P < 0.05$).
[b] Volume expansion ratio (%) = $([A \times D] - V)/V \times 100$, where A = cross-sectional area, D = length (longitudinal cut), and V = volume of *bandegi*.

Bean et al (1984) reported that most of the water was taken up in 1 hr by three milled waxy rices, and equilibration of the moisture took place for the remaining soaking period. Similar results during soaking have been obtained by a number of investigators (Juliano 1985; Noomhorm et al 1997). Considering these facts, the object of the long-period steeping in *yukwa* preparation seems more complex. From the above results, it is quite clear that the long-term steeping of milled waxy rice had a significant influence on structural properties such as density and expansion in *yukwa* preparation. Volume expansion was reported to be the most important characteristic of rice snacks and cracker products (Li and Luh 1980). Hsieh et al (1989) investigated the effects of tempering conditions on rice cake volume and found that a longer tempering time (5 hr vs. 3 hr) resulted in higher specific volumes in rice cakes. Furthermore, the branched structure of starches and their constituents seemed to control the expansion of waxy rice. Chinnaswamy (1993) reported that changes in the branched fraction of starches greatly affect volume expansion. In agreement with this finding, steeping treatment at 50°C for 20 hr affected the gelatinization properties of starch as reported by Sekine et al (2000) and Lorenz et al (1978). They observed that such treatment increased the gelatinization temperature and narrowed the gelatinization temperature range in differential scanning calorimetry. However, little is known about the influence of steeping periods on the constituents of waxy rice in relation to the changes of the functional behavior. Thus, further investigation is needed to understand the mechanism of the long-term steeping of milled waxy rice in *yukwa* preparation.

TABLE II
Effects of Steeping Periods (days) of Waxy Rice on Color Properties Using a Colorimeter

	Hunter Color Value[a]		
Days	*L*	*a*	*b*
0	73.23bc	–1.83d	6.59b
1	76.56a	–1.43c	3.67d
3	72.29c	–1.71d	11.64a
6	75.01ab	–1.35c	5.38c
9	73.41bc	–1.31c	4.06d
12	73.42bc	–1.09b	2.58e
15	72.40c	–0.87a	1.41f

[a] Values: *L* = lightness, *a* = redness, and *b* = yellowness. Means with the same letter are not significantly different ($P < 0.05$, $n = 10$)

Instrumental Measurements

Color characteristics of the samples are shown in Table II. The *L* value, an indication of lightness, of the sample group with one-day steeping was significantly higher, with a value of 76.56, than that of the control group ($P < 0.05$). However, almost none of the sample groups showed significant differences among lightness values of 72.29 through 76.56. The *a* value, indicative of redness, showed green tone, with values of –0.87 through –1.83 in all sample groups. The sample group with 0 days of steeping had a redness value of –1.83, and the color became significantly lighter as the steeping period increased from 6 to 15 days, with the exception of data for one-day steeping ($P < 0.05$). The sample group with 15 days of steeping had the lightest greenish color, with a value of –0.87. These results indicated that the color of the *yukwa* was significantly affected by the steeping period of milled waxy rice.

The results of the texture measured by rheometer are presented in Table III. Of all the textural parameters, both hardness and strength of the *yukwa* were greatly affected by the steeping period of milled waxy rice. Hardness tended to decrease as the steeping days increased. The sample groups steeped for three days showed a hardness value of 19,843 dyne/cm^2. A significantly lower hardness value of 1,727 dyne/cm^2 was observed in the samples steeped for nine days. Strength showed trends similar to those of hardness. However, values of yield, maximum weight, and distance were not remarkably influenced by different steeping periods of milled waxy rice relative to hardness and strength. The adhesiveness of all sample groups showed no significant difference, with values of 1.0 through 1.7 g.

Hardness, an important textural parameter in snacks, is closely related to volume expansion and even distribution of air cells (Chinnaswamy and Hama 1988). Accordingly, an increase in expansion ratios related to steeping periods may be attributed to decreasing hardness.

TABLE III
Effects of Steeping Periods (days) of Waxy Rice on Textural Properties Using a Rheometer

	Textural Parameter[a]					
Days	Hardness (dyne/cm^2)	Adhesiveness (g)	Yield (g)	Maximum Weight (g)	Distance (m/m)	Strength (dyne/cm^2)
0	25,514a	1.7a	869.0ab	1,179.0ab	4.94a	117,900b
1	27,542a	1.3a	1,053.7a	1,420.8a	5.26a	142,080a
3	19,843b	1.0a	551.9c	727.4de	3.73b	72,740d
6	18,517b	1.5a	635.9bc	950.4b–d	5.14a	95,040c
9	1,727c	1.2a	867.4ab	996.4bc	5.93a	996e
12	1,358c	1.5a	567.1c	637.8e	5.06a	638e
15	1,784c	1.3a	667.6bc	853.5c–e	5.12a	854e

[a] Means with the same letter are not significantly different ($P < 0.05$, $n = 10$).

TABLE IV
Effects of Steeping Periods (days) of Waxy Rice on Sensory Properties[a]

	Sensory Attribute[b]								
	Aroma		Color		Flavor		Texture		
Days	Sour	Oil	Uniformity	Roughness	Original	Oil	Hardness	Crispiness	Adhesiveness
0	5.45c	8.90b	7.30e	9.15b	6.25b	9.25b	11.10a	11.30a	8.35de
1	6.45c	7.30c	9.40cd	7.10c	6.90b	8.40b	10.10ab	9.85b	9.15cd
3	3.60d	11.00a	3.30f	10.40a	4.30c	10.75a	10.45ab	12.00a	6.90e
6	6.65c	7.45c	8.35de	7.70c	7.40b	8.20b	9.40bc	9.85b	8.95cd
9	9.60b	5.15d	10.00bc	6.55cd	9.80a	6.60c	8.55c	8.25c	9.95bc
12	11.20a	3.60e	11.10b	5.95d	10.95a	6.30c	6.35d	7.95c	11.75a
15	9.70b	4.60de	13.30a	4.35e	10.20a	6.20c	4.95e	6.55d	11.00ab

[a] Based on a 15-cm line scale, with the left end for very low intensity and right end for very high intensity.
[b] Means with the same letter are not significantly different ($P < 0.05$, $n = 7$).

Sensory Evaluation

Sensory evaluation data showed that *yukwa* with various steeping periods had significant differences in all of the properties examined ($P < 0.05$) (Table IV). The unique sour aroma of *yukwa* increased significantly, with a value of 9.60 for sample groups steeped for nine days compared with values of 3.60 and 6.65 for samples steeped for three and six days, respectively. The oily aroma of the sample groups steeped for nine days decreased significantly to a value of 5.15. However, there were no significant differences when compared with the sample groups steeped for 15 days.

Color uniformity values of 10.00 for the sample groups with nine days of steeping were significantly increased compared with those with zero, three, and six days of steeping. Those sample groups that were steeped for 12 days had color uniformity values of 11.00 and were not significantly different from those steeped for nine days. The color roughness of sample groups steeped for nine days showed 6.55 and was significantly lower than those steeped for 0 days. These sensory color results were almost identical to those measured by the color difference meter.

The typical *yukwa* flavor of the sample groups steeped for nine days showed remarkably high values of 9.80 compared with those steeped for 0 days ($P < 0.05$), However, samples with longer steeping periods did not have values significantly different from those steeped for nine days. The sample groups steeped for nine days had sharply lower oily flavor (values of 6.60) compared with those steeped for 0 days.

Sensory hardness values tended to significantly decrease as the steeping days increased. These tendencies were consistent with mechanical hardness as determined by a rheometer ($R^2 = 0.85$). Sensory crispiness also tended to decrease with increasing steeping periods, although the crispiness of *yukwa* made from milled waxy rice steeped for six days or less failed to show a consistent trend, which was probably due to sample variation. These results may also be explained by the increased expansion of *yukwa* with longer steeping. Similarly, high negative correlations between volume expansion and sensory textural properties such as hardness, crispiness, and chewiness of extruded products were reported in corn and potato extrudates (Onwulata and Heymann 1994; Faller and Heymann 1996).

CONCLUSIONS

The steeping period of milled waxy rice in *yukwa* preparation clearly has significant influence on the physical and sensory properties of *yukwa*. From results obtained in this study, a steeping duration of at least nine days is enough to produce a *yukwa* that displays the most typical physical and sensory characteristics of traditional *yukwa*. The multivariate conditions of optimization for the steeping process could not be fully completed in this study. Therefore, further systematical analysis on the optimization as well as the mechanism involved in long-period steeping is required.

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