한작지(Korean J. Crop Sci.), 51(S): 292~296(2006)

Pasting and Texture Properties of Rice Blends Formulated with Three Rice Cultivars

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ABSTRACT Three rice cultivars of Goami2 (G2), Ilpumbyeo (IP), and Baegjinju (BJJ) of which physicochemical properties are significantly different, were blended by a simplex-lattice mixture design. The effect of blending those rice cultivars on pasting and texture properties were observed. Rapid Visco Analysis (RVA) indicated that the onset gelatinization temperature of pure blend of G2 rice (83.80±0.07℃) was higher than that of IP (68.08±0.01℃) and BJJ (68.08±0.04℃). Increasing G2 rice resulted in lower peak and breakdown viscosity, and adhesiveness and cohesiveness, whereas higher setback viscosity and hardness. Pasting and texture properties of IP and BJJ indicated that G2 rice has quite different physical characteristics compared to IP and BJJ. Thus, it is expected that blending those three rice cultivars can be used to formulate a desirable rice blend on purpose, furthermore to promote the consumption of G2 rice, which has higher indigestible carbohydrate contents.

Keywords : rice blend, pasting properties, texture properties, simplex-lattice mixture design

Rice is the most important cereal crop and the staple food of over half the world's population. As the primary dietary source of carbohydrate in these populations, rice plays an important role in meeting energy requirements and nutrient intake (Hu *et al.*, 2004). The economic value of rice is strongly influenced by pasting and textural properties such as hardness and adhesiveness. Particular combinations of these traits can have an important influence on the end use of rice. For example, products such as sushi require soft, sticky rice while Indian style dishes are usually accompanied by rice with firmer, non-sticky characteristics (Barton *et al.*,1998; Bhattacharjee & Kulkarni 2000).

Although the per capita consumption of rice has steadily decreased since the 1980s, the hypoallergenic property of rice and rice products has received increased interest in Korea (Kang *et al.*, 2003). The interest in rice has led to the development of new rice varieties of Goami2 (G2) rice and Baegjinju (BJJ), which were developed by mutation breeding via *N*-methyl-*N*-nitrosourea (MNU) treatment of Ilpumbyeo (IP). They have quite different physicochemical properties for starch structure and texture when they are cooked (Kang *et al.*, 2004). Cooked rice quality is related to chemical and physical properties of rice. Although it is not entirely clear what factors can affect these properties, much of the research to date has focused on the role of starch with considerable success (Kokini *et al.*, 1992; Vandeputte *et al.*, 2003). When determining cooking and eating quality, focusing on starch as a major factor is not surprising, considering that starch accounts for up to 95% of the dry matter in a milled rice grain (Martin and Fitzgerald 2002). However, recent studies demonstrated that cultivars with similar starch content and composition could have rather different pasting and textural properties, suggesting that components other than starch may contribute to pasting and textural traits (Champagne *et al.*, 1999). Thus, this experiment was conducted to observe the effect of blending on pasting and texture properties of rice blends formulated with Ilpum and the mutant rice varieties of Goami2 and Baegjinju.

MATERIALS AND METHODS

Three rice cultivars of Goami2 (G2), Ilpumbyeo (IP), and Baegjinju (BJJ) were grown at the National Institute of Crop Science, RDA in Suwon, Korea during 2004 growing

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season. Milled rice was obtained by dehulling paddy rice to produce brown rice, then milled by removing 8-9% (by weight) bran layer of the brown rice. Rice blends were obtained by blending these milled rice based on a 3-components simplex-lattice mixture design (designated as {3, 3} design) generating 10 rice blend formulations (Cornell 1983). The ground rice flour of each rice blend was subjected to pasting properties analysis. For texture properties analysis, each rice blend (28-30 g) placed in a stainless steel cup (60 mm in diameter and 70 mm in deep) was soaked for 30 min, then cooked using a stainless round pot, which hold 6 stainless steel cups at a time. The steamed rice was completed by cooking 35 min in the ordinary cooking mode of high heat for 8 min, medium heat for 10 min, low heat for 7 min and heat off for 10 min. The completed cooked rice was stored at 60℃ for 1 hr for texture analysis.

Paste viscosity was determined using a Rapid Visco™ Analyser (Series 4, Newport Scientific Pty. Ltd., Warriewood, Australia) in accordance with the AACC 61-02 method. Rice flour (3.0 g each) was placed in a RVA test canister with 25 ml of distilled water. The test profiles and RVA settings was followed by the previous study (Choi *et al.*, 2006). Texture profile analysis (TPA) was conducted to observe texture properties of cooked rice using a *TA-XT2* Texture Analyzer (Stable Micro System Ltd., Haslemere, UK). A standard TPA operated by two-cycle compression was applied with a test speed of 1.0 mm/sec and a rate of 80% strain using a 20 mm cylindrical probe with a flat end (contact area of 314 mm^2). Each rice blend was measured in triplicate. Data were analyzed by a SAS statistical program (version 8.01) for the significance of difference using Duncan's multiple comparison tests at 5% significance level.

RESULTS AND DISCUSSION

Rice blend formulas by a simplex-lattice mixture design

Ten rice formulas were generated by blending three rice cultivars of Goami2 (G2), Ilpumbyeo (IP), and Baegjinju (BJJ) according to a simplex-lattice mixture design shown in Table 1. The formulas were 3 pure blends at the design points of the vertices estimating main effects (F1-F3), 6 binary blends at the edges estimating 2-way interaction effects (F4-F9), and 1 center point blend of three components in equal proportions (F10). The proximate compositions of G2, IP, and BJJ are in the ranges reported in the previous studies (Kang *et al.*, 2004). Three rice cultivars were clearly identified with the amylose contents, which were 33.96±1.16% in G2, 18.63±0.67% in IP, and 6.43±0.23% in BJJ. Protein contents were higher in G2

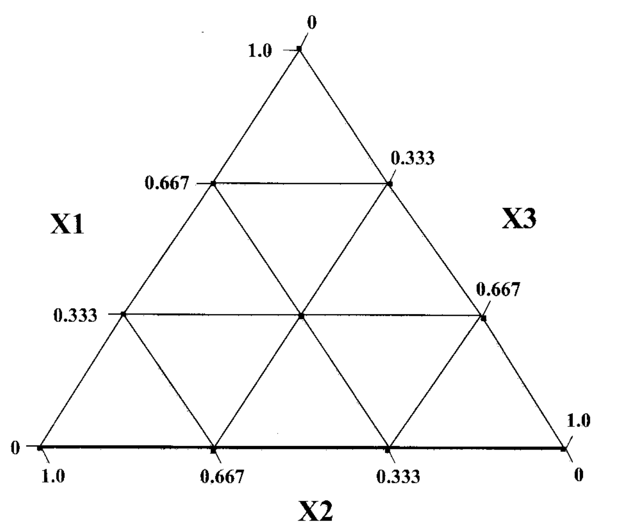

Fig. 1. Configuration of Design Runs for a {3, 3} Simplex-Lattice Design.

Table 1. Levels and compositions of cooked rice in formulation.

formula	levels		
	X1	X2	X3
F1	1	0	0
F2	0	1	0
F3	0	0	1
F4	1/3	2/3	0
F5	1/3	0	2/3
F6	0	1/3	2/3
F7	2/3	1/3	0
F8	2/3	0	1/3
F9	0	2/3	1/3
F10	1/3	1/3	1/3

X1=Goami2, X2=Ilpumbyeo, X3=Baegjinju

and BJJ (7.61±0.03 and 7.12±0.01%) compared to IP (6.66±0.16%). Also, lipid contents were significantly higher in G2 and BJJ (1.89±0.03 and 1.07±0.02%) than IP (0.44±0.01%). The previous study (Choi *et al.*, 2006) reported that G2 rice was characterized by higher indigestible carbohydrate contents compared to its mother variety of IP. Unavailable or slowly digestible carbohydrates have been considered to be important nutritional factors, due to the physiological benefits of reducing caloric contents and glycemic response, which could have beneficial implications in the management of diabetes (Delcour & Eerlingen 1996). Current nutritional concepts consider rice with lower digestible starch and higher resistant starch to be healthful diet (Yang *et al.*, 2006).

Pasting and texture properties of rice blends

Blending three rice cultivars resulted in significant ($p \leq 0.05$) changes in RVA pasting properties (Table 2). The pure blend of Goami2 (G2) shows relatively low peak viscosity, which indicates the lower water-binding capacity of the starch, but not much reduction in hot viscosity resulting in the lowest breakdown. The lower breakdown viscosity indicated that G2 rice tended to be more resistant to high-temperature thinning. Whereas, the highest peak viscosity and breakdown were observed in the pure blend of Baegjinju (BJJ), suggesting BJJ has higher water-binding capacity of the starch. The peak viscosity of Ilpumbyeo (IP) pure blend is slightly lower than BJJ, but IP blend shows higher hot viscosity than BJJ resulting in lower breakdown viscosity. It indicates that the resistance to high-temperature thinning of IP blend is higher than BJJ, but lower than G2 blend. Increasing and/or decreasing G2 and BJJ contents in the rice blends resulted in varying pasting properties. The pure blend of G2 indicated the highest setback viscosity, which was closely associated with the degree of retrogradation (Mazurs *et al.*, 1957), suggesting that G2 would be slow to gelatinize during cooking and quick to retrograde after cooking. The tendency of slow gelatinization of G2 pure blend was also indicated by the lower pasting temperature (83.80±0.07℃) compared to pure blend of IP and BJJ of which pasting temperatures were around 68℃. Contrast to G2 pure blend, setback viscosity of BJJ pure blend was the lowest, which meant softer texture on cooling with slower retrogradation after cooking. The highest setback viscosity of G2 pure blend (45.54±5.48) and the lowest setback viscosity of BJJ (-105.75±1.53) were observed. The lower setback viscosity indicates softer texture of the rice paste. Pasting properties

Table 2. RVA pasting properties of 10 rice blends. (unit : RVU)

Formula	RVA parameters					
	PV	HV	BD	CV	SB	Pasting Temp.
F1	51.38±8.19^{g}	50.08±8.01^{g}	1.29±0.18^{h}	96.92±13.67^{h}	45.54±5.48^{b}	83.80±0.07^{a}
F2	208.63±1.00^{ab}	126.38±0.88^{a}	82.25±1.86^{d}	225.50±0.35^{a}	16.88±1.36^{e}	68.08±0.01^{e}
F3	211.33±1.41^{a}	74.71±0.18^{e}	136.63±1.59^{a}	105.58±0.12^{gh}	-105.75±1.53^{j}	68.08±0.04^{e}
F4	155.87±2.18^{c}	100.04±1.83^{c}	55.83±0.35^{f}	192.88±2.18^{b}	37.00±0.00^{c}	72.33±1.66^{d}
F5	141.46±1.83^{d}	71.33±0.01^{ef}	70.13±1.83^{e}	111.38±0.65^{g}	-30.08±1.18^{h}	68.10±0.14^{e}
F6	205.00±1.65^{ab}	91.21±0.18^{d}	113.79±1.47^{b}	136.25±0.71^{e}	-68.75±0.94^{i}	68.13±0.04^{e}
F7	102.46±0.77^{e}	76.79±1.36^{e}	25.67±0.59^{g}	155.25±0.47^{d}	52.79±0.29^{a}	78.95±0.01^{b}
F8	92.04±0.65^{f}	66.21±1.00^{f}	25.83±0.35^{g}	121.29±1.12^{f}	29.25±0.47^{d}	76.68±0.11^{c}
F9	202.63±3.12^{b}	108.04±0.29^{b}	94.58±2.83^{c}	180.08±0.47^{c}	-22.54±2.65^{g}	68.07±0.11^{e}
F10	144.13±0.18^{d}	86.38±1.24^{d}	57.75±1.41^{f}	151.50±0.12^{d}	7.38±0.06^{f}	68.90±0.07^{e}

[a-h]Means in the same column with different uppercase letter are significantly different at $p \leq 0.05$ by Duncan's multiple comparison

PV=peak viscosity, HV=hot viscosity, CV=cool viscosity, BD=break down, SB=set back,
Past Temp=onset gelatinization temperature

of 6 binary rice blends and 1 center point blend significantly varied depending on the proportions of each rice cultivar. Thus, blending those three rice cultivars could obtain a desirable rice blend for a special purpose.

The TPA texture properties of cooked rice prepared with 10 rice blends were shown in Table 3. Increasing G2 rice increased hardness, but decreased adhesiveness and cohesiveness. Whereas, increasing BJJ deceased hardness, but increased adhesiveness and cohesiveness, suggesting that blending G2 and BJJ could improve the texture property of hardness observed in G2 pure blend. The 6 binary blends at the edges (F4-F9) and 1 center point blend of three components in equal proportions (F10) indicate that the TPA texture parameters vary depending on the proportion of each rice cultivar. For those who are favor to sticky rice, adhesiveness is quite important on determining their choice. Results of this study indicated that adding 10% of G2 rice in the blend with IP and BJJ resulted in no significant difference in adhesiveness ($p \leq 0.05$) by Duncan's multiple comparison. Thus, adding G2 rice by at least one third in a rice blend may not change the adhesiveness of cooked rice. Increasing G2 rice portions resulted in the increment of indigestible carbohydrates were observed in the previous study (Choi *et al.*, 2006). Cereals constitute the "starchy staples" in the human diet as the primary source of dietary carbohydrates. Starch contains a large digestible portion (digestible starch) and a small non-digestible portion called enzymatic resistant starch. Resistant starch is defined as "the sum of starch and products of starch degradation not absorbed in the small intestine of healthy individuals" (Escarpa *et al.*, 1997). Resistant starch slowly absorbed in the small intestine results in decreased postprandial glucose and insulin responses. There are evidences that slowly digested and absorbed carbohydrates are favorable for the dietary management of metabolic disorders such as diabetes and hyperlipidemia (Asp 1994; Wolever & Mchling, 2002). Lee and Shin *et al.* (2005) reported that feeding cooked G2 rice to a group of healthy males reduced significantly the blood glucose levels in the group compared to the group fed with cooked IP rice. The structure and physical properties of G2 were also characterized in the study (Kang *et al.*, 2003). They reported that the higher contents of amylose, protein, lipid, and fiber and looser amylopectin structure of G2 grain may contribute to the higher hardness and/or other unsuitable properties upon cooking, suggesting that hardness retention in finished cooked rice may be attributed to structural and physico-chemical properties of the starch, the major constituent of rice grain.

The present study suggests that three rice cultivars, which are characterized with different physico-chemical properties, can be blended to improve the pasting and texture

Table 3. TPA texture properties of 10 rice blends.

Formula	TPA parameters				
	Hardness (g)	Adhesiveness	Springiness	Cohesiveness	Area (g · s)
F1	887.49±123.08^{a}	-100.88±36.78^{a}	0.63±0.08^{b}	0.10±0.01^{e}	7684.60±2413.40^{a}
F2	707.15±145.92b^{cd}	-414.33±96.97^{b}	0.74±0.08^{ab}	0.29±0.02^{a}	6161.48±608.68^{ab}
F3	561.82±31.78^{d}	-427.24±47.66^{b}	0.80±0.04^{a}	0.29±0.03^{a}	3878.58±340.28^{c}
F4	674.06±47.50^{bcd}	-349.95±5.45^{b}	0.75±0.03^{ab}	0.25±0.00^{bc}	5488.89±344.32^{bc}
F5	647.78±133.94^{cd}	-388.53±71.44^{b}	0.77±0.06^{a}	0.24±0.01^{c}	4751.43±621.32^{bc}
F6	648.66±38.73^{cd}	-409.89±75.81^{b}	0.73±0.03^{ab}	0.28±0.02^{ab}	4412.53±259.89^{bc}
F7	830.19±124.18^{ab}	-196.02±98.83^{a}	0.72±0.08^{ab}	0.17±0.02^{d}	7620.80±1086.88^{a}
F8	681.85±84.02^{bcd}	-193.52±7.39^{a}	0.69±0.08^{ab}	0.18±0.01^{d}	5833.02±457.93^{b}
F9	704.38±70.96^{bcd}	-386.99±76.92^{b}	0.75±0.11^{ab}	0.26±0.03^{abc}	5249.07±812.28^{bc}
F10	752.48±113.04^{abc}	-404.11±40.16^{b}	0.76±0.04^{a}	0.25±0.02^{c}	5759.29±958.33^{b}

$^{a-e}$Means in the same column with different uppercase letter are significantly different at $p \leq 0.05$ by Duncan's multiple comparison properties on the particular purpose of promoting the consumption of G2 rice. Goami2 and Baegjinju are mutant rice, which are characterized by high indigestible carbohydrate contents and by glutinous texture properties, respectively. Blending Goami2 rice with regular rice such as Ilpumbyeo and/or with specialty rice such as Baegjinju could improve the unsuitable cooking quality of Goami2 for ordinary cooking. By adding Goami2 in cooked rice, there may be more chances to uptake indigestible carbohydrates by consuming the G2 blended cooked rice. Those three rice cultivars having unique physico-chemical properties used in this study can be used for other processed foods or special industrial products in terms of health or functional point of view.

ACKNOWLEDGEMENT

This project was supported by the Genetics and Breeding Division incorporated with the Post-Harvest Technology Division in the National Institute of Crop Science, RDA.

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