

Yukwa—A Traditional Korean Puffed Rice Snack

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Yukwa, a traditional Korean puffed snack made from waxy rice, has long been a popular snack item because of its unique texture and sweet flavor, which results from a coating made with honey or starch syrup (5). Some *yukwa* products are also coated with puffed or roasted cereal grits for added nutrition and attractiveness. Koreans have traditionally prepared *yukwa* for festive occasions such as birthdays and weddings, as well as for ancestral memorial services. Today, *yukwa* has become a popular daily food for many, and there are approximately 200 *yukwa* factories in Korea (17).

Yukwa is made from ground waxy rice with a low amylose content (36). The rice must be steeped in water for a prolonged period of time to produce an optimal texture with small cell structure. Because its qualities depend greatly on processing, it is necessary to identify the optimum conditions for producing *yukwa*. In recent years, there have been numerous research studies on methods for quality improvement and standardization of the production process for Korean *yukwa* (3,7,12,15,35).

Park et al. (27), Lee et al. (21), and Yu et al. (45) have reported on the physicochemical properties of hydroxypropylated waxy rice starches and their application in *yukwa*. The influence of steeping and mixing time on quality has been studied by Kang et al. (11), who found that steeping of waxy rice at 15°C for more than 6 days was required to produce a soft texture and small air cell distribution. Mixing of non-waxy rice with waxy rice has been attempted (36), and different waxy rice cultivars have been compared for their resulting *yukwa* quality characteristics (2,10). The color, texture, and volatile flavor

- *Yukwa* is a traditional Korean puffed rice snack with a unique texture and sweet flavor.
- Steeping period, moisture content of *bandegi* (pellet), and frying process affect final product quality.
- Advances in *yukwa* production include new puffing methods to improve shelf life and reduce oil content and addition of enzymes and microorganisms to eliminate steeping and shorten processing time.

compounds of traditional Korean *yukwa* also are affected by the type of packaging material and length of storage (42). Kum et al. (19) and Park et al. (31) found that the addition of antioxidants (tocopherol, oxyfos, or γ -oryzanol) to *yukwa* was effective in extending the shelf life of the product. The effects of microorganism inoculation and enzyme treatment on *yukwa* characteristics also have been studied (5,29). During production, additives such as rice wine (30), soybean (39), green tea powder (16), and safflower (28) have been mixed with waxy rice flour to create desirable properties in the resulting products.

The *Yukwa* Production Process

The quality of *yukwa* can vary considerably depending on process variables, including waxy rice steeping time, kneading (punching) time, moisture conditioning, and drying and frying conditions. The production steps for *yukwa* (Fig. 1) include steeping, grinding, steaming, punching, molding, drying, moisture conditioning, and frying.

Steeping. Waxy rice is steeped in cold water for a substantial period of time until the rice grains have hydrated sufficiently to enable their starch to be gelatinized during subsequent heating (9,23). The water enters the individual starch granules within the rice grains, causing them to swell and then disrupt, which releases free molecular starch and yields a very starchy, pasty mouthfeel. Optimum steeping conditions can be determined as described by Juliano (9).

Kang and Ryu (12) reported that steeping of waxy rice at 15°C for 3 days was required to equilibrate moisture absorption in waxy rice grains. However, steeping for more than 6 days was required to obtain the desired soft texture and small air cell distribution in the final product. In contrast, Lee et al. (22) reported that steeping waxy rice at 20°C for 7 days was required to obtain desirable *yukwa* quality features, and Jeon et al. (7) indicated waxy rice should be steeped at 15°C for 15 days. Choi and Kang (3), on the other hand, found that the expansion rate and crispness of *yukwa* prepared by steeping waxy rice for 24 hr at 8°C was satisfactory.

In a previous study by Chun et al. (4), *yukwa* produced using longer steeping periods had more desirable volume expansion and mechanical and sensory textural properties as the steeping time for waxy rice increased from 0 to 15 days (4). Additionally, the sugar, protein, lipid, and mineral contents of raw waxy rice decreased, and larger amounts of volatile organic compounds were detected in the steeping medium with increased steeping time (21). These observations suggest that some natural fermentation may be involved in *yukwa* production (5). Therefore, possible new processing methods designed to shorten the process and make it more economical by omitting the long steeping time through the addition of enzymes, phosphorus oxychloride, and microorganism inoculations have been investigated (29,44).

Grinding. Water-saturated waxy rice is ground twice through a roller mill into a fine powder. After milling, the rice flour is wet sieved. Shin et al. (38) found that 40- and 80-mesh sized particles of wet-sieved rice flour showed a better expansion rate and hardness than did 100-mesh sized particles. After wet sieving, moisture content is adjusted to 50% for the next step, steaming.

Steaming. It has been reported that the gelatinization temperatures of waxy and nonwaxy rice starches both range from 64.5 to 67°C, with no significant difference between the two types. The viscosity (at 95°C) of waxy rice is significantly higher than that of nonwaxy rice because

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the amylopectin content in waxy rice is higher (37). *Yukwa* quality is inversely related to amylose content over a range from 18.5% in nonwaxy rice to 2–3% in waxy rice (37). Steaming methods and times have also been investigated (3,15,35). Generally, steaming for as little as 15–20 min is sufficient to modify the starch and proteins in rice that has already absorbed sufficient water during steeping (3). During steaming, the endosperm cell wall structure of the rice grain is partially destroyed, and the grains are sterilized (43).

Punching. The final texture of *yukwa* depends on the viscoelasticity and gas cell size distribution of the dough, which are affected by the punching process (11). Air cells are incorporated, and the dough acquires its viscoelastic properties during the punching process. The number and size of the holes or air cells in the final product vary depending on the number of times the raw sample is stirred. The energy input from punching also influences the air cell formation, texture, and expansion rate of *yukwa*.

Data collected by Jeon et al. (7) indicate that stirring at least 160 times (at a rate of 40 times/min) resulted in the most satisfactory final product. Seon (34) also indicated that the texture, flavor, crispness, and overall acceptability of *yukwa* after stirring 160 times was better than for products stirred only 80 times.

Molding. After punching, the gelatinized dough is cut into blocks of the desired size (e.g., 3 × 5 × 0.5 cm) called *bandegi* (waxy rice pellet) (12). Researchers have varying opinions about the ideal *bandegi* size (10,24,41). Because the amylopectin content of waxy rice is higher than in nonwaxy rice and other grains, the dough tends to be sticky and binds to the edge of a knife. In addition, the moisture content of the steamed dough is ≈50%, so it is unstable for prolonged storage at room temperature (13).

Drying. The texture, flavor, appearance, and shelf life of most food products depend on the amount of water they contain. For greater expansion and softer texture in *yukwa*, the optimum moisture content of the dried and conditioned *bandegi* is 14–17% (12). The length of the drying process is affected by dryer speed and design, drying temperature, and initial *bandegi* moisture content. Kim (18) proposed drying at 45°C for 5 min followed by drying at 23°C for 15 min. *Bandegi* can also be dried at room temperature with checking each hour until the moisture content reaches 11–13% (7). Shin et al. (39) reported that the moisture content of *bandegi* was 11–15% when dried at 40°C for 24 hr.

Moisture Conditioning. Moisture conditioning is the process used to equalize moisture throughout a *bandegi* piece. *Bandegi* pieces with moisture contents of 14–17% are sealed in a plastic bag and stored at 4°C for 1–2 days. The highest *bandegi* expansion value is obtained under these conditions (12). Moisture conditioning distributes air bubbles more uniformly in *bandegi*; the RVA (rapid visco analyzer) maximum paste viscosity value for *bandegi* reaches its highest level after 2 days of moisture conditioning and then decreases. The internal cell structure of *bandegi* contains different numbers and sizes of pores depending on steeping times and punching duration, varying from 1 to 6 days of steeping and 5 to 20 min of punching (11).

Frying. *Bandegi* may be fried using a two-stage, continuous deep-frying process. Kang and Ryu (13) observed that *yukwa* fried in 120°C oil for 2 min in the first pan and in 180°C oil for 2 min in the second pan had the crisp exterior and soft, porous internal texture that is popular with consumers (Figs. 2 and 3). Studies on characteristics of *yukwa* prepared with safflower



Steeping: Soak waxy rice in water for at least 24 hr



Grinding: Grind wet waxy rice in roller mill



Steaming: Steam milled rice flour for 15–20 min



Punching: Punch dough by machine for 10–15 min



Final Product: Coat *yukwa* with syrup and puffed cereal grits



Frying: Deep fry *bandegi* in oil using a two-step process



Moisture conditioning: Keep *bandegi* at 4°C for 1–2 days



Drying: Dry *bandegi* until moisture content is <15%



Molding: Cut gelatinized dough into small blocks (*bandegi*)

Fig. 1. *Yukwa* process diagram.

and pigmented rice used frying temperatures and times of 110°C for 1 min followed by 170°C for 2 min (28) and 120°C for 1 min followed by 170°C for 40 sec (22), respectively.

Frying is used to puff the *yukwa* and obtain a crispy, crunchy surface texture. It is generally agreed that the oil content in a food product increases with frying time and moisture loss during frying. Most food products have an optimum cooking time and temperature (33). If the frying time exceeds the optimum, the finished product tends to have a higher oil content (6,14) because the oil adhering to the surface of the product is drawn into its surface pore structure. In contrast, if the product is fried for an insufficient length of time, it will not release enough of the retained moisture, resulting in a soggy texture. Raising the frying temperature tends to reduce oil uptake because the product spends less time in the fryer (25,32,33). After frying, *yukwa* is coated with syrup and packaged (Fig. 4).

Advances in Korean *Yukwa* Production

Shelf Life. Traditional *yukwa* is made by deep-frying *bandegi* in vegetable oil. The oil used can adversely affect the shelf life of fried *yukwa* if the frying oil absorbed becomes rancid (41). The shelf life of an

oil-puffed product was <4 weeks at 30°C when measured using the peroxide value, while negligible changes in physical texture were detected after 9 weeks of storage (39). In 2008, Lee et al. (20) studied the effects of three different puffing methods (convection oven, microwave oven, and fryer) on *yukwa* characteristics. Their results showed that the sample puffed using fryer had the highest expansion rate, and the convection- and microwave-puffed samples were not significantly different from each other. More recently, a vacuum-puffing process has been tested. The microstructure in vacuum-puffed *yukwa* was different from that of deep-fried *yukwa* in that the vacuum-puffed *yukwa* exhibited a smaller, more uniform cell structure compared with deep-fried *yukwa*. Scanning electron microscopy showed a large differ-

ence between the interior textures of deep-fried versus vacuum-puffed samples (Fig. 5) (46).

To improve the functionality and variety of *yukwa* snacks, green tea powder and Korean green vegetable powder (*Angelica keiskei* Koidz.) can be added to the formulation (16). The addition of green tea powder at the 2% level and *A. keiskei* at up to 4% provide beneficial effects with respect to the functionality and storage life of *yukwa*, without any detrimental effects on its quality characteristics. Shin et al. (38) also reported that the addition of soaked soybeans (3%, wt/wt) to dough resulted in a higher expansion rate, improved physical properties, and improved sensory quality. Better results for tenderness, crispness, flavor, and overall desirability were also obtained by adding bean water (8).



Fig. 2. Commercial *yukwa* snack.



Fig. 3. Interior structure of a *yukwa* snack.



Fig. 4. Packaging of commercial *yukwa* snacks.

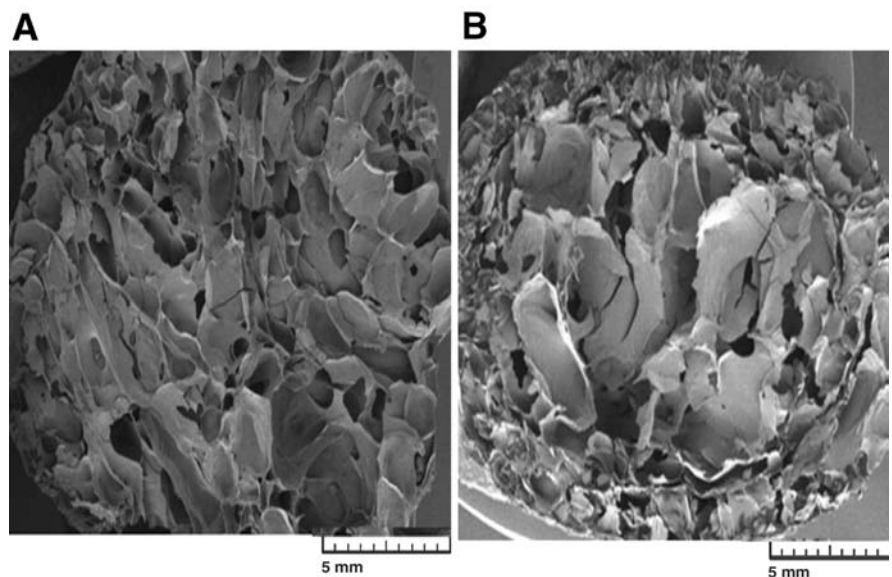


Fig. 5. Scanning electron micrographs of *yukwa* obtained by vacuum puffing (A) and deep frying (B) (46)

Fermentation. Fermentation is commonly used throughout most of the world to enhance food properties such as flavor, texture, nutritional value, and shelf life. The preparation of many traditional and indigenous cereal-based foods, such as *ogi* and *kwunu* (fermented maize), *fufu* (fermented cassava), and *togwa* (fermented sorghum, maize, and millet), is normally performed using natural fermentation with mixed cultures of bacteria, yeast, and/or fungi (1,26,40). The extraordinarily long steeping period used for waxy rice in *yukwa* production is required for proper hydration of the waxy grain and induction of biochemical changes via natural fermentation. The characterization and identification of major strains appearing on selective media after different steeping time periods have been reported. Although they were mixed cultures, the predominant species appears to have been Gram-positive, catalase-negative *Lactobacillus plantarum* (5).

A new processing method that eliminates the steeping process through the addition of enzymes and microorganisms has been developed (29). The major microorganisms present in steeping liquid were found to be *Bacillus* and *Lactobacillus* spp., and the optimal period for inoculation was determined to be 18 hr. The results indicated that *yukwa* samples obtained from all microorganism-inoculated groups had expansion volumes similar to those of *yukwa* prepared after 28 days of steeping with natural fermentation. The hardness values for inoculated samples were significantly lower than those for the 28-day steeping group.

***Yukwa* Preferences in the United States.** Preferences for flavor, texture, packaging, design, printing, and overall acceptability of the traditional Korean snack *yukwa* were surveyed for males and females in their teens (between 10 and 20 years of age) and twenties in New York, Atlanta, Chicago, and San Francisco (17). Approximately 30% of the respondents reported high scores for packaging. The design and color of *yukwa* were rated as “excellent” by 22.0 and 24.1%, respectively. Across the total number of responses, 60.9% reported good or excellent flavor, and 48.5% reported good or excellent texture. Since *yukwa* is not familiar to most Americans, it is not immediately obvious how successful such a snack would be in the United States.

Conclusions

Steeping period, moisture content, and frying process all have a significant influence on the physical and sensory properties of *yukwa*. Reduction in steeping times is of great commercial importance and can

potentially be achieved through inoculation with microorganisms. Use of a vacuum-puffing process for frying *yukwa* might also be considered as a new method to improve the quality and shelf life of commercial *yukwa* while shortening and reducing the cost of the process and lowering the oil content of the product.

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