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Research Article

Study on Korean Traditional Rice Snack (Yukwa) Manufacturing Process

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Abstract: Yukwa is a Korean traditional oil-puffed snack made of waxy rice (*Oryza sativa*). It is reviewed in this report outlining its traditional process as well as any significant scientific and technological steps to develop it to the status of modern processed snack. The stages of traditional process are discussed and include the steeping duration of waxy rice, the punching time and the drying and frying conditions which are necessary for obtaining the desirable quality features of Yukwa. Through controlling the steeping conditions, punching time, moisture content of Bandegi and expansion methods, we can get preference Yukwa product. Furthermore, some additives such as green tea, soy bean, rice wine and safflower were mixed with waxy rice to improve Yukwa quality and extend shelf life.

Keywords: Improvement, Korean, snack, traditional process, waxy rice, Yukwa

INTRODUCTION

Yukwa is a Korean traditional oil-puffed snack made of waxy rice (*Oryza sativa*). It has long been consumed as a popular snack due to its soft texture and unique taste and has become a factory-made product due to its large increase in consumption (Chun *et al*., 2004). Yukwa, is recorded in the book Gao-Zao-Li-So during the era of the Zaocen Dynasty in 1809 and this recordation indicated that Yukwa was necessary for the obsequies, wedding and banquet in Korea (Park *et al*., 2001). And now Yukwa has become daily and popular food for people and there are about 200 Yukwa factories in Korea (Kim *et al*., 2004).

Yukwa is made from only ground waxy rice of low amylose content (Sin *et al*., 1991). And the waxy rice must be steeped in water for a prolonged period time to produce superior texture and microscopic cell structure. On the basis of traditional manufacture, some additives such as rice wine (Park *et al*., 1995), soy bean (Shin *et al*., 1990a), green tea powder (Kim and Kim, 2001), safflower (Park, 2004) and so on are mixed with waxy rice to make more desirable properties of Yukwa. However, it is necessary to study on optimum conditions for procedure of Yukwa.

The traditional lengthy steeping process is still used in South Korea, based on years of experience. Furthermore, in recent years, there are more advanced researches on Yukwa. These researches are thus: More studies were carried out for the quality improvement and standardization of manufacturing process for Yukwa (Shin and Choi, 1993; Jeon *et al*., 1995; Kim, 1998; Choi *et al*., 2000; Kang and Ryu, 2002a). Physicochemical properties of hydroxypropylated waxy rice starches and its application to Yukwa were investigated (Park *et al*., 1995; Lee *et al*., 2001; Yu *et al*., 2006, 2007). Mixing of non-waxy rice and waxy rice was attempted in Yukwa preparation (Shin *et al*., 1991) and different waxy rice cultivars were compared for quality characteristics of Yukwa (Choi and Kang, 2000; Kang and Sung, 2000). Effects of steeping and mixing time on mixing energy input influenced Yukwa quality (Kang *et al*., 2001). Some additives were applied to improve quality and process modifications (Shin *et al*., 1990a; Park *et al*., 2001, 2008). Effect of microorganism inoculation and enzyme treatment were studied on Yukwa characteristics (Park *et al*., 2000a; Chun *et al*., 2004). Changes of Korean traditional Yukwa color, texture and volatile flavor compounds and characteristics during storage were investigated and methods for extending shelf life were also studied (Park *et al*., 2000a; Kum *et al*., 2001; Yoo, 2007).

The aim of this study is to present the traditional manufacturing process of Korean traditional snack Yukwa and to discuss significant scientific or technological steps for modifications of traditional process. Furthermore, we also aim to improve or advance the development of Yukwa.

METHODOLOGY

Manufacturing process: The main procedures for Yukwa's traditional manufacture are showed in Fig. 1 (Kang and Ryu, 2002b). The quality of Yukwa depends primarily on the process variables, including the steeping duration of waxy rice, the punching time and the drying and frying conditions (Chun *et al*., 2004).

Steeping: Rice is soaking in cold, warm or hot water for a substantial period of time, until the rice kernels have increased their moisture content, generally to at least above 20%; is to hydrate the kernel sufficiently to

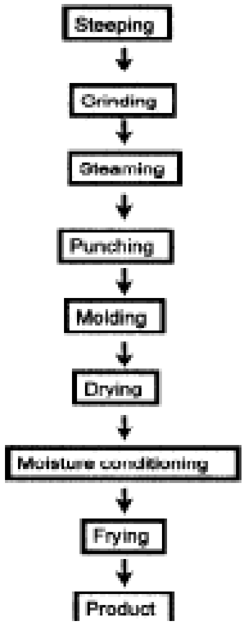

Fig. 1: Process schematics for the Korean rice snacks (Yukwa) (Kang and Ryu, 2002)

enable it to be gelatinized on subsequent heating (Li and Luh, 1980; Juliano, 1985). The water enters the individual starch granules within the rice kernels and causes them to swell, then bursts releasing free molecular starch and yielding a very starchy, pasty feel in the mouth. But the optimum soaking condition has to be selected (Juliano, 1985).

According to Kang and Ryu (2002a), steeping of waxy rice at 15°C for 3 days was required to equilibrate moisture absorption in waxy rice kernel. However, steeping for more than 6 days was required soft texture and small air cell distribution of Yukwa. Meanwhile, Lee *et al*. (2002) reported that the desirable quality features of Yukwa was steeping waxy rice at 20°C for 7 days and Jeon *et al*. (1995) reported that it is to steep waxy rice at 15°C for 15 days. Even though, expansion rate and crispness of Yukwa prepared by steeping waxy rice for 24 h was satisfactory (Choi *et al*., 2000).

In a previous study, Yukwa made from waxy rice with longer steeping periods was found to have desirable volume expansion, mechanical and sensory textural properties as the steeping period of waxy rice changed from 0 to 15 days (Chun *et al*., 2002). Additionally, contents of sugar, protein, lipid and minerals of raw waxy rice were found to decrease and the volatile organic compounds were detected in steeping medium by increasing the steeping time (Lee *et al*., 2001). These facts implied that natural fermentation could be involved in Yukwa production (Chun *et al*., 2004). Furthermore, new methods for skipping the steeping process by addition of enzyme and microorganism inoculation (Park *et al*., 2000a) or phosphorous oxychloride ($POCl_3$, 0.002-0.008%) (Yu *et al*., 2007) were investigated.

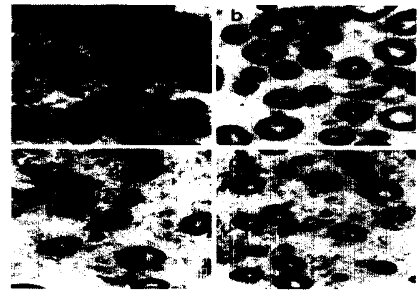

Fig. 2: Air cell structure in bandegi pellets at various punching and steeping time (×40); (a): Steeping for 1 day, punching for 5 min; (b): Steeping for 1 day, punching for 20 min; (c): Steeping for 6 days, punching for 5 min; (d): Steeping for 6 days, punching for 20 min (Kang *et al*., 2001)

Grinding: The water-saturated waxy rice was ground by roller mill two times. After then the wet rice flour was sieved and the 40 and 80 mesh of rice flour by wet milling was better in expansion rate and hardness than 100 mesh (Shin *et al*., 1990a). Furthermore, the moisture content is modified to 50% for next steaming.

Steaming: According to Juliano (1985), steaming for as little as 15-20 min is sufficient to modify the starch and proteins of rice that has absorbed sufficient water. It is reported that the gelatinization temperature of waxy rice and non-waxy rice starch was 64.5-67°C with no significant difference. While the viscosity (at 95°C) and viscosity (at 95°C after 15 min) of waxy rice were significantly higher than non-waxy rice because the amylopectin content in waxy rice was higher (Sin *et al*., 1989). The quality of Yukwa was deeply related with amylose contents ranging from 18.5% of non-waxy rice to 2-3% of waxy rice (Sin *et al*., 1989). Steaming methods and time were also investigated in other researches (Shin and Choi, 1993; Kim, 1998; Choi *et al*., 2000).

During steaming, the starch in rice grains changes to α-form and the protein is denatured, becoming resistant to enzyme action. At the same time, the structure of the rice grain, such as the endosperm cell wall, is partly destroyed and the grains are sterilized (Yoshizawa *et al*., 1978).

Punching: Punching is the traditional manufacturing after steaming. Choi and Kang (2000) reported that the gelatinized dough was punched 12 min for getting the desirable expansion degree, texture and sensory characteristics of Yukwa. Jeon *et al*. (1995) investigated the influence of beating times on Yukwa properties and included that 160 times of beating would be required. Seon (1995) also reported that the texture, flavor, crispness and overall acceptability of 160 beating times were better than 80 times. Figure 2 showed the air cell structure in Bandegi with different steeping and punching time.

The texture of Yukwa is influenced by dough viscoelasticity, cell size and distribution in dough which are affected by punching process (Kang *et al*., 2001). During punching process, gas cells are beaten in as the dough acquires its viscoelastic properties. Also, punching energy input influenced the air cell formation, texture and expansion rate of Yukwa.

Molding: After punching, according to Kang and Ryu (2002a), the gelatinized dough is cut into desired size: 3×5×0.5 cm which is called Bandegi (waxy rice pallet). Amylopectin content of waxy rice is higher than non-waxy rice and another grain, so the dough is sticky to the edge of knife. Also, the moisture content of the steamed dough is about 50% and it is floating and proteiform (Kang and Ryu, 2002b). The shape, size and uniform of Bandegi (waxy rice pallet) play an important role in the following drying and frying process, especially the thickness. Researchers (Kang and Sung, 2000; Lim *et al*., 2003; Yang *et al*., 2008) also have different opinions about the Bandegi (waxy rice pallet) size.

Drying: The texture, taste, appearance, stability and also the shelf life of the final product depend on the amount of water it contains. Excess moisture in mixes can cause clumping and the moisture content will continue to increase during storage, causing the product to deteriorate. For higher expansion and softer texture of Yukwa, the optimum moisture content of dried and conditioned Bandegi (waxy rice pallet) is 14-17% (Kang and Ryu, 2002a). The drying time is affected by the dying speed, drying temperature and the moisture content of Bandegi. Kim (1982) reported that the molding Yukwa was placed at 45°C for 5 min and then transferred it to 23°C for 15 min. This process was repeated for 5 h. Otherwise, Bandegi was dried at room temperature using 1 h as one unit until the moisture content is 11-13% (Jeon *et al*., 1995). Shin *et al*. (1990b) reported that it was dried at 40°C for 24 h and the lowest moisture content of Bandegi was 11-15%.

Moisture conditioning: Moisture conditioning is the process used to equalize the moisture. The Bandegi (waxy rice pallet) with moisture content about 14-17% is sealed in plastic bag at 4°C for 1-2 days. Air bubbles in Bandegi were distributed uniformly by moisture conditioning and RVA maximum paste viscosity of Bandegi was the highest after 2 days of moisture conditioning process and decreased 2 days after (Kang and Ryu, 2002a). At this condition, the highest popping value of Bandegi was obtained.

Frying: Traditional frying process is performed Yukwa in oil at 120°C for 2 min first and then put it in 180°C oil for another 2 min (Kang and Ryu, 2002b). In this process, the product Yukwa will become scrip, soft and popular to consumers. Park (2004) showed that Bandegi was fried in 110°C oil for 1 min and then in 170°C for 2 min could obtain the desirable Yukwa product. Also, Lee *et al*. (2002) reported that Bandegi was fried in 120°C for 1 min and then in 170°C for 40 sec.

Frying process is used to puff and obtain crispy, crunchy texture of Yukwa. It is generally agreed that the oil content in a product increases with frying time. Most of the food products have an optimum cooking time and temperature (Rossell, 2001). If the frying time exceeds the optimum time, the finished product will tend to have higher oil content (Kayacier and Singh, 1999; Esturk *et al*., 2000), as the oil adhering to the surface of the product is drawn into its pore structure. In contrast, if the product is fried for insufficient time, it will not release the retained moisture and result in a soggy texture. It is clear that increasing frying temperature tends to decrease the oil uptake as the product spends less time in the fryer (Rossell, 2001; Pedreschi and Moyano, 2005; Moyano and Predreschi, 2006).

In fact, oil puffed Yukwa tends to develop unpleasant rancid odors of off-flavors during storage (Yang *et al*., 2008). Therefore, Lee *et al*. (2002) compared three kinds of puffing methods (convection oven, microwave oven and fryer) on the characteristics of Yukwa. Results showed that the sample puffed by frying had the highest expansion rate, whereas the convection-, microwave-puffed samples showed no significant differences. In the consumer acceptance evaluations and characteristics intensity rating tests, the samples puffed using convection and microwave methods showed higher scores for the majority of evaluated characteristics as compared to the samples puffed by frying.

IMPROVEMENT OF THE KOREAN TRADITIONAL RICE SANCK-YUKWA

Steeping process and fermentation: Considering that steeping for 30-60 min in water appears sufficient to reach the equilibrium state (Bean *et al*., 1984; Noomhorm *et al*., 1997), the extraordinary lengthy steeping period of waxy rice in Yukwa preparation is required for hydration of the waxy kernel and for induction of biochemical changes via natural fermentation. It is well known that fermentation is usually a desirable process for biochemical modification of primary food products resulting from the activity of microorganisms and their enzymes. Fermentation is a commonly used food process throughout most of the world for the purpose of enhancing food properties such as taste, flavor, texture, nutritional value and shelf life. The preparation of many traditional or indigenous cereal-based foods such as Ogi (fermented maize), Kwunu (fermented corn), Fufu (fermented cassava) and Togwa (fermented sorghum,

Table 1: Characterization and identification of major strain appearing on selective media at different steeping periods

Day	Strain	Selective medium and expected genus of isolated strain	Colony form on selective medium		Colony count (mL)	
			Color	Size/other	Isolated uniformed colony	Total colony
3	Y75	mLBS/lactobacillus	Ivory	Middle	7.4×10^{6}	8.5×10^{6}
	Y74	MRS/GLAB[2]	Ivory	Middle	1.2×10^{7}	1.2×10^{7}
	Y73	PES/leuconostoc	Transparence	Middle/mucus	5.0×10^{6}	8.8×10^{6}
	Y12	KF/entrococcus	Red	Middle	1.5×10^{6}	3.6×10^{6}
6	Y15	mLBS/lactobacillus	White	Small	1.0×10^{8}	1.1×10^{8}
	Y58	MRS/GLAB	White	Large	9.2×10^{7}	1.5×10^{8}
	Y37	PES/leuconostoc	Transparence	Large/mucus	9.3×10^{7}	1.1×10^{8}
	Y68	KF/entrococcus	Red	Middle	7.0×10^{6}	1.5×10^{7}
9	YB4	mLBS/lactobucillus	White	Small	1.8×10^{7}	2.0×10^{7}
	YB18	MRS/GLAB	White	Small	2.7×10^{7}	3.0×10^{7}
	YB1	PES/leuconostoc	Transparence	Large/mucus	3.3×10^{7}	4.7×10^{7}
	YB7	KF/entrococcus	Red	Middle	3.1×10^{6}	6.8×10^{6}
12	Y26	mLBS/lactobacillus	White	Small	1.2×10^{8}	1.4×10^{8}
	Y25	MRS/GLAB	White	Large	8.2×10^{7}	1.4×10^{8}
	Y40	PES/leuconostoc	Transparence	Small/mucus	1.0×10^{8}	1.2×10^{8}
	Y69	KF/entrococcus	Red	Middle	1.9×10^{7}	2.7×10^{7}

Day	Strain	Characteristics			API50CHL	
		Gram staining	Cell form	Catalase	Scientific name	% ID[1]
3	Y75	+	C[3]	+	*Brev. laterosporus*[5]	99.3
	Y74	+	C	-	*Leuconostoc citreum*	95.8
	Y73	+	C	+	*Paenib. mocerans*[6]	-
	Y12	+	C	-	*Lacto. pentosus*[7]	72.3
6	Y15	+	R[4]	-	*Lacto. pentosus*	98.5
	Y58	+	C	-	*Lacto. plantarum*	81.0
	Y37	+	C	-	*Lacto. plantarum*	99.0
	Y68	+	C	-	*Lacto. plantarum*	76.9
9	YB4	+	C	-	*Lactov plantarum*	82.4
	YB18	+	R	-	Un-interpretable profile	-
	YB1	+	C	-	*Lacto. plantarum*	60.0
	YB7	+	C	-	Un-acceptable profile	-
12	Y26	+	R	-	*Lacto. plantarum*	99.9
	Y25	+	R	-	*Lacto. plantarum*	99.9
	Y40	+	R	-	*Lacto. plantarum*	99.9
	Y69	+	C	-	Un-interpretable profile	-

[1] % ID: Percentage of identification; [2] GLAB: General type of lactic acid bacteria; [3] C: *Coccus*; [4] R: Rod; [5] Brev.: *Brevibacillus*; [6] Paenib.: Paenibacillus; [7] Lacto.: Lactobacillus

maize and millet) is normally carried out by natural fermentation involving mixed cultures of bacteria, yeast and/or fungi (Odunfa and Adeyele, 1985; Adegoke and Babaola, 1988; Uzogara *et al*., 1990). Table 1 shows the characterization and identification of major strain appearing on selective media at different steeping periods for Yukwa.

New method for skipping the steeping process by addition of enzyme and microorganism was developed (Park *et al*., 2000b). Main microorganism in steeping liquid were Basillus spp. and Lactobacillus spp. and the optimal period of cell cultivations for making the glutinous rice powder was determined for 18 h. Results (Park *et al*., 2000a) showed that in the evaluation of the expansion volume of Yukwa, all microorganism inoculated groups showed similar to that of Yukwa prepared from 28-day steeping. In all microorganism inoculated groups, hardness and peak number of Yukwa showed significantly lower level than 28-day steeping group.

Quality improvement and shelf life extending of Yukwa: For improving functionality and variety of Yukwa, green tea powder and Angelica keiskei powder were added (Kim and Kim, 2001). The results showed that addition of green tea powder by 2% level and angelica keiskei powder up to 4% gave a beneficial effect in the aspects of functionality and storage life of Yukwa without any detrimental effects on the quality characteristics of it. Shin *et al*. (1990b) also reported that addition of soaked soybean (3%, w/w) to dough showed higher expansion rate and better physical properties with more acceptable quality by sensory evaluation of Yukwa. And the better results about tenderness, crispness, taste and overall desirability were also obtained by adding bean water (Jo and Jeon, 2001).

The shelf life of oil puffed Yukwa was less than 4 weeks at 30°C by peroxide value and negligible changes in physical texture was detected after 9 weeks storage (Shin *et al*., 1990a). Furthermore, this research investigated that it was possible to apply air puffing method for Yukwa making and its optimum temperature was around 250°C. Air puffed Yukwa was only a little less expansion rate, same level of hardness and high brittleness compared with oil puffed.

Table 2: Preference test of Yukwa quality characteristics in 10's and 20's

		Age									
		Male				Female					
		10		20		10		20		Total	
Sensory parameter	Contents	N[1)]	(%)	N	(%)	N	(%)	N	(%)	N	(%)
Package	Excellent	14	28.6	19	26.8	22	36.7	23	28.10	78	30.8
	Good	24	49.0	40	56.3	28	46.7	44	53.70	136	51.9
	Moderate	9	18.4	11	15.5	10	16.7	12	14.60	42	16.0
	Bad	2	4.1	-	-	-	-	3	3.70	5	1.9
	Worst	-	-	1	1.4	-	-	-	-	1	0.4
Design	Excellent	13	27.1	17	23.9	16	26.7	11	13.40	57	22.0
	Good	20	41.7	39	54.9	32	53.3	50	61.00	141	54.4
	Moderate	11	22.9	14	19.7	9	15.0	18	22.00	52	20.1
	Bad	4	8.3	1	1.4	1	1.7	2	2.40	8	3.1
	Worst	-	-	-	-	1	1.7	-	-	1	0.4
Printing	Excellent	14	28.6	17	24.3	15	25.0	17	20.70	63	24.1
	Good	20	41.7	34	48.6	27	45.0	38	46.30	119	45.6
	Moderate	10	20.4	14	20.0	16	26.7	24	29.30	64	24.7
	Bad	3	6.1	5	7.1	2	3.3	3	3.70	13	5.0
	Worst	2	4.1	-	-	-	-	-	-	2	0.8
Flavor	Excellent	8	16.3	19	26.8	14	23.3	12	14.60	53	21.2
	Good	21	42.9	28	39.4	22	36.7	33	40.20	104	39.7
	Moderate	14	28.6	20	28.2	21	35.0	28	34.20	83	31.7
	Bad	6	12.2	4	5.6	3	5.0	8	9.60	21	8.0
	Worst	-	-	-	-	-	-	1	1.22	1	0.4
Texture	Excellent	7	14.3	20	28.2	8	13.3	10	12.20	45	17.2
	Good	17	34.7	19	26.8	23	38.3	23	28.10	82	31.3
	Moderate	17	34.7	27	38.0	27	45.0	33	40.20	104	39.7
	Bad	7	14.3	4	5.6	2	3.3	16	19.50	29	11.1
	Worst	1	2.0	1	1.4	-	-	-	-	2	0.8
Overall	Excellent	7	14.3	11	15.7	8	13.3	10	12.20	36	13.8
	Good	16	32.7	33	47.1	32	53.3	31	37.80	112	42.9
	Moderate	23	46.9	22	31.4	16	26.7	33	40.20	94	36.0
	Bad	3	6.1	4	5.7	4	6.7	8	9.80	19	7.3
	Worst	-	-	-	-	-	-	-	-	-	

[1)] N: Number of consumer (Kim *et al*., 2004)

Preference of Yukwa in America: The preference of flavor, texture, packaging, design, printing and overall preference of Korean traditional snack-Yukwa was surveyed among 10's and 20's in New York, Atlanta, Chicago and Sanfrancisco in USA (Kim *et al*., 2004). About thirty percent of the respondents showed high score in packaging among the items. The design and color of Yukwa was 22.0 and 24.1% in "excellent" (Table 2). On the basis of this result, Yukwa would be developed for western country people's preference.

CONCLUSION

In Korea, Yukwa is one of the most important traditional snacks. It has been widely consumed by Korean people for more than 200 years. Throughout history, the Koreans seemed to follow their own ways in developing the product without foreign influences. To produce the products in mass and under standardized processes, further studies are needed to reduce the production cost and time through the analysis of traditional processes and normalization of manufacturing processes. If innovations in taste, flavor and product quality are made and the shelf life is prolonged, Yukwa may become more widely popular all over the world.

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