NOTE

Effect of Aqueous Impregnation of Rice Kernels with Gum Arabic and Xanthan on Storage Stability of Frozen Rice Cakes

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ABSTRACT

Rice kernels were steeped (10°C, 5 h) in an aqueous solution containing gum arabic (0.36%) and xanthan (0.24%) and then drained, wet-milled, and steamed to prepare rice cakes. The cakes were then frozen (–40°C for 50 min). The effect of the gum addition on the textural properties of the cakes during storage for 46 h at 25°C after being thawed was examined. Using the combination of gum arabic and xanthan mitigated the quality deterioration of rice cakes such as aggregation of rice flour, which had been induced by xanthan alone. Also, the increase in hardness during storage was substantially reduced by soaking rice kernels in the gum arabic/xanthan solution. Overall results revealed that the steeping in the gum solution improved the storage stability of rice cakes.

Freezing has been applied to many foods to increase their shelf-life and minimize physical changes during storage. However, it may cause a quality deterioration that is induced by the physical stress onto the food matrix owing to the formation of ice from the residual water (Rahman 1999). Syneresis, retrogradation, and textural changes occur during freezing and thawing, especially in starch-based foods, and are accelerated by repeating the freezing and thawing cycle (Lee et al. 2002). Various hydrocolloids are widely used to stabilize any textural changes and to restrict syneresis by controlling ice crystal growth in the frozen foods (Ferrero et al. 1993). Ferrero et al. (1994) reported that xanthan addition reduced amylose retrogradation, syneresis, and rheological changes during frozen storage of gelatinized starch suspensions, although ice recrystallization and amylopectin retrogradation still occurred.

Preparation of rice cakes in Korea is unique because wet rice flours prepared by steeping and wet-milling rice kernels are used. The procedures of steeping and wet-milling thus affect the physical properties of rice cakes. In Korea, rice cakes prepared in manufacturing factories are usually transported in a frozen state to retail stores, where the rice cakes are thawed or recooked for sale. Therefore, the stability of the rice cakes during frozen storage and the thawing process is a key factor for the quality of rice cakes. In this study, the addition of hydrocolloids such as gum arabic and xanthan during steeping of the rice kernels was investigated on its effect on the textural properties of a rice cake during an ambient storage after being thawed.

MATERIALS AND METHODS

Preparation of Rice Cakes. Japonica rice was purchased from Ottogi Corp. (Seoul, Korea), and gum arabic and xanthan were purchased from Sam Woo TD (Seoul, Korea). Rice kernels (1 kg) were soaked in an aqueous solution (900 g) of gum arabic and/or xanthan (0.36 and 0.24% w/v, respectively) at 10°C for 5 h. After the steeping, rice kernels were recovered by draining the mixture using a 20-mesh sieve and were then ground using a roll-miller (KM-18, Kyung-Chang Machinery Co., Daegu, Korea). After the first milling, 25% water, 15% sugar, and 1% salt (w/w, based on the weight of the rice flour) were added to rice flour. The mixture was milled again, moved to a mold (55 × 90 × 25 mm), and then steam-cooked in a pan (39.5 × 39.5 × 10 cm) for 30 min. The rice cakes were then cooled by leaving uncovered at 20°C for 30 min and then frozen in a deep freezer (–40°C, Se-Jin, Korea) for 50 min. The weight of the rice cakes was determined after cooling and before freezing.

Moisture Content of Rice Cakes. For the investigation of gum addition on the storage stability of rice cakes, the frozen rice cakes were thawed by leaving at 25°C for 2 h, steam-cooked by heating at 95°C for 3 min, and cooled at 25°C for 30 min. After storage at 25°C for 0, 15, 24, 39, and 46 h, the center portion of rice cakes was collected and dried in a convection oven at 105°C for the determination of moisture content.

Textural Properties of Rice Cakes. After storage for 0, 15, 24, 39, and 46 h at 25°C, the textural properties of the rice cakes were analyzed by texture profile analysis with a texture analyzer (Lloyd Instruments, Fareham, U.K.) with a 5 kg load cell. The center of the rice cake (55 × 90 × 25 mm) was compressed twice to 50% of the original thickness using a cylindrical probe (20 mm diameter) at a speed of 0.8 mm/s and a contact force of 5 g. Pre- and posttest speeds were 1.0 and 2.0 mm/s, respectively.

Statistical Analysis. All experiments were conducted in triplicate, and statistical analysis of the data was performed with SAS version 9.1 software (SAS Institute, Cary, NC, U.S.A.). Differences among experimental mean values were tested for significance at $P < 0.05$ using Tukey's studentized range test.

RESULTS AND DISCUSSION

Figure 1 shows the rice cakes prepared with gum arabic (0.36%), xanthan (0.24%), and a mixture of gum arabic (0.36%) and xanthan (0.24%). When gum arabic alone or the mixture was added in the steeping solution, the rice cakes appeared similar to the control rice cake. However, the rice cake containing xanthan appeared different from the control cake. As shown in Figure 2, the rice cake containing xanthan showed much higher weight than the control, which indicated that xanthan increased the density of the rice cake. gum arabic/xanthan mixture induced slightly higher weight than the control but lower than that containing xanthan alone. Rice cakes were produced using a mold in the same dimension of volume, not based on the weight of rice flour mixture. The same dimension of rice cakes led to similar weight of rice cakes, as shown in control rice cakes and those prepared with gum arabic. However, xanthan induced excessive aggregation of rice flour, resulting in uneven

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surface and more input of rice flour into the mold. It was noteworthy that the addition of gum arabic to xanthan did not show this quality deterioration caused by xanthan addition. The gum arabic might mitigate the adverse effect of xanthan on the appearance and density of rice cakes by preventing the aggregation of rice flour. The moisture content of rice cakes was increased when the gums were added, indicating that those gums increased the hygroscopic property of the cakes (Fig. 3). However, no difference among the cakes containing gums was observed.

Based on the appearance, the rice cakes containing gum arabic and xanthan were selected for the analysis of textural properties of the rice cakes during storage after being thawed. Textural characteristics of the rice cakes at different periods of storage are summarized in Table I. The differences in hardness between the control and the rice cake containing gum mixture were significant during the storage up to 46 h. The fresh rice cake containing gum mixture showed a slightly lower value of hardness than the control sample (0 h storage), but the difference in hardness between the two samples became more significant as the storage period increased. Springiness and chewiness in the control rice cake appeared unchanged or slightly increased during the storage up to 46 h, but the rice cake containing gum mixture exhibited continuous increases in springiness and chewiness during storage. Eventually the rice cake containing gum mixture showed a higher springiness than the control but similar chewiness, after 46 h of storage. There was no difference in cohesiveness between the control and the gum-added cake. Overall, the data revealed that the textural changes, typically shown as hardness increase, during the storage of rice cakes after being thawed could be retarded by the addition of a gum arabic/xanthan mixture during the steeping process of rice kernels. In a sensory analysis (data not shown), overall properties including appearance, taste, stickiness, chewiness, moistness, springiness, and preference revealed that the rice cakes prepared with the gum arabic and xanthan mixture were more favored than control rice cakes.

From this study, two possible mechanisms for the antihardening effect in rice cakes induced by the aqueous impregnation of rice kernels with gum arabic and xanthan could be suggested. Soaking the rice kernels in water is commonly practiced as a preliminary step for preparing rice cakes in Eastern Asia. Water is absorbed into the ventral side surface and the embryo site of endosperm during soaking, and it then migrates into the endosperm through the cracks and the region along the central line (Horigane et al. 2006). It was observed that the amount of water retained in rice kernels after draining was increased by using gums: the weight of rice kernels (initial weight of 30 g) after drainage was 39.1 g for the control, whereas it was 43.1 g for the sample containing the gum arabic and xanthan mixture. The uptake of water loosens the structure of rice kernels, and some soluble components such as proteins, carbohydrates, and some lipids may leach out during soaking (Chiang and Yeh 2002). Han and Lim (2009) suggested that the main soluble carbohydrate leaching out would be amylose, owing to its small molecular mass and greater mobility compared with amylopectin. Steeped rice kernels without any hydrocolloids lose most of the leached soluble components when the steeping water is drained. However, the viscous and hygroscopic gums such as gum arabic and xanthan in steeping water might not induce the complete loss of the soluble components. Moreover, leaching of amylose and small amylopectin could be inhibited by addition of gum arabic, as previously presented by Funami et al. (2008). Consequently, rice kernels steeped in gum arabic/xanthan solution retained more water, amylose, and other soluble components than control rice kernels. The presence of hydrocolloids and soluble components with the high amount of water in rice kernels might change the water distribution and retention in rice cakes, leading to the antihardening effect in rice cakes, especially in frozen and thawed rice cakes. At a molecular level, some of the gum molecules might interact with starch chains, especially during cooking, which could contribute to the retardation of hardening of rice cakes, especially during the early stage of storage. Xanthan effectively reduced the amylose–amylose interaction and syneresis because of its superior ability to interact with starch chains (Lo and Ramsden 2000; Lee et al. 2002). The storage period tested in this study (46 h) was the approximate shelf life of rice cakes displayed in retail stores. It was reported that the chain association of amylose was responsible for the hardening in a short-term storage (≈24 h), whereas amylopectin retrogradation

Fig. 1. Rice cakes prepared with rice kernels steeped in distilled water (control) and solutions containing gum arabic, xanthan, and a mixture of gum arabic and xanthan.

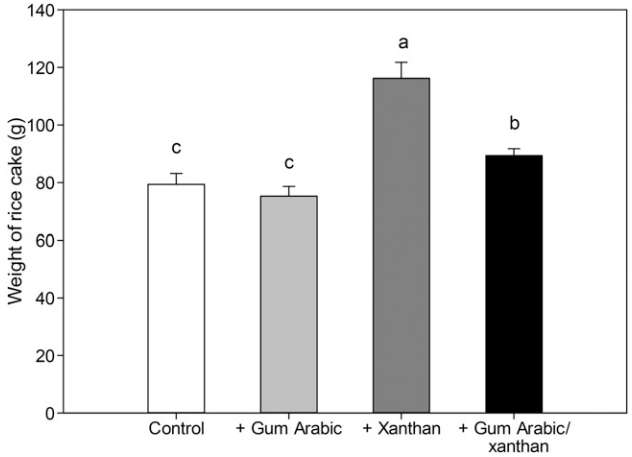

Fig. 2. Weight of rice cakes containing gum arabic, xanthan, or both in the same dimensions (55 × 90 × 25 mm).

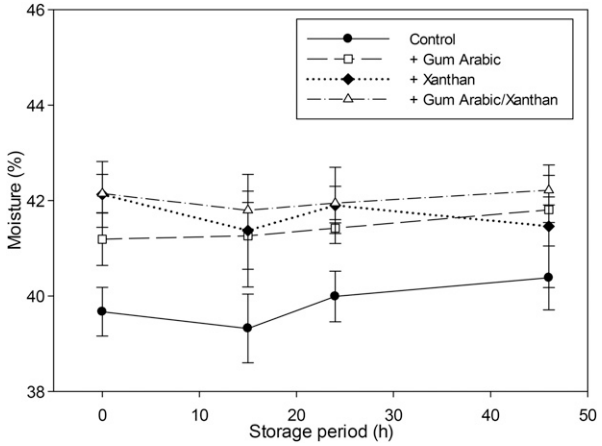

Fig. 3. Moisture content of rice cakes prepared with rice kernels steeped in distilled water and solutions containing gum arabic, xanthan, and a mixture of gum arabic and xanthan.

TABLE I
Textural Properties of Rice Cakes Prepared with Rice Kernels Steeped in Gum Arabic/Xanthan Solution[z]

Property	Sample	Storage Time (h)				
		0	15	24	39	46
Hardness (g)	Control	588a	1,318a	1,545a	1,684a	2,424a
	Gum arabic/xanthan	530b	730b	794b	936b	1,021b
Springiness	Control	0.51a	0.46a	0.48a	0.43b	0.48b
	Gum arabic/xanthan	0.40a	0.43a	0.51a	0.85a	0.93a
Chewiness (g)	Control	133a	276a	311a	297b	402a
	Gum arabic/xanthan	82b	157b	214b	446a	487a
Cohesiveness	Control	0.44a	0.47a	0.48a	0.47a	0.64a
	Gum arabic/xanthan	0.38a	0.47a	0.54a	0.55a	0.60a

[z] Mean values with different letters within each column for each texture parameter are significantly different ($P < 0.05$).

proceeded slowly with crystallinity increase afterward (Orford et al. 1987). The interaction of gums with amylose and/or linear segments of amylopectin would be one of the major reasons for retarding the retrogradation (Guarda et al. 2004). In this study, starch retrogradation induced mainly by amylopectin chain association was not observed under DSC analysis (data not shown). Therefore, it was assumed that the use of gums affected mainly the retrogradation induced by amylose association. In addition, gum molecules may influence the ice crystallization occurring in frozen rice cakes. It was reported that xanthan delayed the rate of ice formation in sucrose solution (Muhr and Blanshard 1986). Aqueous impregnation of rice kernels with gum arabic and xanthan was effective in storage stability of frozen rice cakes, but further study with different types and contents of gums should be conducted for optimization.

CONCLUSIONS

The impregnation of rice kernels with gum arabic and xanthan through steeping improved storage stability of frozen/thawed rice cakes. Xanthan alone induced aggregation of wet-milled rice flour, resulting in high-density rice cakes, whereas the combination of gum arabic and xanthan alleviated this quality deterioration. Also, gum arabic and xanthan minimized the hardening of rice cakes during storage for 46 h at 25°C. Therefore, steeping rice kernels in gum solution may be an effective approach for improving storage stability of rice cakes.

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