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Effects of *Jisil* (*Poncirus trifoliata* L.) Powder on the Physicochemical Properties of *Sulgidduk*

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Abstract: *Sulgiduk* was made with *Jisil* powder with the intention to take advantage of its functional properties. Appropriate amount of *Jisil* powder (0-8%) was mixed with rice flour, sugar, salt and water and then steamed for predetermined time and their physicochemical were measured. pH decreased significantly while Titratable Acidity (TA) increased significantly with the addition of *Jisil* ($p<0.05$). The addition of 2 or 4% *Jisil* powder significantly decreased the moisture content ($p<0.05$) although no significant differences were found but appeared to decrease among sample with 4, 6, or 8% samples. Lightness (L-value) decreased significantly with the addition of *Jisil* ($p<0.05$), indicating that the color of *Sulgidduk* became dark as also indicated by the visual observation. Redness (a-value) and yellowness (b-value), on the other hand, increased significantly as the amount of *Jisil* increased in the sample ($p<0.05$). Both hardness and firmness decreased significantly with the addition of *Jisil* ($p<0.05$). pH, TA, hardness and firmness could be well estimated by the quadratic equations developed.

Key words: *Poncirus trifoliata* L., *Jisil*, physicochemical, quality, *Sulgidduk*

INTRODUCTION

The dried immature fruit of *Poncirus trifoliate* (L.) Raf. (Rutaceae), Poncirus Fructus (PF), well known as "*Jisil*" in Korea, has been widely used as a remedy for allergic, digestive and chronic inflammatory diseases (Kim *et al*., 1999; Lee *et al*., 2003; Yi *et al*., 2004). Several biological activities related to PF have been reported: anti-platelet and anti-thrombotic (Teng *et al*., 1992; Wong and Chen, 2003), anti-bacterial and anti-viral (Kim *et al*., 1999; Ho *et al*., 2003), anti-allergic and anti-anaphylactic activities (Kim *et al*., 1999; Lee *et al*., 1996, 1997). Despite these functional properties of PF, little attempts were made to develop new food products which include PF.

Rice cake (*Dduk*) is one of the most important Korean traditional foods and more than hundreds various kinds are available. Among them, *Sulgidduk* is most representative of Korean rice cake, which made by steaming the rice flour. The *Sulgidduk* has different kinds of name depending upon what is added. Fruits, vegetable and even herbal medicine can be added and this makes *Sulgidduk* healthy functional food (Hong *et al*., 1999).

A Number of researchers have been investigated quality characteristics of Sulgidduk made with green tea powder (Hong *et al*., 1999), citric acid (Hong *et al*., 2003), Hericium erinaceus powder (Yoon and Lee, 2004), tapioca flour (Hyun *et al*., 2005), citron preserved in sugar (Lee and Hong, 2005) and sea tangle (Cho and Hong, 2006). Nevertheless, no study has been reported so far on the quality of *Sulgidduk* added with *Jisil* powder. Attempts were made to produce a rice cake having advantages of functional properties of *Jisil*.

The present research aimed at providing reliable experimental data for *Sulgidduk* made with *Jisil* powder and investigating the effects on the physicochemical properties.

MATERIALS AND METHODS

Preparation of raw material: Prewashed non-glutinous rice (produced in Sangbaek, Gyeongbuk, Korea) was soaked in the water for 12 h and removed the excessive water by straining for 30 min. The samples were then ground before use. Dried *Jisil* (*Poncirus trifoliata* L.; produced in Hadong, Gyeongnam, Korea) was ground using an analytical mill (model M20, IKA Works, Inc., Wilmington, NC, USA) at maximum speed for 5 min and sieved to obtain uniform particle size (c. 40 mesh) before use. Salt and sugar were procured from a local market.

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Preparation of *Sulgidduk*: Nonglutinous rice powder (350 g) was mixed with 1% salt (3.5 g), 8% water (28 mL) and 12% sugar (42 g) and appropriate amount of *Jisil* powder (0, 2, 4, 6 and 8%). The mixture was steamed in a stainless steel steam pan (25×25×15 cm) with 580 mL of water for 20 min at high power, 10 min at low power and then 5 min conditioning using a multi-functional oven (model GOR-704C, Tong Yang Magic Corp., Seoul, Korea).

Physicochemical properties evaluation: The pHs of *Sulgidduk* were determined by a pH meter (model 340, Mettler Delta Co., Halstead, UK) after mixing each 5 g of sample with 45 mL of distilled water. Same sample was used to measure titratable acidity, amount of 0.1 N NaOH solution to titrate the sample beyond pH = 8.3. Moisture contents of *Sulgidduk* were measured using a dry oven at 105□ overnight.

Texture characteristics were evaluated by 30% compression of individual *Sulgidduk* (3×2×2 cm) with a computer-controlled Advanced Universal Testing System (model LRX*Plus*, Lloyd Instrument Limited, Fareham, Hampshire, UK) at room temperature. A 100-Newton (N) load cell was used and the crosshead speed was 10 mm/min. A 1.2-cm diameter stainless steel cylinder probe was used. Five samples for each treatment were tested and their mean values were compared.

Color parameters (L, a and b) of Sulgidduk were measured using a Chromameter (model CR-200, Minolta Co., Osaka, Japan) calibrated with a white tile (Y = 94.2, x = 0.3131 and y = 0.3201). All measurements were repeated at least three times.

Statistical analysis: The statistical analysis was done using the SAS Statistical Analysis System for Windows v8.1 (SAS Inst. Inc., Cary, N.C., U.S.A.). The means were compared with Duncan's Multiple Range test at 5% level of significance.

RESULTS AND DISCUSSION

Visual observation: Photographs taken for each *Sulgidduk* as affected by the addition of *Jisil* are shown in Fig. 1. Apparently they showed a distinctive color with the addition of *Jisil* and the color became darker with higher amount of *Jisil* in the *Sulgidduk*. In addition, more particles of *Jisil* become apparent on the surface of the sample as the *Jisil* concentration increased.

pH and titratable acidity: Changes in pH and titratable acidity of *Sulgidduk* are shown in Fig. 2 and 3, respectively. pH of the control was 6.43 and that of 2% sample was 5.68, respectively. pH decreased abruptly

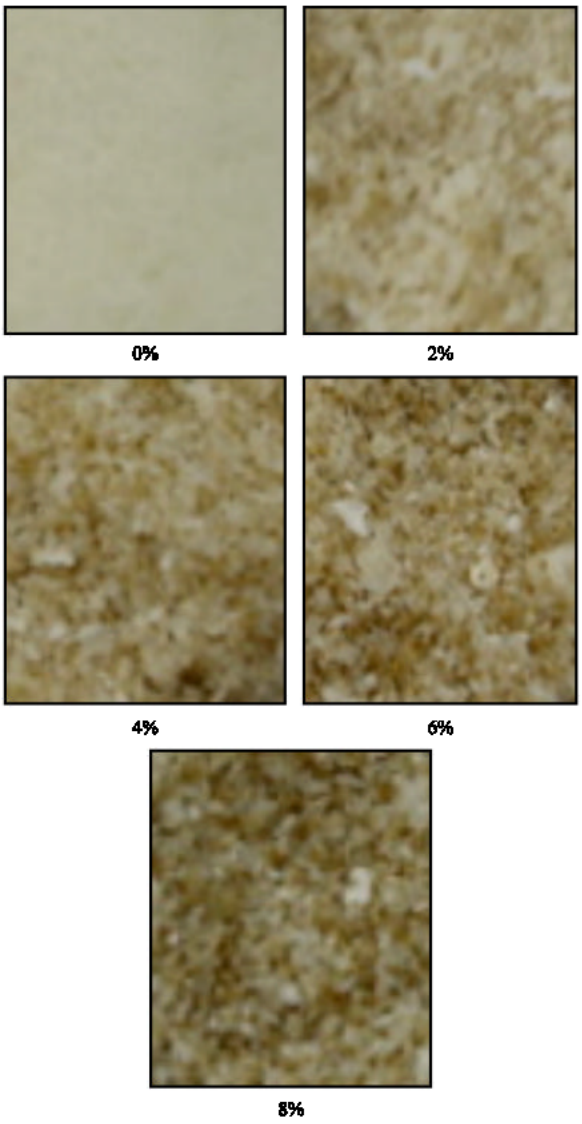

Fig. 1: Photographs taken for *Sulgidduk* as influenced by *Jisil*

with the addition of 2% *Jisil* and after that the reduction was relatively small but significant ($p<0.05$) and appeared to be linear. Apparently acidic characteristics of *Jisil* whose pH is 4.92 affected the pH of *Sulgidduk*. The overall changes in pH can be well described by a following quadratic equation:

$$pH = 0.028\ Jisil^2 - 0.352\ Jisil + 6.380\ (R^2 = 0.9675)$$

On the other hand, Titratable Acidity (TA) increased significantly with the addition of *Jisil* ($p<0.05$). TA of the control was 0.33 mL and it increased to 1.48 mL for 8% sample. Similar findings were reported for Mulberry

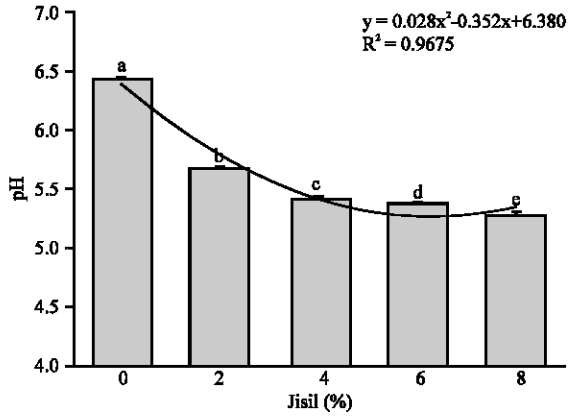

Fig. 2: pH of *Sulgidduk* as influenced by *Jisil*

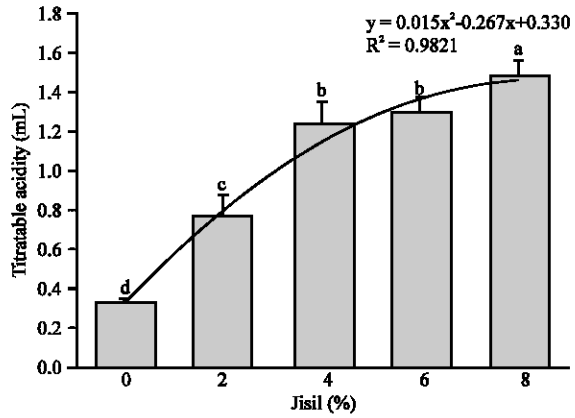

Fig. 3: Titratable acidity of *Sulgidduk* as influenced by *Jisil*

Sulgidduk added with citric acid (Hong *et al*., 2003) and *Sulgidduk* added with citron (Lee and Hong, 2005). Cho and Hong (2006); however, reported no significant changes in pH with the addition of up to 35% of sea tangle (whose pH is 6.33) in *Sulgidduk*. The change in TA was almost linear and can be well estimated by the following quadratic equation:

$$TA = 0.015\ Jisil^2 + 0.267\ Jisil + 0.330\ (R^2 = 0.9821)$$

Moisture content and color: Moisture content and color characteristics of *Sulgidduk* as influenced by *Jisil* are summarized in Table 1. The addition of 2 or 4% *Jisil* powder significantly decreased the moisture content ($p<0.05$) although no significant differences were found among sample with 4, 6, or 8% samples. Several other researchers reported decrease in the moisture content with the addition of citric acid (Hong *et al*., 2003), hericium erinaceus powder (Yoon and Lee, 2004) and citron preserved in sugar (Lee and Hong, 2005). However, a significant increase in the moisture content was also reported for the *Sulgidduk* make with sea tangle (Cho and Hong, 2006), or waxy sorghum flour (Yeon and Hong, 2006). This is due to the fact that concentration of added materials was relatively higher, ranged from 30 to 50% as compared to this research, which was up to 8%. Those materials have high amount fiber, which increases water boding capacity.

Lightness, redness and yellowness of *Jisil* powder was 56.07, -0.64 and 26.70, respectively. Lightness (L-value) of *Sulgidduk* decreased significantly with the addition of *Jisil* ($p<0.05$), indicating that the color of

Table 1: Moisture content and color characteristics of *Sulgidduk* as affected by *Jisil*

		Concentration of *Jisil*				
Property		0%	2%	4%	6%	8%
Moisture content		38.33±0.24a	34.76±0.83b	33.48±0.30c	32.76±0.97c	32.65±0.19c
Color	L-value	81.13±1.12a	77.84±0.71b	74.53±0.71c	71.69±0.68d	70.61±0.67d
	a-value	-3.28±0.02e	-1.78±0.11d	-1.41±0.08c	-1.02±0.06b	-0.86±0.07a
	b-value	6.16±0.39e	13.15±0.28d	15.42±0.61c	17.01±0.30b	18.77±0.62a

[a-e]Any two means (±standard deviation) within the same row followed by the same letter are not significantly different ($p>0.05$) by Duncan's multiple range test

Table 2: Textural characteristics of *Sulgidduk* as affected by *Jisil*

	Concentration of *Jisil*				
Characteristics	0%	2%	4%	6%	8%
Cohesiveness	0.38±0.03b	0.51±0.03a	0.50±0.03a	0.46±0.04a	0.37±0.13b
Springiness (mm)	6.18±0.31c	7.23±0.21ab	7.41±0.20a	7.26±0.19ab	6.69±0.86bc
Gumminess (N)	1.86±0.15ab	2.26±0.20a	1.97±0.24ab	1.55±0.23b	1.07±0.54c
Chewiness (N•m)	1.86±0.003b	2.26±0.002a	1.97±0.002ab	1.55±0.002b	1.07±0.004c
Adhesiveness (N•mm)	0.27±0.05a	-0.03±0.01b	-0.03±0.02b	-0.04±0.04b	-0.05±0.02b

[a-c]Any two means (±standard deviation) within the same row followed by the same letter are not significantly different ($p>0.05$) by Duncan's multiple range test

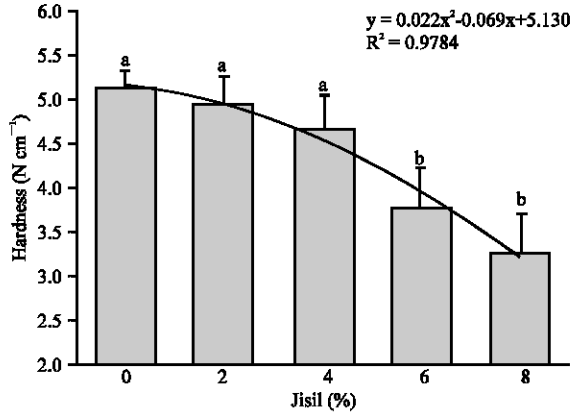

Fig. 4: Hardness of *Sulgidduk* as influenced by *Jisil*

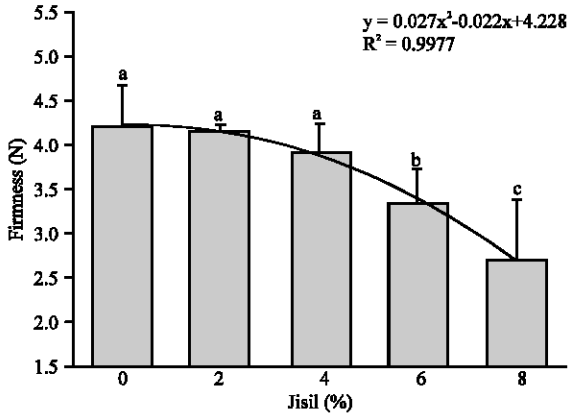

Fig. 5: Firmness of *Sulgidduk* as influenced by *Jisil*

Sulgidduk became dark as also indicated by the visual observation earlier. Redness (a-value), on the other hand, increased significantly as the amount of *Jisil* increased in the sample ($p<0.05$). Similar changes in the lightness and redness were reported (Hyun *et al*., 2005; Lee and Hong, 2005; Yeon and Hong, 2006; Hong and Kim, 2005). Again, yellowness (b-value) significantly increased with increase in *Jisil* content ($p<0.05$). This is due to the natural color of *Jisil*. It appeared that color characteristics of *Jisil* were well carried onto the *Sulgidduk*. This natural color can be easily measured and can be controlled to produce desired sample by changing the amount of *Jisil* added in the sample.

Textural properties: Hardness and firmness of *Sulgidduk* as influenced by *Jisil* are shown in Fig. 4 and 5, respectively. From a typical force-deformation curve, hardness and firmness were derived using the following relationship:

Hardness = Maximum force (N) / Maximum deformation (cm) [=] N/cm

Firmness = Maximum force [=] N

Both hardness and firmness decreased significantly with the addition of *Jisil* ($p<0.05$). Others also reported similar decrease in the hardness with the addition of citric acid (Hong *et al*., 2003), sea tangle (Cho and Hong, 2006), or persimmon paste (Hong and Kim, 2005). Other textural parameters including springiness, gumminess and chewiness increased and then decreased with the addition of *Jisil* (Table 2). The changes in the hardness and firmness can be described by curvilinear relationship and can be readily estimated by the following quadratic equations:

$$\text{Hardness (N cm}^{-1}) = -0.022\,\text{Jisil}^2 - 0.069\,\text{Jisil} + 5.130 \quad (R^2 = 0.9784)$$

$$\text{Firmness (N)} = -0.027\,\text{Jisil}^2 + 0.022\,\text{Jisil} + 4.228 \quad (R^2 = 0.9977)$$

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