

Effect of Harvesting Time on the Yield, Color, and Proximate Compositions of Jinbu Variety Green Rice[®]

– Research Note –

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Abstract

The degree of maturity of rice greatly affects the quality of the rice, including factors such as the integrity of grains, color, and the nutritive components. Green Rice[®] is rice (*Oryza sativa* L.) that has been harvested earlier than brown rice and appears green in color. To determine suitable harvesting time of the Jinbu variety of Green Rice[®] in Gyeonggido, rice samples harvested on 23, 26 and 42 days after heading (DAH) were compared on their yield, color intensity, and proximate compositions. The maximum paddy yield of Green Rice[®] was 61.4% at 23 DAH, which decreased to 45.4%, 5.5% at 26 and 42 DAH, respectively. Greenness was darker at 23 DAH (-0.27 ± 0.03), and significantly weaker ($p < 0.05$) at 26 DAH (0.07 ± 0.01) and at 42 DAH (5.25 ± 0.08). All proximate compositions, except carbohydrate, including moisture, crude fat, protein, ash and total minerals were higher in the earlier-harvested Green rice[®] than in brown rice, without variations among the 23 and 26 DAH Green rice[®]. Overall, the optimum harvest time of Jinbu Green Rice[®] at Gyeonggido would be 23 DAH. We suggest that timely harvesting could be a potent determinant of the quality of Green Rice[®].

Key words: Green Rice[®], harvest time, days after heading, color value, proximate compositions

INTRODUCTION

Green Rice[®] is rice (*Oryza sativa* L.) that has been harvested about 14~30 days earlier than brown rice and appears green in color. Green Rice[®] has been dehulled, but not milled, so that the layers of bran around the endosperm are retained. Green Rice[®] is different from the green-kerneled rice, which maintained green color in pericarp even after physiological maturity stage (1). Since Green Rice[®] has desirable color, physicochemical characteristics, and delayed retrogradation, it has been used to make various rice products in Southern Asia, such as cakes (“Banh com” in Vietnam), flakes, candy, ice cream, etc. Although rice varieties showing high quality and functional property have been developed, characteristics such as color value and proximate compositions of Green Rice[®] have never been determined. Cereals differ in their nutrient composition, physical and chemical properties depending on their maturity period. In particular, the bioactive substances including γ -amino butyric acid (GABA), ferulic acid, and α -tocopherols peak during the premature period in rice (2). The pigments in rice are well characterized and have been shown to possess both antioxidant and anti-inflammatory properties (3-5). On the other hand, earlier harvesting results in

higher levels of moisture, protein and amylose in brown rice cereal (6,7). Champagne et al. (8) demonstrated that the harvest time affected protein content rather than amylose content in rice. And this change induced higher cohesion and hardness of rice after steaming. It is natural that a higher yield of brown rice corresponds to a lower yield of Green Rice[®]. Thus, the time of harvest is a critical determinant of the quality of rice as well as total and head yield of rice according to the usage purpose such as for steamed rice or for other processing.

In this study, field experiments were performed to determine the optimum harvest time and characteristics of Green Rice[®] by the head yield, the weight of 1,000 rice kernels, color value, and proximate compositions using the early season cultivar, Jinbu. The experiments were performed at Gyeonggido in Korea, during the crop years 2004 and 2005.

MATERIALS AND METHODS

Rice samples

The field experiments were conducted in 2004 and 2005 with an early season rice variety, Jinbu, at Gyeonggido, Korea by contract farming. Jinbu rice variety was obtained from the Korea Seed and Variety Service.

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Chemicals

All chemicals used were at least analytical grade and obtained from Sigma-Aldrich (St. Louis, MO, USA) unless indicated otherwise.

Yield of Green rice[®] according to days after heading

To determine the range of days after heading (DAH) for Jinbu Green Rice[®], 4 harvesting dates (20, 23, 26, 40 DAH) were selected for the preliminary experiment in 2004. The grain samples were first dried until their moisture content reached 15%, and then dehulled using the THU testing husker (Satake, Tokyo, Japan). Three different sub-samples of 200 g each were weighed on each heading day using a L110 balance (Sartorius, Frankfurt, Germany). The weight of 1,000 rice kernels from both brown and Green Rice[®] was measured 3 times during each heading day, using the L110 balance. Green Rice[®] was selected by visual inspection, from 1,000 brown rice kernels. The total yield of Green Rice[®] was expressed as the percentage of brown head rice, while the means were compared using Duncan's multiple range test. We then selected the following harvest days for Green Rice[®] for contract farming in 2005: at 23 and 26 DAH as Green Rice[®], compared to 42 DAH as brown rice, using Jinbu variety.

Measurement of color value

The Minolta CR 200 colorimeter (Osaka, Japan) was used for all color determinations. Measurements were initiated by inserting the rice sample into a round bottomed light-projection tube (41 × 12.5 mm). Color measurements were made in triplicate for all samples. L^* is a measure of the brightness from black (0) to white (100). The parameter a^* describes from red (100) to green color (-80), with positive a^* values indicating redness and negative a^* values indicating greenness. The parameter b^* describes yellow to blue color, with positive b^* values indicating yellowness and negative b^* values indicating blueness (9).

Measurement of proximate and mineral contents

The paddy of each rice sample was cleaned and dried in the shade until the final moisture content reached up to 15%. A rough rice sample was dehulled in a laboratory sheller (THU, Satake) and then ground to pass through a 100 mesh screen, and analyzed for percentage proximate analysis and mineral element content. The determination of moisture content (105°C/12 hr), ash content (550°C/5 hr), crude fat in soxhlet apparatus (solvent ether), crude protein by nitrogen determination using Kjeldhal's method ($N \times 5.95$), and carbohydrate content by formula difference method are carried out according to their respective methods given in AOAC (10). The mineral content (*i.e.*, potassium, magnesium, calcium

and sodium) was determined using inductively coupled plasma spectrometry (ICP, JY 138 Ultrace, Horiba, Longjumeau, France). Briefly, samples were wet digested, transferred to 100 mL volumetric flask and made up to mark with distilled water and then filtered and analyzed in ICP and each element estimated.

Statistical analysis

Statistical analysis was performed using the SPSS package (version 15.0). The differences between the individual rice samples were assessed by examining the contrasts within the ANOVA. All data are expressed as mean \pm SD and the significance level was set at $p < 0.05$.

RESULTS AND DISCUSSION

Effect of harvesting time on the yield of Green rice[®] from Jinbu variety

In the 2004 preliminary study, the ratio of Green Rice[®] to brown rice among 1,000 rice kernels of Jinbu variety decreased as DAH increased. The ratio of Green Rice[®] to brown rice was consistently maintained at 98.5% and 82.7% at 20 and 23 DAH, respectively, whereas the ratio significantly decreased beyond 26 DAH and decreased further up to 19.9% at 40 DAH (data not shown). The weight of 1,000 brown rice kernels increased with increasing DAH; 17.7 g at 20 DAH, increased to 19.9 g at 23 DAH, and then remained around 22.7 g until 40 DAH in the early-season variety Jinbu (data not shown). These results are in agreement with those of Shin et al. (11). The results from preliminary studies indicated that a suitable harvest time to obtain the highest yield of Jinbu Green Rice[®] at Gyeonggido would be between 22 and 24 DAH.

In the present study, the ratio of Green Rice[®] to brown rice among 1,000 rice kernels was found to be 74.2% at 23 DAH, which decreased significantly to 52.4% at 26 DAH (Fig. 1). The weight of 1,000 Green Rice[®] kernels was 20.28 g at 23 DAH and 21.25 g at 26 DAH, whereas that of brown rice kernels was 24.53 g at 42 DAH. The results obtained for the head rice yield and the weight of 1,000 kernels of Jinbu Green Rice[®] may be explained by seasonal high temperatures in summer accelerating the maturation of Green Rice[®] to brown head rice. The total yield of Green Rice[®] of the Jinbu variety was significantly higher at 23 heading days (61.4%) than at 26 heading days (45.4%) in this study. The results of this study suggest that timely harvesting for the greater yield of Green Rice[®] would be 23 DAH.

Effect of harvesting time on the color value of Green rice[®] from Jinbu variety

The color value of rice samples is shown in Table 1.

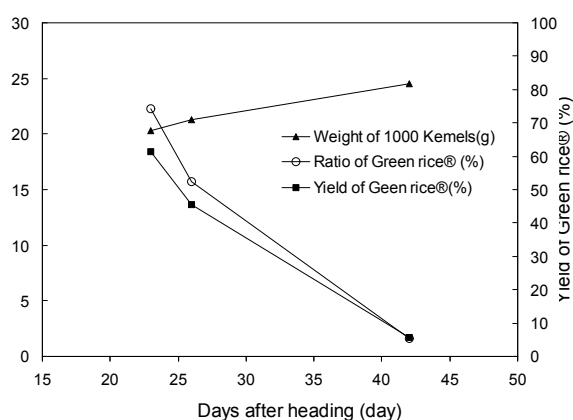


Fig. 1. The 1,000 kernel weight, the ratio of the GR[®] among 1,000 kernel and the yield of the GR[®] at 23, 26 and 42 days after heading in Jinbu variety at Gyeonggido, Korea, in 2005.

Table 1. The color value of Jinbu variety Green rice[®] according to heading days

Color value	Days after heading		
	Green rice [®]		Brown rice
	23	26	42
L	63.46 ± 0.98	63.66 ± 1.72	64.98 ± 1.32
a	-0.27 ± 0.03*	0.07 ± 0.01*	5.25 ± 0.08
b	23.71 ± 0.42	23.37 ± 0.33	24.34 ± 0.23

*p<0.05 compared to Brown rice.

The L^* value was not significantly different from heading days, while b^* values was fluctuated from day to day. On the other hand, a^* values significantly increased as the heading days increased in the Jinbu variety. Therefore, the a^* value, which indicates greenness from -80 (green) to 100 (red), can be a determinant of greenness intensity of Green Rice[®]. Specifically, the a^* value in Jinbu was the lowest at 23 DAH (-0.27 ± 0.03), which increased at 26 DAH (0.07 ± 0.01) and 42 DAH (5.25 ± 0.08) (Table 1). The results of this study indicate that the greenness intensity of Green Rice[®] is weaker than known green-kernelled rice varieties (12). Lee et al. (12) reported that a^* values of green-kernelled rice varieties, Saegdongchalbyeo (Korea) and Hexi 41 (China) were -10.09 and -2.85, respectively. Chu et al. (1) reported that there was a strong correlation between the greenness and DAH, indicating that the greenness was largely affected by air temperature during ripening as well as by

the genotype. We propose that the appropriate harvest time to obtain the desirable color of Jinbu Green Rice[®] in Gyeonggido would be 23 DAH from the early season. However, the greenness of the rice kernel can be affected by planting time, nitrogen fertilizer level (12) or storage conditions after harvest, including the temperature, and the light/dark condition. Therefore, further quality control studies on post-harvest management for Green Rice[®] are warranted; for example, color fixation that results from parboiling pretreatment on rice, or the association between color change and nutritional properties (13,14).

Effect of harvesting time on proximate compositions of Green rice[®] from Jinbu variety

Proximate compositions of rice samples were shown in Table 2. All proximate compositions like moisture, crude fat, crude protein and crude ash except for carbohydrate content were higher in Green rice[®] than brown rice in this study. The present study shows that Green rice[®] (356.85 kcal/100 g) can be a less dense energy source rather than brown rice (364 kcal/100 g), however, it can provide good energy as a staple food. There were no significant differences on the proximate compositions in Green rice[®] according to DAH. For the brown rice, we compared the proximate compositions of the present data with those of the Food Composition Table (FCT; 15) to determine the following values: moisture content (10.5%) of our data was lower than that of FCT (11.6%), carbohydrate content (78.2%) was higher than that of the FCT (77.1%), crude fat content (2.4%) was higher than that of the FCT (2.1%), crude protein content was similar to that of the FCT (7.6%), crude ash content was lower (1.3%) than that of the FCT (1.6%). The energy density of brown rice in the present study was a little higher (364 kcal/100 g) than that of the brown rice in FCT (350 kcal/100 g); however, these differences can exist depending on the sample preparation, measurements, and other possible factors such as planting time and fertilizer levels.

Effect of harvesting time on mineral contents of Green rice[®] from Jinbu variety

Mineral contents of Green rice[®] of the Jinbu variety

Table 2. Proximate compositions of Jinbu variety Green rice[®] according to heading days

Proximate compositions	Days after heading		
	Green rice [®]		Brown rice
	23	26	42
Moisture (%)	12.63 ± 0.58	12.64 ± 0.25	10.53 ± 0.12
Carbohydrate (%)	75.67 ± 1.38	75.64 ± 2.01	78.22 ± 4.28
Crude fat (%)	2.58 ± 0.14	2.59 ± 0.78	2.37 ± 0.38
Crude protein (%)	7.73 ± 0.57	7.75 ± 0.23	7.55 ± 0.21
Crude ash (%)	1.39 ± 0.12	1.38 ± 0.02	1.33 ± 0.06
Energy density (kcal/100 g)	356.82 ± 0.82	356.87 ± 1.68	364.41 ± 2.93

Table 3. Mineral contents of Jinbu variety Green rice[®] according to heading days

Mineral contents	Days after heading		Green rice [®]		Brown rice
	23	26	26	42	42
Mg (mg/100 g)	144.29 ± 6.93	143.28 ± 7.38	143.28 ± 7.38	145.27 ± 7.98	145.27 ± 7.98
K (mg/100 g)	267.34 ± 2.32*	251.25 ± 3.90*	251.25 ± 3.90*	213.80 ± 3.25	213.80 ± 3.25
Ca (mg/100 g)	10.38 ± 0.38	9.44 ± 0.22	9.44 ± 0.22	10.49 ± 0.12	10.49 ± 0.12
P (mg/100 g)	350.12 ± 10.27	332.20 ± 9.48	332.20 ± 9.48	348.54 ± 12.53	348.54 ± 12.53
Na (mg/100 g)	18.49 ± 0.21	24.22 ± 0.11	24.22 ± 0.11	18.63 ± 0.18	18.63 ± 0.18
Fe (mg/100 g)	0.95 ± 0.02	1.27 ± 0.04	1.27 ± 0.04	0.85 ± 0.31	0.85 ± 0.31
Mg/K	0.54 ± 0.09*	0.57 ± 1.03	0.57 ± 1.03	0.68 ± 2.02	0.68 ± 2.02
Total (mg/100 g)	791.57 ± 5.89*	761.66 ± 13.45	761.66 ± 13.45	737.58 ± 10.98	737.58 ± 10.98

*p<0.05 compared to brown rice.

are shown in Table 3. Total mineral content decreased with increased heading days for the Jinbu variety in this study. Major minerals obtained from this rice were phosphorus (44.2, 43.6%), potassium (33.8, 33.0%), and magnesium (18.2, 18.8%) at 23 and 26 DAH respectively, whereas major minerals for brown rice according to the data from the FCT were potassium (40.7%), phosphorus (34.8%), and magnesium (13.7%) and for polished rice, the major minerals were potassium (41.6%), phosphorus (35.8%), and sodium (16.9%). Interestingly, the sodium content in Jinbu rice in the present study was significantly lower than that of FCT, regardless of milling. The levels of P, Mg and K and their distributions in rice grains have been studied during the ripening period. These elements rapidly translocated into the grains between the 10th and 20th day after flowering and their amounts remained constant until maturation. The ratio of the electric charges K⁺ + Mg²⁺ to -PO₄²⁻ (monoester-P) became 1 with maturation (16). In addition, Itani et al. (17) reported that P, Mg, K, and Mn were extremely rich in the outer portion, while N and Ca were only relatively rich there.

In this study, the magnesium to potassium ratio (Mg/K) increased with increasing DAH. Koshihikari, which is the most popular variety of rice in Japan because of its excellent eating quality, showed the highest Mg/K ratio (0.78) in the outermost portion of polished rice (17).

Green rice[®] at 23 DAH had the lowest Mg/K ratio (0.54 ± 0.09), which gradually increased during the maturation period to brown rice at 42 DAH (0.68 ± 2.02), whereas the Mg/K ratio was lower in brown rice (0.34) or in polished rice (0.11) according to the FCT. These variations on the mineral content could be attributed to a number of factors, such as the rate of fertilization application and the availability by soil nutrients, as well as species differences (18). This report is the first recorded attempt at investigating whether the modulation of harvest time with the Jinbu variety can produce another type of rice for specific use, such as a functional food resource. More investigation is required to determine

methods for the production of potent Green rice[®] varieties using other rice varieties, and for the development of post-harvesting technique on color fixation.

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