Effects of Drying Conditions, Final Moisture Content, and Degree of Milling on Rice Flavor

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ABSTRACT

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The extent that postharvest processing parameters influence the sensory quality of cooked rice is not well known. In this investigation, the effects of drying conditions, final moisture content, and degree of milling on the flavor of rice varieties Bengal, M-401, and Koshihikari were determined by descriptive sensory analysis. No trends were observed indicating an increase or decrease in flavor attributes with increased drying temperatures (18–60°C). Intensities of desirable and undesirable flavor attributes were higher in rice dried to 15% moisture compared to 12% moisture. The effects of deep-milling on flavor attribute intensities were dependent on moisture content and variety or location.

The sensory quality of cooked rice strongly affects the economic value of the grain in domestic and world markets. This quality varies due to factors such as variety, growing location, cultivation methods, harvesting methods, and processing after harvesting (drying, storage, milling). These factors affect constituent content and their interactions in the rice that govern sensory quality. Conventionally, sensory quality of rice has been assessed by a combination of sensory and physicochemical property evaluations. Through statistical methods, relationships between sensory and physicochemical properties are determined, allowing assessment of sensory quality. Sensory evaluations are generally preference ratings of flavor and texture, with the emphasis on textural attributes. A preference panel states their opinion of how much they like or prefer a rice sample based on personal examination and judgment according to individual senses. The panel is intended to represent a target population. If samples are presented to panelists representing a different population, results will differ.

An alternative to preference sensory analysis for evaluating sensory properties of rice is descriptive sensory analysis (Meilgaard et al 1987). In contrast to preference evaluations, descriptive analysis is an objective methodology. Descriptive analysis utilizes trained panelists that have been screened for normal abilities to perceive sensory attributes. They are not a sample of the population, but an analytical instrument. They evaluate the intensities of the various sensory attributes using a universal intensity scale. Following calibration, panelists theoretically should give the same results for a given sample, regardless of nationality, age, or gender.

USDA Agricultural Research Service scientists in collaboration with industry, U.S. rice breeders, and international scientists have initiated investigations to develop universal methods for assessing and predicting the sensory quality of rice for domestic and international markets. As part of this collaborative effort, the effects of drying conditions, final moisture content, and degree of milling (DOM) on the flavor and texture of U.S. medium grain varieties have been determined using descriptive analyses and instrumental means. This article reports the influences of these postharvest processing parameters on the flavor of the cooked rice.

MATERIALS AND METHODS

Rice Samples

Rice from 1994 crops of Bengal and Koshihikari grown in Louisiana and Texas and M401 grown in Texas was harvested at 20% moisture. Bengal and M401 are two U.S. medium-grain rices considered by the U.S. industry to be of high quality. Koshihikari, a Japanese variety, is regarded by the Japanese as a premium rice of excellent quality when grown in Japan. The rices were dried within 24 hr of harvesting by one of three techniques to 12 and 15% moistures levels: 1) air-drying at 18°C and 40% rh, 2) air-drying at ambient temperatures (26–28°C), and 3) continuous-flow drying with heated air. The continuous-flow drying was on a pilot-scale unit that simulates commercial dryers located at Riviana Foods, Inc. (Houston, TX). High (60°C), normal (50°C), and low (32°C) commercial drying temperatures were used. Following drying, the paddy (rough) rice was stored in closed containers for two to three months at 18°C and 40% rh. One week before sensory testing, the samples were shelled using a Satake Rice Machine model SB and then immediately milled. Regular (light) milling was accomplished using a laboratory one-pass mill (Satake pearler, model SKD). The first pass was with a 50-g weight in the 5th position; the second pass was with a 50-g weight in the 3rd position. This standard milling protocol was determined to be appropriate for yielding rice with whiteness values in the targeted 40 ± 2 range considered typical of regular milled rice. Whiteness was measured using a milling meter (Satake model MM-1B). Deep milling was performed on 250-g portions of the regular-milled rice using a laboratory grain testing mill (Satake model TM05). Milling conditions were 1 min at 1,250 rpm using a fine-mesh abrasive wheel and were appropriate for whiteness values of 49 ± 2, typical of deep-milled rice. Broken grains were removed with appropriate laboratory-sizing devices using standard indented plates and cylinders.

Sample Preparation for Sensory Analyses

Samples of milled rice were preweighed into 600-g portions and stored in plastic bags (Ziploc, DowBrand L. P., Indianapolis, IN) at room temperature until sample presentation. The rice was washed, soaked for 20 min, and prepared using a rice-to-water

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weight of 1:1.3 (Min et al 1994). Rice was cooked in a 5-cup rice cooker-steamer (Panasonic SR-W10G HP) to completion, followed by a 10-min postcooking (warming) period. The top 1-cm layer of cooked rice and rice adhering to the sides of the cooker were not presented for tasting. Cooked rice for sampling was taken directly from the middle of the pot, transferred to a prewarmed (250°F/120°C) glass bowl and mixed thoroughly while minimizing kernel breakage. Rice samples (≈48 g) were taken using a size 18 stainless steel ice cream scoop, transferred to prewarmed (250°F/120°C) 6-oz glass custard cups (Anchor Hocking) insulated by fitted styrofoam bowls, and covered with 125-mm watch glasses. Samples were evaluated for sensory quality using descriptive analysis.

Sensory Evaluation Protocol

Sensory evaluation was performed by a trained panel made up of 13 panelists. Panelists were trained in descriptive analysis by methods described by Johnsen (1994). A linear universal intensity scale (Meilgaard et al 1987) ranging from 0 to 15 in equal increments was used to evaluate the intensities of rice attributes. Various points on the scale are represented by flavor attributes in commercially available food products (e.g., grape flavor in grape Kool-ade = 4). The lexicon for rice flavor used by the panel was based on that developed by Goodwin et al (1996) (Fig. 1). The study consisted of 21 taste sessions in which rice samples were presented at 15-min intervals and analyzed under red lights to discourage preconceptions associated with food coloration. Flavor was assessed by smelling and tasting, respectively, and the higher intensity of the two assessments was recorded. Based on the randomized complete block design chosen, each of 20 sensory panel sessions contained rice samples for all five levels of drying for the same combination (variety, location, moisture, milling); a "standard"; and a blind control (Calrose, commercial product). The 21st panel session consisted of a sixth variety by location sample processed under a single drying condition for the four moisture by milling combinations, a standard, and two blind control samples to provide an independent estimate of error variability for analysis of variance (ANOVA). The standard, the warm-up sample presented at the beginning of each session, was used to calibrate the panel. Distilled, deionized water (Millipore Milli-Q water system) was used to cleanse the mouth between samples. The individual panelist's scores, panel means, and standard deviation for each descriptor of a test sample were made available to the panelists following each taste session and were discussed.

DESCRIPTOR	DESCRIPTION
AROMATICS	
Sewer-Animal	An immediate and distinct pungent aromatic in the flavor characterized as sulfurlike and generic animal. Animal aromatic in the flavor can sometimes be identified as "piggy".
Floral	Aromatics associated with dried flowers, such as lilac or lavender. This aromatic is characterized as spicy floral as in an "old fashioned sachet".
Grain-Starchy	General term used to describe the aromatics in the flavor associated with grains such as corn, oats and wheat. It is an overall grainy impression characterized as sweet, brown, sometimes dusty, and sometimes generic nutty or starchy.
Haylike-Musty	Dry, dusty, slightly brown aroma or flavor with a possible trace of musty.
Popcorn	Dry, dusty, slightly toasted and slightly sweet aromatic in the flavor that can be specifically identified as popcorn.
Corn	Sweet aromatics of the combination of corn kernels, corn milk, and corn germ found in canned yellow creamed-style corn.
Alfalfa-Grassy-Green Bean	A dried, green, slightly earthy, slightly sweet aroma or flavor including grassy and fresh green bean aroma or flavor.
Dairy	General term associated with the aromatics of pasteurized cow's milk. Most apparent just before swallowing.
Sweet Aromatic	Sweet impression, such as cotton candy, caramel, or sweet fruity that may appear in the aroma or aromatics.
TASTES	
Sweet Taste	Basic sweet taste associated with sugar.
Sour-Silage	Sour fermented vegetation aroma or flavor, not decaying vegetation.
FEELING FACTORS	
Astringent	The chemical feeling factor on the tongue, described as puckering or dry and associated with tannins or alum.
Waterlike-Metallic	Aromatics and mouthfeel of the minerals and metals commonly associated with tap water. This excludes any chlorine aromatics that may be perceived.

Fig. 1. Rice flavors detected and evaluated in cooked rice samples. Lexicon adapted from Goodwin et al (1996).

Statistical Analyses

A scatterplot consisting of the scores assigned to each of the five experimental treatments in a panel session was produced for each panelist and each attribute. For a given session, these scatterplots were visually examined to identify which panelists were not performing to consensus during a session. Outlier scores for each attribute were removed. The blind control samples were used to adjust out session effects before conducting the ANOVA. This was accomplished by calculating the panel mean of blind control samples for each session and by calculating the panel mean over all sessions to obtain a grand blind control mean. The difference between the overall blind control mean and a given panel session blind control mean was added to all panel mean scores in the panel session to remove any session effect.

The limited availability of resources for this experiment dictated its unreplicated design and suggested two options for conducting ANOVA to examine the effects of processing conditions on each flavor attribute. First, the five distinct samples of rice varieties and growing location were utilized as replicate experimental units (i.e., random effects). Estimates of error variability for conducting a three-way ANOVA (Table I) were obtained by pooling all effects involving variety and location. Alternatively, an unreplicated five-way ANOVA was conducted to determine whether processing condition effects differed among variety and location combinations. Estimates of error variability for conducting this five-way ANOVA were obtained by pooling the variability between the duplicate blind control samples of the 21st panel session with the variety by location by drying by moisture by milling effect, assumed for practical purposes to be negligible. Subsequently, separate three-way ANOVA (Table I) were conducted for each variety and location combination using half-normal plot analyses (Milliken and Johnson 1989) to identify negligible single degree-of-freedom orthogonal component effects to pool for an estimate error variability.

Each subsequent section begins with discussion of results from the ANOVA using variety and location as replicates (i.e., combined sample ANOVA) and conclude with the results of separate ANOVA for each variety and location. Significant differences are reported using α = 0.05, unless otherwise noted in the text.

TABLE I
Full Fixed-Effect Factorial Analysis of Variance (ANOVA)

Source of Variation	Degrees of Freedom
Dry	4
Moisture	1
Dry × moisture	4
Milling	1
Dry × milling	4
Moisture × milling	1
Dry × moisture × milling	4
Error (1)[a]	80
Error (2)[a]	*n*[b]

[a] Error source of variation and error degrees of freedom differ for (1) using variety and location combinations as replicates and (2) conducting a separate ANOVA for each variety and location.

[b] Error degrees of freedom determined by the number of nonsignificant single degree of freedom components resulting from the half-normal plot analyses; *n* < 19.

TABLE II
Flavor Attributes with Intensities that were Significantly (S, α = 0.05, S*, α = 0.10) Affected by Drying Conditions. Significant (α = 0.05) Drying × Moisture, Drying × Milling, and Drying × Moisture × Milling Interaction Effects from Three-Way Analysis of Variance.

	Koshihikari		Bengal		M401
Flavor Attributes	**Louisiana**	**Texas**	**Louisiana**	**Texas**	**Texas**
Sewer-Animal	S	S*			S*[b]
Floral			S*	S	
Grain-Starchy					S[a–c]
Haylike-Musty	S[a–c]	S			
Popcorn	S[c]		S*[a]	S*	
Corn	S[b]		S[a,b]	S*	
Alfalfa-Grass-Green Bean			S*[a–c]		S[a–c]
Dairy	S[b]				
Sweet Aromatic				S*[c]	
Sweet Taste					
Sour-Silage	S				
Astringent					
Water-Metallic	S			S*	

[a] Significant (α = 0.05) drying × moisture interaction effects.

[b] Significant (α = 0.05) drying × milling interaction effects.

[c] Significant (α = 0.05) drying × moisture × milling interaction effects.

TABLE III
Flavor Attributes with Intensities that were Significantly[a] (α = 0.05) Affected by Final Moisture Content. Values are Differences Between Measures for 15 and 12% Moisture Rice.[b]

Flavor Attribute	Effect (15 – 12%)
Corn	0.042
Floral	0.043
Sweet Aromatic	0.112
Sweet Taste	0.062
Haylike-Musty	0.073
Sewer-Animal	0.203

[a] Three-way analysis of variance (ANOVA) combining variety × location combinations as replicates and examining the main effect of final moisture content on intensity of flavor attributes.

[b] Range of means for flavor attribute intensities was 0.4–1.7.

TABLE IV
Flavor Attributes with Intensities that were Significantly[a] (α = 0.05) Affected by Final Moisture Content. Values are Differences Between Measures for 15 and 12% Moisture for Regular and Deep Milled Rice.[b]

		Effect (15 – 12%)	
Variety (Location)[c]	**Flavor Attribute**	**Regular Milled**	**Deep Milled**
Koshihikari (LA)	Haylike-Musty*[d]	–0.34	0.02
	Corn*	–0.46	0.16
	Alfalfa-Grassy	–0.22	–0.16
	Dairy*	–0.08	0.26
	Sour-Silage	0.34	0.22
	Astringent	0.18	0.36
Koshihikari (TX)	Floral	–0.11	–0.26
	Grainy-Starchy*	–0.49	0.06
Bengal (LA)	Sewer-Animal	0.32	0.22
	Grainy-Starchy*	0.38	–0.20
	Alfalfa-Grassy	0.14	0.12
	Dairy	0.08	0.10
	Astringent	0.12	0.20
Bengal (TX)	Sewer-Animal	0.48	0.36
	Floral*	0.46	0.10
	Haylike-Musty*	0.34	–0.06
	Popcorn	0.14	0.08
	Corn	0.14	0.14
	Sweet Aromatic*	0.32	–0.06
	Sweet Taste*	0.30	0
	Astringent	0.28	0.24
M401 (TX)	Sewer-Animal*	0	0.34
	Floral	0.10	0.16
	Grainy-Starchy*	0.36	–0.06
	Popcorn	0.16	0.08
	Corn	0.26	0.16
	Alfalfa-Grassy*	0	0.26
	Sweet Aromatic	0.28	0.20
	Sweet Taste	0.30	0.16

[a] Three-way analysis of variance (ANOVA) conducted separately for each variety and location, examining the main effect of final moisture content and its interaction with degree of milling on intensity of flavor attributes.

[b] Range of means for flavor attribute intensities: 0.4–1.9

[c] LA = Louisiana. TX = Texas.

[d] Asterisks denote a significant (α = 0.05) moisture × milling interaction effect.

RESULTS AND DISCUSSION

Effects of Drying Conditions on Flavor Attribute Intensities

Rough rice samples were dried to 12 and 15% moisture contents under five conditions ranging from mild (air-drying at 18°C, 40% rh) to harsh (commercial drying at 60°C). Flavor attributes significantly affected by drying were sewer-animal, haylike-musty, corn, sour-silage, and waterlike-metallic for combined rice samples (data for all varieties, locations, moisture contents, DOM combined). No trends were observed indicating an increase or decrease in flavor attribute intensities with increased drying temperatures. The effects of drying conditions on the intensities of sewer-animal, haylike-musty, and sour-silage were dependent on final moisture content. As for the combined set, no trends in flavor attribute intensities were observed for samples within each moisture level. The effects of drying conditions on flavor attribute intensities were statistically similar for regular- and deep-milled rice samples, with the exception of corn. Differences in the intensity of this attribute between drying levels in the deep-milled rice was generally larger than those in the regular-milled rice. No significant drying by moisture by milling interaction effects were observed.

Table II shows the flavor attributes with intensities that were significantly affected by drying conditions for individual varieties grown at specific locations. As with the combined set, no trends were observed indicating an increase or decrease in flavor attribute intensities with increased drying temperature. Significant drying by moisture, drying by milling, and drying by moisture by milling interaction effects are noted in the table.

Effects of Final Moisture Content on Flavor Attribute Intensities

The moisture content (12 or 15%) to which the rice was dried significantly affected the intensities of corn, floral, haylike-musty, sweet aromatic, sewer-animal, astringent, and sweet taste in the combined rice samples. The intensities of both the desirable (corn, floral, sweet aromatic, sweet taste) and undesirable (haylike-musty, sewer-animal) flavors were higher in rice dried to 15% moisture as compared to 12% moisture (Table III). The effects of moisture content on the intensities of corn and floral were dependent on the DOM.

The effects of final moisture content on flavor attribute intensities were dependent on variety and location. Table IV lists the flavor attributes that were affected by moisture content for individual varieties grown at specific locations. The table shows the effects of drying to 15% moisture versus 12% moisture for regular- and deep-milled rice. Significant moisture by milling interaction effects are indicated. As noted above for the combined set, flavor attribute intensities were generally higher in rice dried to the higher moisture content. Notable exceptions were flavor attribute intensities in Koshihikari grown in Louisiana and Texas. The intensities of haylike-musty, corn, alfalfa-grassy, and dairy in regular-milled and alfalfa-grassy in deep-milled Koshihikari (LA) were lower at 15% moisture than at 12% moisture. Floral in regular- and deep-milled and grain-starchy in regular-milled Koshihikari (TX) were lower at the higher moisture content. The absolute value of the moisture effect was larger for the regular-milled rice than the deep-milled rice with a few exceptions.

TABLE V

Flavor Attributes with Intensities that were Significantly[a] (α = 0.05) Affected by Degree of Milling and Those Exhibiting a Significant (α = 0.05) Milling × Moisture Interaction Effect. Values are Differences Between Measures for Deep Milled and Regular Milled Rice.[b]

Flavor Attribute	Effect (Deep – Regular) 12% Moisture	Effect (Deep – Regular) 15% Moisture
Corn[c,d]	0.012	0.142
Grain-Starchy[c,d]	0.008	–0.179
Dairy[d]	0.060	–0.033
Floral[d]	0.036	–0.029
Popcorn[d]	–0.044	0.105
Waterlike-Metallic[c]	0.064	0.071

[a] Three-way analysis of variance (ANOVA) combining variety × location combinations as replicates and examining the main effect degree of milling and its interactions with final moisture content on intensity of flavor attributes.

[b] Range of means for flavor attribute intensities: 0.6–1.7.

[c] Flavor attribute intensities significantly (α = 0.05) affected by degree of milling.

[d] Flavor attribute intensities significantly (α = 0.05) affected by milling × moisture interaction effect.

Effects of DOM on Flavor Attribute Intensities

The DOM significantly affected the intensities of corn, grain-starchy, and waterlike metallic in the combined rice samples. Significant milling by moisture interaction effects were observed for corn, grain-starchy, dairy, floral, and popcorn. Table V shows the effects of DOM on the intensities of the flavor attributes that were affected by milling or exhibited milling by moisture interaction effects for rice dried to 12 and 15% moisture. Deep-milling resulted in small increases in the intensities of dairy, floral, and waterlike metallic and a small decrease in popcorn in rice dried to 12% moisture. Deep-milling had the opposite effect on the intensities of dairy and floral in rice dried to 15% moisture. The absolute value of the milling effect of flavor attribute intensities tended to be larger for the rice dried to 15% moisture than that dried to 12%.

The effects of DOM were dependent on variety and location, as shown in Table VI. Milling by moisture interaction effects were exhibited by most of the flavor attributes. Most of the flavor attributes in Koshihikari (LA) and Bengal (TX) were significantly

TABLE VI

Flavor Attributes with Intensities that were Significantly[a] (α = 0.05) Affected by Degree of Milling and Those Exhibiting a Significant (α = 0.05) Milling × Moisture Interaction Effect. Values are Differences Between Measures for Deep Milled and Regular Milled Rice.[b]

Variety (Location)[c]	Flavor Attribute	Effect (Deep – Regular) 12% Moisture	Effect (Deep – Regular) 15% Moisture
Koshihikari (LA)	Sewer-Animal[e]	–0.20	0.10
	Haylike-Musty[d,e]	–0.06	0.30
	Floral[d]	0.26	0.14
	Popcorn[d,e]	–0.16	0.34
	Corn[d,e]	–0.02	0.60
	Alfalfa-Grassy[d]	–0.16	–0.10
	Dairy[d,e]	–0.06	0.28
	Sweet Taste[e]	–0.16	0.30
Koshihikari (TX)	Haylike-Musty[d]	–0.12	0.02
	Grainy-Starchy[d]	–0.22	0.33
Bengal (LA)	Floral[d]	–0.30	–0.18
	Grainy-Starchy[d,e]	0.38	–0.20
	Popcorn[d,e]	–0.12	0.02
	Waterlike-Metallic[e]	0.12	–0.18
Bengal (TX)	Haylike-Musty[e]	0.10	–0.30
	Floral[d,e]	0.34	–0.02
	Grain-Starchy[d,e]	–0.14	–0.54
	Corn[d]	0.14	0.14
	Dairy[d,e]	0.18	–0.02
	Sweet Aromatic[d,e]	0.28	–0.10
	Sweet Taste[d,e]	0.28	–0.02
	Waterlike-Metallic[d]	0.38	0.32
M401 (TX)	Sewer-Animal[e]	–0.14	–0.20
	Grain-Starchy[e]	0.18	–0.24
	Dairy[d,e]	0.02	–0.34
	Sweet Aromatic[d,e]	–0.10	–0.18
	Sour-Silage[e]	–0.34	0.02

[a] Three-way analysis of variance (ANOVA) conducted separately for each variety and location, examining the main effect of degree of milling and its interaction with final moisture content on intensity of flavor attributes.

[b] Range of means for flavor attribute intensities: 0.5 –1.8.

[c] LA = Louisiana. TX = Texas.

[d] Flavor attribute intensities significantly (α = 0.05) affected by degree of milling.

[e] Flavor attribute intensities exhibiting significant (α = 0.05) milling × moisture interaction effect.

affected by deep-milling. In Koshihikari (LA), the effect of deep-milling on sewer-animal, haylike-musty, popcorn, dairy, and sweet taste was to decrease the intensities of these flavors in 12% moisture rice and increase them when the moisture content was 15%. In contrast, deep-milling Bengal (TX) resulted in haylike-musty, dairy, and sweet taste of higher intensity when the rice was dried to 12% and lower intensity when dried to 15%. Floral was higher in intensity in regular-milled Bengal (TX) and deep-milled Koshihikari (LA) at both 12% and 15% moisture contents.

CONCLUSIONS

In conclusion, drying at higher temperatures did not adversely affect the flavor of the rice, as judged by descriptive analysis. No trends were observed indicating an increase or decrease in flavor attributes with increased drying temperatures. In general, intensities of desirable and undesirable flavors were higher in rice dried to 15% moisture as compared to 12% moisture. Therefore, for flavor impact, it may be advantageous to dry rough rice to 15% as practiced in Japan rather than 12% as is common in the United States. Storing rough rice in the southern United States at 15% moisture content, however, would be problematic. The rice would require special handling (e.g., aeration) to prevent spoilage. Alternatives would be to shell or mill the rice shortly after drying to 15% moisture content and store it under refrigerated conditions, as is practiced in Japan. The effects of deep-milling on flavor attribute intensities were dependent on variety or location and moisture content.

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LITERATURE CITED

Goodwin, H. L., Koop, L. A., Rister, M. E., Miller, R. K., Maca, J. V., Chambers, E., Hollingsworth, M., Bett, K., Webb, B. D., and McClung, A. 1996. Developing A Common Language for the U.S. Rice Industry: Linkages Among Breeders, Producers, Processors, and Consumers. TAMRC Report. Texas A&M University: College Station, TX.

Johnsen, P. B. 1994. The human chemosensory system: An instrument for flavor research. In: Proceedings of the United States–Japan Cooperative Program in Natural Resources (UJNR) Protein Resources Panel. 23rd Annual Meeting. A. E. Pavlath, ed. USDA-ARS Western Regional Research Center: Albany, CA.

Meilgaard, J., Civille, G. V., and Carr, B. T. 1987. Sensory Evaluation Techniques, Vol. II. CRC Press: Boca Raton, FL.

Milliken, G. A., and Johnson, D. E. 1989. Analysis of Messy Data, Vol. II. Nonreplicated Experiments. Van Nostrand Reinhold: New York.

Min, B. K., Hong, S. H., Shin, M. G., and Jung, J. 1994. Study on the determination of the amount of added water for rice cooking by extrusion test of cooked rice. Korean Soc. Food Sci. Technol. 26:98-101.

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