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Changes in pasting properties and free fatty acids of different brown rice cultivar during storage

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Abstract

Paddy rice is typically stored during postharvest until rice grain is processed into brown rice and milled rice by hulling and milling procedure, respectively. Recently, instead of storing paddy rice, storage of brown rice has been in the spotlight because it is more convenient and economically feasible. Different brown rice cultivars with varying amylose contents including waxy rice, medium-waxy rice, and non-glutinous rice were stored in room temperature storage for four months, and the changes in grain qualities of brown rice were evaluated. Amylose content significantly affected pasting properties in which rice cultivar with higher amylose content showed longer pasting time and higher peak viscosity. Storage also affected pasting viscosities, showing an increase in peak viscosity, but a decrease in breakdown viscosity. The changes in pasting viscosity during storage could be an important starch property for aged brown rice utilization. Waxy brown rice showed the weakest aging property in terms of free fatty acids (FFA) accumulation, whereas non-glutinous rice was more substantial grain quality against aging. The FFA values of two months storage were not significantly different from the initial FFA contents, suggesting that brown rice stored in room temperature for two months could be feasible for direct consumption of brown rice.

Key words : brown rice, storage, free fatty acids, pasting properties

Introduction

Brown rice is dehulling unmilled rice with bran layer intact, thus having a variety of nutritional and bio-functional components compared to milled rice. Although brown rice provides health benefits from higher functional compositions, including protein, vitamins, mineral elements, dietary fiber and polyphenols (1), milled rice has been the most common form for steamed rice. Low consumer preference of brown rice was due to undesirable and unacceptable eating qualities, such as high hardness of steamed form, long cooking time, and dark color appearance after cooking (2). In addition, short shelf life of brown rice has been implicated as deterrents to the direct consumption.

Despite a small amount of rice crop for being used as food ingredients and feed constitutes, the bulk of rice has been used as cooked rice in most countries in Asia (3). Thus, rice crop is needed to store for a certain period of time over the year. However, there has been issued some changes in rice qualities, such as physicochemical and cooking properties, during the storage. The importance of rice quality during storage has been increasing, as the rice quality significantly affected the end-use qualities of rice crop. During the storage, the changes of rice qualities have been observed in chemical composition, physicochemical properties, cooking properties, and consumer preferences (4-6). Fat acidity is one of the most useful indicators for the lipid oxidation of rice grain during storage. In the present study, five brown rice cultivars with different amylose contents were stored in room temperature storage for four months, and the changes in pasting viscosity and free fatty acids accumulation were evaluated.

Materials and Methods

Rice samples and storage

Five japonica rice cultivars with dehulling unmilled brown

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rice used in this study were 2 waxy (W1, W2) cultivars, 1 medium-waxy (MW) cultivar, and 2 non-glutinous rice (NG1, NG2) cultivars, respectively. They were developed in the National Institute of Crop Science, RDA (Rural Development Administration, Republic of Korea) and cultivated in the experimental research field during 2015 growing season. Waxy brown rice included normal waxy (W1), colored waxy rice (W2), medium-waxy rice (MW), non-glutinous rice (NG1), and non-glutinous functional rice (NG2). After harvesting, the paddy rice was air-dried in a shaded greenhouse until the moisture content of 14-15%, which was suitable for storage. The hulls were removed from the paddy rice using a roller husking machine (SY88-TH; Ssangyong Ltd., Incheon, Korea) to produce brown rice. The five brown rice cultivars were stored in room temperature storage where temperature range was between 22℃ to 30℃ during storage time. Brown rice samples were taken from the storage at two and four months, respectively, for rice quality analysis.

Chemical composition analysis

Ash, protein and lipid contents were determined according to the AACC official method of 08-01.01, 46-13.01, 30-10.01, respectively (7). Crude protein contents were measured by micro Kjeldahl method by applying the nitrogen conversion index of 5.95. Crude lipid was extracted with hexane by a Soxhlet method using a Soxtherm® rapid extraction system (Gerhardt, Königswinter, Germany). Amylose contents were determined by a simplified colorimetric assay for amylose in the brown rice samples (8). Rice flour (100 mg) was gelatinized with 95% ethanol and 1N sodium hydroxide solution at 100℃ for 10 min. After cooling the solution, the dispersion was neutralized with 1.0 N acetic acid to provide a final pH of 4.5 t 4.7 after iodine (I2-KI) addition. After placing the solution at 30℃ for 30 min, followed by another set at 20℃ for 10 min for color development, the absorbance of starch-iodine solutions were measured at 620 nm.

Pasting properties analysis

Pasting properties of brown rice flour were determined using a Rapid Visco™ Analyser (Series 4, Newport Scientific Pty. Ltd., Warriewood, Australia) in accordance with the AACC 61-02 method (7). Rice flour (3.0 g) placed in a clean RVA test canister with 25 mL of distilled water was dispersed with high speed mix (960 rpm) for the initial 10 sec, followed by moderate application of shear (160 rpm) for the remainder of 12.5 min of test period. The test profiles were to equilibrate at 50℃ for 1.0 min, ramp up to 95℃ in 4.8 min, and hold at 95℃ until 7.5 min. Temperature was linearly ramped down to 50℃ at 11 min and held at 50℃ until 12.5 min. Pasting viscosity parameters of peak viscosity, breakdown viscosity, and setback viscosity were measured, and all parameters were determined in arbitrary rapid visco units (RVU). The measurements were conducted in triplicates.

Free fatty acid analysis

Free fatty acid (FFA) was measured by a Titrimetric method (AOAC Official Method 939.05) with slight modification (9). Brown rice flour (20 g) was dispersed in 50 mL of ethanol-ether (2:1) mixture, which was shaken for 30 min in a mechanical shaker. After centrifuging the dispersion at 8,000 rpm for 10 min, the supernatant (25 mL) was carefully collected and mixed with 25 mL of alcohol-phenolphthalein solution. The mixed solution was titrated with 0.0178 N KOH to the endpoint, matching the color of a standard solution. The free fatty acid value (mg of KOH required to neutralize FFA from 100 g of grain, dry matter basis) was calculated as follows.

Fat acidity=10×(titration-blank), calculated on dry basis

Statistics

The data were analyzed using SAS statistical software (V. 9.1, SAS Institute Inc., Cary, NC, USA), expressed as mean standard deviation (SD). The significant differences between the means were calculated by analysis of variance (ANOVA) with subsequent Tukey's multiple comparison at 95% significance level.

Results and Discussion

Approximate compositions and amylose contents of the five brown rice samples are shown in Table 1. The rice samples included waxy rice (W1), colored waxy rice (W2), medium-waxy rice (MW), non-glutinous rice (NG1), and non-glutinous functional rice (NG2). Ash content was higher in waxy and medium-waxy rice followed by non-glutinous rice, being ranged in 2.24-2.85% and 1.15-1.22%, respectively. Protein content was also higher in waxy and medium-waxy (6.48-6.61%), than in non-glutinous rice (5.58-6.19%). Amylose content was ranged in 6.80-6.81% for waxy rice, 10.06% for medium waxy, and 16.69-16.72% for non-glutinous brown rice.

Table 1. Chemical compositions of different brown rice cultivar

code[1)]	Ash (%)	Protein (%)	Lipid (%)	Amylose (%)
W1	2.45±0.3[ab2)]	6.61±0.02[a]	2.68±0.05[b]	6.81±0.21[c]
W2	2.85±0.20[a]	6.56±0.04[ab]	3.43±0.01[a]	6.80±0.17[c]
MW	2.24±0.72[ab]	6.48±0.01[b]	2.29±0.03[c]	10.06±0.03[b]
NG1	1.15±0.02[b]	6.19±0.02[c]	2.40±0.03[c]	16.72±0.60[a]
NG2	1.22±0.03[b]	5.85±0.01[d]	2.30±0.04[c]	16.69±1.05[a]

[1)]W1, waxy rice; W2, waxy rice with black color; MW, medium-waxy rice; NG1, non-glutinous rice; NG2, non-glutinous rice.
[2)a-b]Values followed by different letters in the same column are significantly different at $p<0.05$.

Pasting properties

The pasting viscosity of five brown rice samples was measured, and the RVA profiles of the rice flour slurries are shown in Fig. 1. The corresponding pasting parameters (peak, breakdown and setback viscosity) are also shown in Table 2. Pasting temperature at peak viscosity varied from 3.30 to 6.00 min, showing the lowest values of W1 and W2 at 3.30-3.76 min followed by MW at 5.20-5.40 min and NG1 and NG2 at 5.70-6.00 min. The varied pasting temperature

Table 2. Changes in RVA pasting viscosity of different brown rice cultivar during storage

(unit: RVU)

code[1)]	Storage period (month)	PV[2)]	BDV	SBV	Pti (min)
W1	0	63.5±1.5[b3)]	34.3±0.5[a]	8.8±0.2[b]	3.30[b]
	2	72.7±0.8[a]	34.5±0.4[a]	10.3±0.1[b]	3.44[b]
	4	69.3±0.9[a]	25.6±1.6[b]	12.0±0.6[a]	3.76[a]
W2	0	63.9±0.3[a]	41.9±0.5[a]	7.9±0.1[a]	3.40[a]
	2	59.4±0.4[b]	31.8±0.4[b]	10.0±0.8[a]	3.60[a]
	4	46.4±0.2[c]	27.3±1.2[c]	8.7±0.5[a]	3.60[a]
MW	0	147.0±0.8[c]	98.9±1.2[b]	23.8±0.2[b]	5.20[b]
	2	163.8±0.4[b]	107.9±0.2[a]	30.0±0.9[b]	5.24[b]
	4	178.1±4.8[a]	101.4±2.8[ab]	35.3±0.2[a]	5.40[a]
NG1	0	112.8±0.4[c]	50.7±0.2[a]	61.5±0.2[c]	5.73[b]
	2	121.1±0.5[b]	54.2±0.7[a]	69.3±0.1[b]	5.84[ab]
	4	134.3±2.8[a]	46.3±5.9[a]	73.3±1.4[a]	6.00[a]
NG2	0	142.4±0.2[c]	63.7±2.1[b]	70.6±0.5[c]	5.70[b]
	2	163.7±0.6[b]	78.8±1.1[a]	90.3±0.2[a]	5.76[b]
	4	170.9±0.9[a]	64.2±0.1[b]	82.7±2.4[b]	6.00[a]

[1)]W1, waxy rice; W2, waxy rice with black color; MW, medium-waxy rice; NG1, non-glutinous rice; NG2, non-glutinous rice.
[2)]PV, peak viscosity; BDV, breakdown viscosity; SBV, setback viscosity; Pti, pasting time.
[3)a-c]Values followed by different letters in the same column and sample code are significantly different at $p<0.05$.

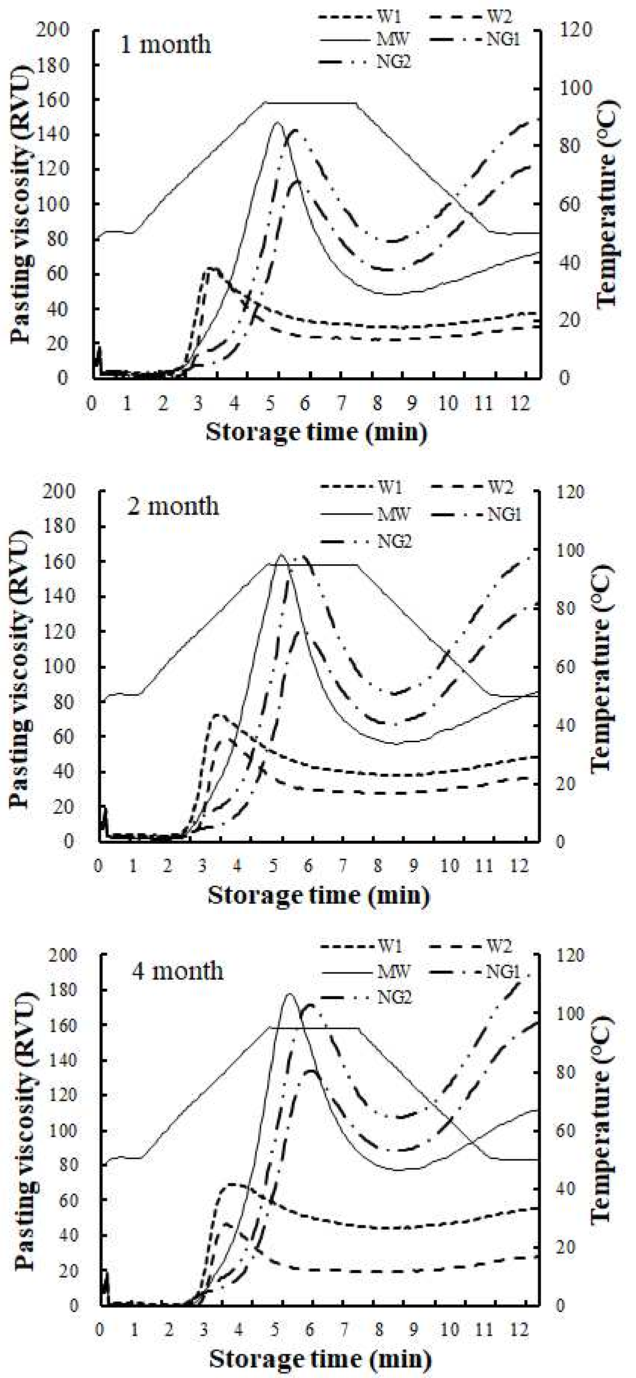

Fig. 1. RVA profiles of different brown rice cultivar according to storage time.

W1, waxy rice; W2, colored waxy rice; MW, medium waxy rice; NG1, non-glutinous rice; NG2, non-glutinous functional rice.

was attributed to the rice cultivar with varying amylose content, which could be the major factor for determining pasting temperature. Amylose and protein contents in brown rice flour played an important role in pasting temperature determination (10). Kong et al. (11) also reported that the higher pasting temperature was attributed to the amylose content of starch. Peak viscosity, as an indicator of starch swollen during heating, ranged in 63.5-63.9 RVU for waxy rice, 147.0 RVU for medium-waxy rice, and 112.8-142.4 RVU for non-glutinous rice. Higher peak viscosity of MW brown rice with medium amylose content (10.06%) was different from the results by Ye et al. (10), reporting that RVA peak viscosity of brown rice increased with increasing amylose content. The highest peak viscosity of MW rice with medium amylose content than non-glutinous rice with higher amylose (avg. 16.7 %) could be explained by the development of MW rice in breeding program. The rice was developed by mutation breeding via N-methyl-N-nitrosourea (MNU) treatment of Ilpumbyeo, a high-quality japonica rice (12). The breeding procedure could result in the varied pasting viscosities of MW rice. It was also observed that the MW rice had the highest breakdown viscosity (98.9 RVU) of which values were significantly different from other rice samples. Upon cooking qualities of steamed rice, higher peak and breakdown viscosity could be connected to the enhancement of the cooked grain qualities in which steamed rice is soft and glutinous in texture (13). Based on the grain qualities for steamed brown rice, the MW rice could be the most suitable rice cultivar for steamed rice.

Fig. 1 illustrated the RVA pasting properties of the rice samples during storage, showing that storage significantly affected the pasting viscosity. Pasting temperature increased gradually with increasing storage period up to four months. This result was corresponded to the studies (14,15), reporting that aging process resulted in increasing breaking point temperature so as to increase energy for the disorder of rice starch. Changes in peak viscosity in rice samples during four months storage ranged in 46.4-72.7 RVU for waxy rice, 147.0-178.1 RVU for medium waxy, and 112.8-170.9 RVU for non-glutinous rice. Peak viscosity also increased with increasing storage time in all brown rice samples except W2, which was colored waxy rice cultivar. The increased peak viscosity was attributed to the progressive reduction in α-amylase activity in aged rice grains (16). Breakdown viscosity decreased as storage time was prolonged, whereas setback viscosity increased. The setback viscosity, which indicates the retrogradation of steamed rice, showed the highest values in NG1 and NG1 followed by MW, W1, and W2. It could explain as the amylose contents increased, the retrogradation of steamed rice also increased. A decrease in breakdown and an increase in setback viscosity during storage were also reported in previous studies (5,17). Viscosity properties of rice flour play an important role as a physical index to estimate the qualities of cooking and processing properties (18,19).

Free fatty acid analysis

Free fatty acids (FFA) increased during the storage, although there was a slight fluctuation throughout the storage time (Table 3). The FFA values of brown rice samples at two and four months storage ranged in 15.45-25.18 and 22.70-35.86 mg KOH (100 g d.b.)$^{-1}$, respectively. The W1 exhibited the highest increase in FFA from 15.77 to 21.57 and 35.86 mg KOH (100 g d.b.)$^{-1}$ up to four months storage, whereas the NG2 showed the lowest FFA from 16.93 to 16.31, 22.70 mg KOH (100 g d.b.)$^{-1}$. As shown in Fig. 2, the FFA value of W1 and W2 tended to accumulate more FFA content, followed by MW, NG1, and NG2. Lipid hydrolysis and oxidation reactions in rice kernel were attributed not to starch lipids but non-starch lipids in rice. As waxy rice contains higher non-starch lipids in the endosperm compared to non-glutinous rice, waxy rice tended to produce higher free fatty acids than non-waxy rice (20-22).

It was observed that the W1 showed the weakest aging property in terms of FFA accumulation during storage, whereas the NG1 and NG2 had more substantial grain quality against aging properties. Results indicated that the changes of FFA values at two months storage were not significantly different from the initial FFA values statistically at $p<0.05$ (Table 2). However, at four months storage, the FFA contents were accumulated significantly. The initial FFA values were ranged from 15.77 to 20.00 mg KOH (100 g d.b.)$^{-1}$, which were slightly higher than FFA analysis results by Sung et al. (23). They reported the FFA increment from 12.3 to 71.5 mg KOH/100 g. It was assumed that higher lipid content in the bran layer of brown rice could accelerate lipid

Table 3. Free fatty acid (FFA) of different brown rice cultivar accumulated during storage

Code[1)]	Storage (month)		
	0	2	4
W1	15.77±1.83[b2)y3)]	21.57±0.48[by]	35.86±5.25[ax]
W2	20.00±1.11[ay]	19.39±1.81[bcy]	29.12±1.34[abx]
MW	17.79±0.16[abx]	25.18±0.24[ax]	27.38±4.15[abx]
NG1	19.32±0.31[aby]	15.45±0.17[dy]	26.04±1.95[abx]
NG2	16.93±0.48[aby]	16.31±0.40[cdy]	22.70±1.28[bx]

[1)]W1, waxy rice; W2, waxy rice with black color; MW, medium-waxy rice; NG1, non-glutinous rice; NG2, non-glutinous rice.
[2)a-b]Values followed by different letters in the same column are significantly different at $p<0.05$.
[3)x-y]Values followed by different letters in the same row significantly different at $p<0.05$.

hydrolysis. Studies (24,25) explained that a mechanical procedure, such as dehulling for brown rice production, could rupture the cell walls, which surround oil shperosomes. It resulted in exposing rice kernel to lipase, then lipid started to oxidize.

Five different brown rice cultivar with varying amylose contents were stored in room temperature storage for four months, and the aging properties of rice samples were evaluated. Amylose content significantly affected pasting properties, showing varied peak viscosity and pasting time. The medium-waxy rice showed the highest peak and setback viscosity with the lowest breakdown viscosity, which could be the most suitable standards for steamed brown rice. Storage also significantly affected pasting viscosities, showing varied viscosity properties depending on the rice cultivars. Pasting viscosity during storage could be important starch properties upon using stored brown rice for direct consumption and processed products. Waxy brown rice showed the weakest aging property in terms of FFA accumulation, whereas non-glutinous rice cultivar had more substantial grain quality against aging. The FFA values of two months storage were not significantly different from the initial FFA contents, which could suggest that brown rice stored the most for two months could be feasible for direct consumption.

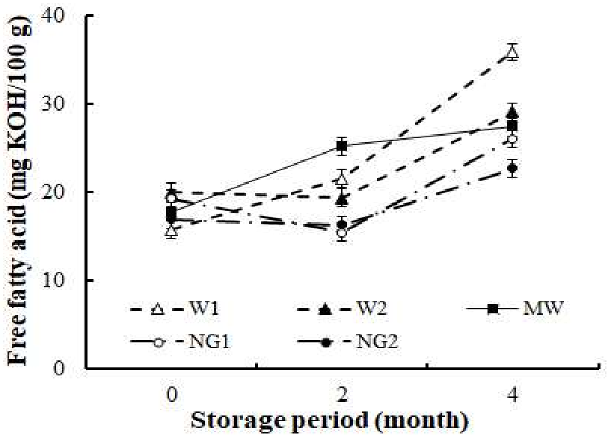

Fig. 2. Accumulation of free fatty acids (FFA) compared to different brown rice cultivar during storage.

W1, waxy rice; W2, colored waxy rice; MW, medium waxy rice; NG1, non-glutinous rice; NG2, non-glutinous functional rice.

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