Influence of Water-to-Rice Ratio on Cooked Rice Flavor and Texture

Karen L. Bett-Garber,1,2 Elaine T. Champagne,1 Daphne A. Ingram,1 and Anna M. McClung3

ABSTRACT

Water-to-rice ratio is known to affect cooked rice texture, whereas the effects on flavor are largely unknown. To determine the influence of the amount of water during cooking on flavor and texture attributes, three water-to-rice ratios of low (less than recommended), recommended, and high (more than recommended) were evaluated. The recommended amount used was based on amylose content and cook type for the cultivar. Four diverse cultivars were compared: Dellmont (aromatic long-grain), Saber (conventional long-grain), Neches (waxy long-grain), and Bengal (conventional medium-grain). A descriptive sensory panel evaluated flavor and texture attribute intensities. The water-to-rice ratio did not significantly affect flavor attributes across all cultivars. The amount of water affected 11 of the 14 texture attributes evaluated. Of these 11, initial starchy coating, slickness, stickiness between grains, cohesiveness, and uniformity of bite increased in intensity with greater amounts of water at cooking, whereas hardness, stickiness to lips, springiness, and chewiness decreased in intensity.

Rice is consumed throughout the world and is a staple in many cultures. Rice is generally cooked by using either excess water or exact amounts of water. The excess water method consists of boiling rice in large quantities of water followed by draining when the rice is hydrated. The exact water, or pilaf, method consists of cooking rice in a measured amount of water until all of the water is absorbed (Juliano 1982; Sinki 1994).

Different cultivars of rice can absorb differing amounts of water. Factors affecting water absorption include surface area, amylose and protein contents, and gelatinization temperature. Long-grain cultivars tend to require more water than medium-grain and short-grain types (Batcher et al. 1957; Khan and Ali 1985). If a specific rice cultivar is cooked with a higher water-to-rice ratio than recommended, the resulting cooked rice will have a higher moisture content, be less hard and more adhesive, have larger grain size, and show less yellowness (Juliano et al. 1984; Kainuma and Ema 1987). Grain stickiness increases when rice is cooked with increasing water-to-rice ratios (El-Hissewy and El-Kady 1992; Kim and Kim 1996; Lee 1996). Using the excess water method, water content and stickiness were not related (Juliano et al. 1984). It was presumed that the stickiness was removed with the excess water upon draining.

Limited research has examined the effects of water-to-rice ratio on cooked rice flavor and textural properties other than hardness and stickiness. Kim et al. (1986) found, using subjective means, that changes in water-to-rice ratios had an effect on texture and appearance, but flavor remained unchanged for the four rice cultivars. Rousset et al. (1999) found that cooking rice in excess water for increasingly longer time periods resulted in very few flavor differences, while decreasing firmness. Recently, Srisawas and Jindal (2007) examined the effects of water-to-rice ratios on sensory hardness and stickiness and fragrance. With increasing water-to-rice ratios, sensory hardness decreased and stickiness increased. Fragrance was not significantly affected by water-to-rice ratio.

The goal of this research was to determine the consequences of slightly decreasing or increasing the water-to-rice ratio from that "recommended" for a specific cultivar on cooked rice flavor and texture, as measured by descriptive sensory analysis, which is an objective analysis technique that finds distinct, small differences in the flavor (Champagne et al. 1997) and texture (Lyon et al. 1999) attributes of rice.

MATERIALS AND METHODS

Rice Samples

Four diverse rice cultivars were used for this experiment (Table 1). Dellmont is a fragrant, long-grain cultivar with relatively high-intermediate amylose content and intermediate gelatinization temperature (Bollich et al. 1993). Saber is a long-grain rice cultivar with intermediate gelatinization temperature and amylose content. Neches is a long-grain waxy cultivar with essentially no amylose and low gelatinization temperature. Bengal is a medium-grain cultivar with low amylose content and low gelatinization temperature. The grain samples were preweighed into 600-g portions for sensory analysis and stored at 4°C in glass jars flushed with nitrogen until the sensory session.

Sample Preparation for Sensory Analyses

Rice was cooked in a rice cooker using the pilaf method. Portions of white rice (600 g) were rinsed by covering the rice with cold water followed by straining to remove excess water. After rinsing, the samples were transferred to preweighed rice cooker insert bowls, and water was added to give a suitable water-to-rice weight ratio (Table 1). Low (less than recommended), recommended, and high (more than recommended) amounts of water were evaluated; the amounts were based on amylose content and grain type for the cultivar. The rice was soaked for 30 min and then cooked in a 5-cup rice cooker-steamer (model SR-W10G HP, Panasonic Co. of America, Cypress, CA) to completion, followed by a 10-min holding period. Samples were taken from the cookers as described by Champagne et al. (1999). Cooking was staggered so that samples were analyzed at 20-min intervals.

Sensory Evaluation Protocol

Ten panelists trained in the principles and concepts of descriptive sensory analysis (Meilgaard et al. 1999) participated in the study. The rice flavor lexicon, based on that reported by Goodwin et al. (1996), included 13 unique flavor attributes that were determined.

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Rice Cultivars and Water-to-Rice Ratios Used for Cooking Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivar</td>
<td>Low</td>
</tr>
<tr>
<td>Dellmont (aromatic, long-grain)</td>
<td>1.5:1</td>
</tr>
<tr>
<td>Saber (long-grain)</td>
<td>1.4:1</td>
</tr>
<tr>
<td>Neches (waxy, long-grain)</td>
<td>1.0:1</td>
</tr>
<tr>
<td>Bengal (medium-grain)</td>
<td>1.2:1</td>
</tr>
</tbody>
</table>

1 ARS, USDA, Southern Regional Research Center, P.O. Box 19687, New Orleans, LA 70179. Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by the USDA implies no approval of the products to the exclusion of others that may also be suitable.
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doi:10.1094/CHC86-6-0614
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mined by smelling and evaluation in the mouth (Fig. 1). The intensi-
ties were scored based on a universal scale for all foods (Meilgaard
et al 1999); the maximum rating for rice flavor attributes is gen-

erally ≥5. The lexicon for rice texture used by the panel was based
on that developed by Lyon et al (1999) and Goodwin et al (1996)
and is described in Fig. 2. The profile used by the panelists in-
cluded 14 attributes that described rice texture at different phases
of sensory evaluation, beginning with the feel of the rice when it
was first placed in the mouth and ending with mouthfeel charac-
teristics after the rice was no longer in the mouth. Each sample
was presented to the panelists twice, in separate sessions. At each
session, the panelists evaluated the texture of one cultivar cooked
with varying water-to-rice ratios. The protocol followed for present-
ing samples and standards (warm-up sample of commercial long-
grain) to panelists at each session are described in detail by

**Statistical Analyses**

Sensory data were analyzed using a split-plot design with four
cultivars as the main units and the three water-to-rice ratios being
the subunits. Cultivar samples were randomly chosen for a given
session with two replicates for each cultivar, for a total of eight
sessions. Within each session, the three ratios were randomly pre-

Table:<br>
| Sewer/Animal | An immediate and distinct pungent aromatic in the flavor cha-
| Floral       | Aromatics associated with dried flowers such as lilac or lavan-
| Grain/Starchy| A general term used to describe the aromatics in the flavor asso-
| Hay-like/Musty| A dry, dusty, slightly brown aroma/flavor with a possible trace
| Popcorn      | A dry, dusty, slightly toasted and slightly sweet aromatic in the
| Corn         | The sweet aromatics of the combination of corn kernels, corn milk,

**Fig. 1.** Descriptive sensory analysis attributes and definitions used to evaluate cooked rice flavor.

**Fig. 2.** Sensory descriptive texture attributes and definitions used to evaluate cooked rice texture.

**Table:**

| PHASE I. Place 6-7 grains of rice in mouth behind front teeth. Press tongue over surface and evaluate. |
|---|---|
| Attributes | Definition |
| Initial Starchy Coating | amount of paste-like thickness perceived on the product before mixing with saliva (three passes) |
| Slickness | maximum ease of passing tongue over the rice surface when saliva starts to mix with sample |
| Roughness | amount of irregularities in the surface of the product |
| Stickiness to Lips | degree to which kernels adhere to lips |
| Stickiness Between Grains | degree to which the kernels adhere to each other |

**PHASE II. Place 2 tsp of rice in mouth. Evaluate before or at first bite.**

**Attributes**

| Definition |
|---|---|
| Springiness | degree to which the grains return to original shape after partial compression |
| Cohesiveness | degree to which the grains deform rather than crumble, crack, or break when biting with molars |
| Hardness | force required to bite through the sample with the molars |

**PHASE III. Evaluate during chew.**

**Attributes**

| Definition |
|---|---|
| Cohesiveness of Mass | maximum degree to which the sample holds together in a mass while chewing |
| Chewiness | amount of work to chew the sample |
| Uniformity of Bite | evenness of force throughout bites to chew |
| Moisture Absorption | amount of saliva absorbed by sample during chewing |

**PHASE IV. Evaluate after swallow.**

**Attributes**

| Definition |
|---|---|
| Residual Loose Particles | amount of loose particles in mouth |
| Toothpack | amount of product adhering in/on teeth |

**Fig. 1.** Descriptive sensory analysis attributes and definitions used to evaluate cooked rice flavor.

**Fig. 2.** Sensory descriptive texture attributes and definitions used to evaluate cooked rice texture.
Proc mixed in SAS v.9.1 (SAS Institute, Cary, NC) was used for analysis of variance (ANOVA). Least square (LS) means (Tukey's adjustment method) was used to compare treatment means. Significance is reported at \( P < 0.05 \) for all data.

Ward's minimum-variance method was used to divide the data into clusters (Ward 1963). Based on eigenvalues <1, three clusters were utilized. Principal component analysis was used for summarizing the data in graphic form in a two- or three-dimensional space (Hotelling 1933).

### RESULTS AND DISCUSSION

#### Effect of Water-to-Rice Ratios on Texture

Some texture attributes were affected by water-to-rice cooking ratio (Table II). A comparison of means across cultivars for low (less than recommended), recommended, and high (more than recommended) water-to-rice ratios showed that the intensity of the initial starchy coating increased and hardness decreased with increasing amounts of water. Slickness, stickiness between grains, cohesion-
ness, and uniformity of bite were lower and the stickiness to lips, springiness, and chewiness were higher at the low water-to-rice ratio compared with the high water-to-rice ratio. Water-to-rice ratio did not significantly affect roughness, cohesiveness of mass, moisture absorption, residuals, and toothpacking.

An examination of individual cultivars showed that initial starchy coating and hardness were the only attributes significantly affected by water-to-rice ratio for Bengal, with initial starchy coating being higher and hardness being lower at the high ratio compared with low ratio. In Dellmont, the initial starchy coating was higher, and springiness and hardness were lower at the high ratio compared with the low ratio. The only texture attributes of Neches significantly affected by water-to-rice ratio were springiness and hardness, with springiness being lower at the high ratio compared with the recommended ratio, and hardness being lower at the high ratio compared with the low ratio. The texture of Saber appeared to be the most responsive to water-to-rice ratio compared with other cultivars. Initial starchy coating, stickiness between grains, uniformity of bite, and cohesiveness of mass was lower at the low water-to-rice ratio and higher at the high water-to-rice ratio. Stickiness to lips, hardness, and chewiness were higher at the low water-to-rice ratio.

**Effect of Cultivar on Texture**

In comparing the means of ratios for the individual cultivars, Neches was more intense than the other cultivars for initial starchy coating, roughness, stickiness between grains, cohesiveness, uniformity of bite, and cohesiveness of mass, and toothpacking. Neches was less intense than the other cultivars for springiness and hardness. Thus, when cooked, Neches has the soft-sticky texture typical of a waxy cultivar. Waxy cultivars tend to have a high protein content and essentially no amylose, which influence these typical sensory properties (Champagne et al 2004). Dellmont was more intense in initial starchy coating than Bengal and Saber. It was less intense in hardness than Bengal. Saber had the least roughness of the four cultivars.

**Comparison of Texture Attributes**

Using Ward's Cluster Analysis and Principal Component Analysis (PCA), it was determined that Neches grouped alone, as depicted in Fig. 3. If the flavor attributes were added to the analysis, the outcome was similar (Fig. 4). In analyzing texture attributes only, Dellmont at the low and recommended water-to-rice ratios and Saber at all ratios grouped together. Dellmont at the high water-to-rice ratio and Bengal were in a separate group. Thus, at the high water-to-rice ratio, Dellmont had texture similar to Bengal; at lower ratios, the texture was more like Saber.

When flavor attributes were included, Dellmont at all water-to-rice ratios grouped with Bengal, but was away from Bengal in the cluster and more distant from the cluster for Saber. This can be
attributed to the high intensities of popcorn and corn flavors in Dellmont (Fig. 4).

**Effect of Water-to-Rice Ratios on Flavor**

None of the flavor attributes were significantly affected by water-to-rice ratios in a comparison of means across cultivars (Table III). Within the Dellmont cultivar, water-like/metallic flavor was significantly higher in intensity in the recommended ratio than in the low ratio. No other significant differences in flavor due to differences in water-to-rice ratio were observed within cultivars.

**Effect of Cultivar on Flavor**

In a comparison of the means of ratios for the individual cultivars, the rice cultivar significantly affected five flavor attributes (grain/starchy, hay-like/musty, popcorn, corn, and sour/silage), and two mouthfeel attributes (water-like/metallic and astringent). Popcorn and corn are flavors associated with aromatic rice (Bett-Garber et al. 2001). Both of these flavors were more intense in Dellmont (an aromatic cultivar) than in the other cultivars. Grains/musty is the dominant flavor of rice in general (Bett-Garber et al. 2001) and tends to be more intense in waxy rice. Accordingly, Neches had significantly higher grain/starchy flavor than Dellmont and Saber. The intensity of this flavor attribute in Bengal, however, was similar in intensity to Neches. Intensities of grain/starchy and haylike/musty flavors were significantly lower in Saber than the other cultivars. Sweet aromatic flavor was the most intense in sweet aromatic than nonaromatic cultivars. Neches, the waxy cultivar, was significantly more intense in astringency than the other cultivars. Sour/silage was more intense in waxy aromatic than nonaromatic cultivars. Bett-Garber et al. (2001) found that general aromatic rice cultivars are more intense in sweet aromatic than nonaromatic cultivars. Neches, the waxy cultivar, was significantly more intense in astringency than the other cultivars. Sour/silage was more intense in Dellmont and Neches and least intense in Saber and Bengal.

**CONCLUSIONS**

When cooking rice using the pilaf method, the water-to-rice ratio significantly affects texture quality but has little to no effect on flavor. Increasing the amount of water used for cooking can increase intensities of the texture attributes, initial starchy coating, stickiness, stickiness between grains, cohesiveness, and uniformity of bite. Increasing the amount of water decreases the intensities of hardness, stickiness to lips, springiness, and chewiness. Rice texture can be maximized by adjustment of water-to-rice ratio without affecting the flavor.

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[Received January 18, 2007. Accepted July 7, 2007.]