Effects of Rough Rice Drying and Storage Conditions on Sensory Profiles of Cooked Rice

Jean-Francois C. Meullenet,[1,2] Bradley P. Marks,[3] Kaye Griffin,[1] and Melissa J. Daniels[3]

Cereal Chem. 76(4):483–486

ABSTRACT

In both domestic and international markets, the end-use quality of rice affects its market value and acceptability to consumers. The effect of various postharvest processing treatments on sensory characteristics of cooked rice was investigated using sensory descriptive methods. Cooked rice quality was affected ($P < 0.05$) by rough rice wet holding, drying temperature, storage temperature, and storage duration. Cohesiveness of mass and hardness of sample were significantly affected by the temperature of drying. A higher storage temperature reduced the cohesiveness of mass and gluiness, while sample hardness, clumpiness, and geometry of slurry increased. Storage duration had more profound effects on the sensory attributes studied. Perceived starchy note, clumpiness, gluiness, and overall sensory impression decreased after four weeks of storage. Storage duration also influenced hardness, moisture absorption, sulfury notes, and cardboardy notes.

Much work has been done investigating the effect of postharvest handling of rice on raw product quality. However, few studies have been conducted on the relationship between postharvest handling and sensory properties. As rice consumption continues to increase, there is a need for more research on these effects on cooked rice. Sensory analysis techniques have been used by several researchers to evaluate the effects of storage (Okabe 1979, Juliano and Perez 1983, Chrastil 1990), processing (Rousset et al 1995), and variety (Juliano et al 1984, Damardjati et al 1986, Kumari and Padmavathi 1991, Perez et al 1993) on end-use quality of rice.

The effects of postharvest handling on sensory profile of cooked rice can be thoroughly investigated by a professionally trained descriptive panel capable of evaluating a wide range of sensory properties in a quantitative and reproducible manner. Such research involves sensory profiling or descriptive analysis methods consisting of formal procedures for assessing specific product attributes with suitable scales. These methods can include evaluations for aroma, flavor, appearance, and texture, separately or in combination (ISO 11036: Sensory analysis, Methodology, Texture profile). In a descriptive sensory profile, trained panelists differentiate and rate intensities of food sensory characteristics. As such, descriptive sensory profiling is the most sophisticated sensory methodology available (Stone and Sidel 1993). Descriptive analysis also provides a complete sensory description of an array of products and a basis for distinguishing those sensory attributes that are important for acceptance by consumers (Stone and Sidel 1993). Sensory profiling is useful in evaluating sensory changes over time with respect to processing conditions and shelf life (Meilgaard et al 1991). As such, descriptive analysis may be the most appropriate sensory tool to evaluate the effects of drying and storage of rough rice conditions on sensory characteristics of cooked rice. The objective of this investigation was to differentiate and rate the intensities of rice postharvest parameters including wet holding, drying conditions, storage temperature, and storage duration to the sensory characteristics of cooked rice using a trained sensory panel.

MATERIALS AND METHODS

Postharvest Treatments

Long-grain rice (variety Cypress) harvested from Stuttgart, AR, in September, 1995, at a 20.5% moisture content (mc, wet basis) was used in the study. This long-grain variety was studied because of its predominance in the rice acreage cultivated in Arkansas at the time of this study. Rough rice (150 lb.) was cleaned (dockage tester, Carter-Day Co., Minneapolis, MN) and mixed thoroughly before being divided into two lots (Boener divider, Seedboro, Chicago, IL). The first lot was prepared for immediate drying, while drying of the second lot was delayed for 86 hr. Both immediate and delayed drying lots were subsequently divided into two lots and dried under two different drying treatments in a laboratory-scale drying system. The high-temperature drying treatment (HT) was 54.3°C and 21.9% rh, and the low-temperature treatment (LT) was 33°C and 67.8% rh. Both drying treatments consisted of exposing a thin layer (<4 cm) of rice for 30 min in a drying chamber, followed by slow equilibration to the final moisture content. Subsequent equilibration of both lots occurred over several days in a controlled chamber set at 33°C and 67.8% rh until the rice reached 12.5% mc. After drying, each lot was further divided and placed in air-tight buckets for storage at three temperatures (4, 21, and 38°C). Sensory evaluation was performed before storage and after four and 20 weeks of storage.

Sensory Methodology

Nine professionally trained panelists (21st Sensory, Inc., Bartlesville, OK) participated in this experiment. During panel orientation, 10 flavor and texture characteristics were identified by the panelists as adequately describing the sensory profile of cooked Cypress rice (Table I). Flavor attributes evaluated were starch, cardboardy, and sulfury notes. The overall sensory impact, the sum of total sensory impressions (Meilgaard et al 1991), was also obtained from the panel and included in the final analysis. Texture attributes included clumpiness, roughness, hardness, gluiness, moisture absorption, cohesiveness of mass, and geometry of slurry. All samples were evaluated under white lights in a sensory testing laboratory featuring individual booths. Intensities of each of the nine attributes evaluated were quantified on a continuous scale of 0–15 (Meilgaard et al 1991). Panelists used paper ballots and intensified each sensory attribute using a number between 0 and 15 with one significant digit. Intensity references (based on Uncle Ben's brand converted rice) for texture and flavor attributes were assigned during the panel orientation sessions.

Rice samples were cooked in water using a 1:2 (v/v) ratio. Rice was added to a 2-qt stainless steel saucepan containing boiling water. The pan was covered and simmered on a low setting for 17 min. The saucepan was removed from heat and allowed to stand for 5 min. Cooked samples were mixed and fluffed in the saucepan using a plastic fork to ensure homogeneity. The rice was spooned into coded glass beakers, covered with aluminum foil, and placed in a 71°C water bath to maintain temperature. Samples were served as soon as possible to the panel and not held in the water bath for more than 5 min. Serving temperature is important because samples

[1] Dept. Food Science, University of Arkansas, 272 Young Ave., Fayetteville, AR 72704.
[2] Corresponding author. E-mail: JFMEULL@comp.uark.edu Phone: 501/575-6822. Fax: 501/575-6936.
[3] Dept. Biological and Agric. Engineering, University of Arkansas, Fayetteville.

Publication no. C-1999-0524-04R.

need to be evaluated before the temperature falls <60°C. All samples were evaluated by all panelists, in duplicate, on two separate days. In addition, samples were evaluated by the same nine panelists at each of the three sampling times. The order of sample presentation within a session was randomized across treatments but not randomized across panelists because of limited sample availability and the importance of serving temperature. Reference rice samples were available during each session. Panelists were instructed to clean their palate between samples by eating bites of unsalted crackers and drinking filtered water.

Statistical Data Analysis

The experiment was treated as a 2^3 full-factorial design with repeated measures over time. Independent variables were predrying treatment (immediate vs. delayed), drying temperature (HT vs. LT), and storage temperature (4, 21, or 38°C). The sensory evaluation of all treatments was conducted before storage and after four and 20 weeks of storage. Panel performance was evaluated for the various sampling times with a treatment-by-subject design (Stone and Sidel 1993). SAS macro Grapes (Schlish 1994), PROC GLM (SAS Cary, NC), and Duncan's Multiple Comparison tests ($\alpha = 0.05$) were used to evaluate the effects of experimental treatments on sensory profiles reported by the descriptive panel. Data are reported in two different ways. Figures 1–3 are spider web representations of the main effects of drying temperature, storage temperature, and storage duration, respectively. Even though there were some significant interactions between independent variables, analysis of main effects provides general trends about the effects of individual postharvest variables on rice quality. Tables II–IV present a closer look at the effects of drying temperature, delayed drying, and storage temperature at the various storage durations.

RESULTS AND DISCUSSION

No significant effects ($\alpha = 0.05$) of immediate versus delayed drying treatments were reported on the sensory perception of rice samples. Cooked kernel hardness and cohesiveness of mass were affected by the rough rice drying temperatures (Fig. 1). Kernel hardness was higher, while cohesiveness of mass was lower in LT-dried samples.

Five of the 10 sensory attributes evaluated exhibited significant differences in intensities due to rough rice storage temperature (Fig. 2). Storage temperature influenced only textural characteristics. Perceived intensities for clumpiness, hardness, gluiness, cohesiveness of mass, and geometry of slurry were significantly different for samples stored at various temperatures (4, 21, and 38°C). Clumpiness and gluiness significantly decreased as storage temperature increased from 4 to 38°C. A significant decrease in gluiness was not observed between samples stored at 21 and 38°C. Cooked kernel hardness was significantly greater in rice stored at

TABLE I
Definitions of Rice Sensory Profile Attributes

Sensory Attribute	Definition	References
Overall flavor impact	Sum of the intensity of all aromatics perceived in the mouth	Universal aromatic scale (Meilgaard et al 1992): Nabisco saltines (2.0), Mott applesauce (5.0), Minute Maid frozen orange juice concentrate (7.5), Welch's grape juice (10.0)
Flavor		
Starch note (grain flavor)	Aromatics associated with starch flavor	Universal aromatic scale
Cardboard note (stale)	Aromatics associated with slightly oxidized but not rancid substances and packaging flavor effects	Universal aromatic scale
Sulfur note (off note)	Aromatics associated with sulfur compounds	Universal aromatic scale
Texture		
Clumpiness	Degree to which kernels adhere to each other	Uncle Ben's converted rice (1.0)
Roughness	Feel of the kernel from smooth to rough	Uncle Ben's converted rice (3.0), Cheerios (6.0)
Hardness	Force required to penetrate kernels with teeth	Uncle Ben's converted rice (3.0)
Gluiness	Degree to which kernels sticks together when chewed	Uncle Ben's converted rice (2.0)
Moisture absorption	Degree to which saliva is absorbed	Uncle Ben's converted rice (5.0), Popcorn (7.0)
Cohesiveness of mass	Degree to which samples remain in a wad	Uncle Ben's converted rice (4.0)
Geometry of slurry	Smooth to gritty, lumpy and inconsistent	Uncle Ben's converted rice (7.0), Carrot (13.0)

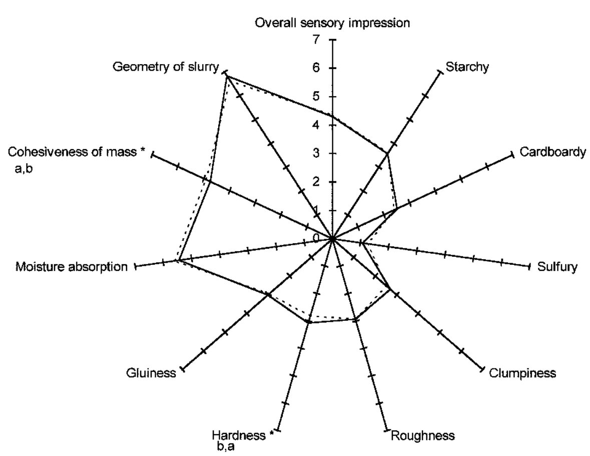

Fig. 1. Effect of drying temperature on sensory profile of cooked rice. Letters associated with different attributes represent results of Duncan's multiple comparison tests. The first and second letters are associated with high and low drying temperatures, respectively. Different letters indicate significant differences ($\alpha = 0.05$) between treatments. High temperature drying (- - - -) and low temperature drying (——).

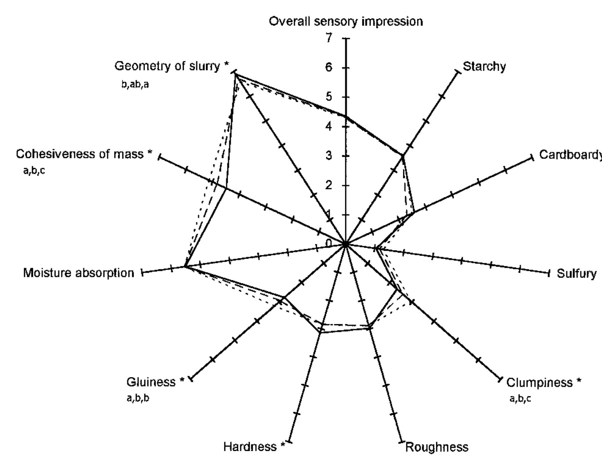

Fig. 2. Effect of storage temperature on sensory profiles of cooked rice. Letters associated with different attributes represent results of Duncan's multiple comparison tests. The first, second, and third letters are associated with results from storage temperatures of 4, 21, and 38°C, respectively. Different letters indicate significant differences ($\alpha = 0.05$) between treatments. Storage temperature at 4°C (- - - -), 21°C (– – –), and 38°C (——).

38°C. Cohesiveness of mass significantly decreased with increasing storage temperatures. Finally, the geometry of the slurry was grittier for samples stored at 38°C as compared to those stored at 4°C.

Storage duration had a significant ($\alpha = 0.05$) effect on sensory intensities for eight of the 10 attributes evaluated (Fig. 3). Storage duration significantly influenced both flavor and texture notes. The overall impact was greater before storage (week 0) than after four weeks of storage. The starch note significantly decreased between week 0 and week 4. The intensity of cardboardy notes was significantly greater after weeks 4 and 20 than at week 0. The intensity of the sulfury note significantly decreased after week 20. This phenomenon could be the result of the volatilization of the sulfur compounds during extended storage. Clumpiness significantly decreased between weeks 0 and 4. This result is in accordance with results reported by Juliano (1985) and Perez and Juliano (1981). Hardness of cooked samples was significantly greater at week 4 than at weeks 0 and 20. This is in partial conflict with data published by Pushpamma and Reddy (1979), who reported that firmness of cooked rice increased with storage duration. Gluiness was greatest at week 0 and lowest at week 4. Moisture absorption was significantly higher for rice sampled at week 4 than at weeks 0 and 20.

At week 0, no significant differences in the perception of the sensory attributes of cooked rice were reported between samples dried at HT and LT (Table II). However, the effect of wet holding significantly ($P < 0.05$) affected both clumpiness and hardness. Samples in which drying was delayed (wet holding) were clumpier and less hard than samples dried immediately after harvest. The wet holding period in this experiment was designed to simulate an extended delay in drying, as might occur during the peak harvest season. It is interesting that this first step in postharvest handling and storage influences the sensory characteristics of the final product (cooked rice). No other significant differences were attributed to wet holding of the rough rice.

After four weeks of storage, the effect of drying temperature became apparent (Table III). A more gentle drying (LT) resulted in a significantly ($P < 0.05$) greater roughness and hardness, and a lower starchy note, cohesiveness of mass, and overall impact. After 20 weeks of storage (Table IV), the same trends were observed, and significant differences found for sulfury note, clumpiness, and moisture absorption. Samples dried at LT exhibited significantly greater clumpiness and lower starchy notes and moisture absorption.

The effects of immediate versus delayed drying after four weeks of storage were significant for overall impact, hardness, and geometry of slurry. Rice samples submitted to a wet holding period exhibited a higher overall sensory impression, a lower hardness, and a less gritty geometry of slurry than did those dried immediately. These results are in general agreement with reports for rice samples evaluated before storage. The sensory profiles reported by the descriptive panel for samples stored at week 20 differ from those reported for weeks 0 and 4. Samples subjected to delayed drying were harder and exhibited higher moisture absorption than did samples dried immediately after harvest. The perceived hardness of the samples with delayed drying was not significantly different ($P < 0.05$) for samples evaluated after weeks 4 and 20. On the other hand, samples dried immediately after harvest exhibited a significant decrease in hardness after week 20. No obvious explanation of this result can be proposed at this time. However, this phenomenon may be due to changes in the starch functionality and warrants further investigation.

After four weeks, rough rice storage temperature significantly affected sulfury notes, hardness, cohesiveness of mass, and geometry of slurry (Table III). Sulfury notes significantly decreased as storage temperature increased from 4 to 38°C. Sulfur compounds are probably volatilized at a higher rate as temperature increases. Sulfury notes significantly decreased after 20 weeks (Table IV) across all storage temperatures. For samples tested after four weeks of storage, perceived hardness intensities increased as storage temperatures increased from 4 to 38°C. Samples with lowest hardness also exhibited a significantly higher cohesiveness of mass and a less gritty geometry of slurry. After 20 weeks, increasing storage temperatures resulted in decreased clumpiness, gluiness, and cohesiveness of mass.

SUMMARY AND CONCLUSIONS

Sensory profiles of cooked Cypress rice samples were significantly affected by rough rice wet holding, drying temperature, storage temperature, and storage duration. The 86-hr delay in drying of rough rice decreased perceived hardness after samples were stored

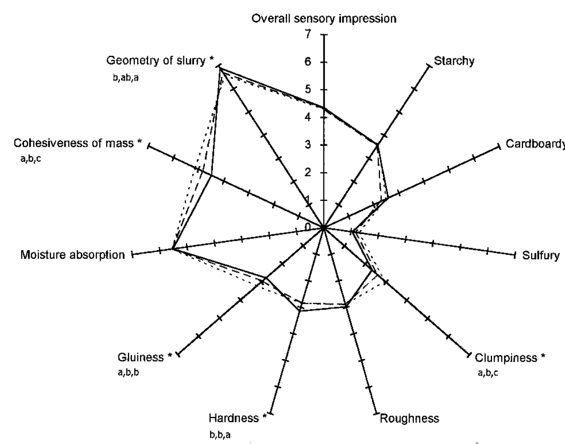

Fig. 3. Effect of storage duration on sensory profiles of cooked rice. Letters associated with different attributes represent results of Duncan's multiple comparison tests. The first, second, and third letters are associated with results from weeks 0, 4, and 20, respectively. Different letters indicate significant differences ($\alpha = 0.05$) between treatments. Storage for 0 (- - - -), 4 (– – –), and 20 (——) weeks.

TABLE II
Effect of Drying Temperature and Wet Holding on Sensory Profiles of Cooked Rice Before Storage[a]

Sensory Attributes	High-Temperature Drying	Low-Temperature Drying	Immediate Drying	Delayed Drying
Overall sensory impression	4.33a[b]	4.53a	4.44a	4.42a
Starchy	3.70a	3.85a	3.76a	3.80a
Cardboardy	1.60a	1.46a	1.41a	1.64a
Sulfury	0.96a	1.43a	1.23a	1.16a
Clumpiness	3.18a	3.24a	2.93b	3.48a
Roughness	3.00a	2.99a	3.01a	2.98a
Hardness	2.62a	2.79a	2.83a	2.58b
Gluiness	3.60a	3.55a	3.47a	3.68a
Moisture absorption	5.14a	5.25a	5.22a	5.17a
Cohesiness of mass	4.96a	5.10a	4.90a	5.15a
Geometry of slurry	6.82a	6.55a	6.60a	6.77a

[a] Initial sensory profiling (week 0).
[b] Values followed by the same letter in the same row are not significantly different ($P < 0.05$).

TABLE III
Effect of Drying Temperature, Wet Holding, and Storage Temperature After Four Weeks of Storage on Sensory Profiles of Cooked Rice

	Drying[a]				Storage		
Sensory Attributes	**HT**	**LT**	**Immediate**	**Delayed**	**4°C**	**21°C**	**38°C**
Overall sensory impression	4.33a[b]	4.17b	4.18b	4.32a	4.32a	4.27a	4.17a
Starchy	3.58a	3.43b	3.51a	3.50a	3.54a	3.52a	3.45a
Cardboardy	2.33a	2.43a	2.28a	2.47a	2.40a	2.23a	2.51a
Sulfury	1.51a	1.51a	1.44a	1.58a	1.76a	1.59a	1.17b
Clumpiness	2.70a	2.67a	2.60a	2.78a	2.72a	2.76a	2.58a
Roughness	2.88b	3.01a	3.00a	2.89a	2.85a	2.99a	2.99a
Hardness	2.94b	3.32a	3.40a	2.87b	2.98b	3.07ab	3.34a
Gluiness	2.85a	2.85a	2.83a	2.88a	2.89a	2.80a	2.87a
Moisture absorption	5.77a	5.76a	5.81a	5.72a	5.77a	5.88a	5.65a
Cohesiveness of mass	4.95a	4.71b	4.85a	4.81a	4.96a	4.88ab	4.66b
Geometry of slurry	6.50a	6.70a	6.72a	6.48b	6.45b	6.61ab	6.74a

[a] HT = high temperature; LT = low temperature.
[b] Values followed by the same letter in the same row are not significantly different ($P < 0.05$).

TABLE IV
Effect of Drying Temperature, Wet Holding, and Storage Temperature After 20 Weeks of Storage on Sensory Profiles of Cooked Rice

	Drying[a]				Storage		
Sensory Attributes	**HT**	**LT**	**Immediate**	**Delayed**	**4°C**	**21°C**	**38°C**
Overall sensory impression	4.36a[b]	4.40a	4.41a	4.34a	4.25b	4.35ab	4.54a
Starchy	3.61a	3.69a	3.61a	3.69a	3.66a	3.58a	3.72a
Cardboardy	2.48a	2.59a	2.49a	2.58a	2.60a	2.38a	2.63a
Sulfury	0.98a	0.62b	0.80a	0.80a	0.78a	0.69a	0.93a
Clumpiness	2.35b	2.73a	2.54a	2.53a	3.16a	2.41b	2.05c
Roughness	2.96a	2.82a	2.83a	2.95a	2.92a	2.78a	2.97a
Hardness	2.69a	2.81a	2.61b	2.90a	2.72ab	2.60b	2.94a
Gluiness	3.03a	3.15a	3.03a	3.16a	3.54a	3.08b	2.65c
Moisture absorption	5.44a	5.14b	5.17b	5.41a	5.31a	5.20a	5.35a
Cohesiveness of mass	4.88a	4.74a	4.74a	4.88a	5.30a	4.79b	4.33c
Geometry of slurry	6.72a	6.94a	6.70a	6.96a	6.70a	6.79a	7.00a

[a] HT = high temperature; LT = low temperature.
[b] Values followed by the same letter in the same row are not significantly different ($P < 0.05$).

for at least four weeks. High drying temperature (54.3°C) resulted in less firm cooked kernels. Elevated storage temperatures (38°C) decreased cooked rice clumpiness and sulfury notes faster than did low storage temperatures (4 and 21°C). Storage up to 20 weeks resulted in a significant decrease of sulfury notes, clumpiness, gluiness, and moisture absorption, and a significant increase of cardboardy notes. In general, these results indicate that all aspects of postharvest handling, from predrying procedures to rough rice storage duration, significantly influence various aspects of cooked rice quality. However, the results discussed here are only representative of one long-grain variety. The effects of postharvest handling on rice quality are expected to be variety-dependent and should be further investigated for other rice varieties.

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[Received July 17, 1998. Accepted February 22, 1999.]