PHYSICOCHEMICAL PROPERTIES OF THREE RICE VARIETIES

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ABSTRACT

Physicochemical properties of three rice varieties were studied. Textural properties of gels from La Grue, Bengal, and S201, were investigated using the Universal Texture Analyzer, and pasting characteristics by Brabender Visco/amylography. Gels from La Grue (long grain) had higher fracturability, hardness, amylographic consistency, and setback viscosity (P<0.05). Gels from S201, a short grain variety, were harder and had higher fracturability values than those from Bengal, a medium grain variety. Analysis of texture profiles of rice gels could be an alternative to Brabender viscoamylographs for differentiating among rice varieties. Tests on in-vitro starch digestibility showed that La Grue had lower maltose released than S201 or Bengal during the first 15 and 45 min of hydrolysis with human salivary α-amylase.

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INTRODUCTION

Consumption of rice in the U.S. has increased dramatically over the past decade. The increase from 26.9 million hundred weight (cwt) in 1978/79 to almost 47.5 million cwt in 1988/89, a 77% increase, is mainly due to awareness of rice as a healthful food (Myers 1994). Generally, most of the rice is consumed as cooked intact grain. However, in recent times, there has been a steady increase in new processes and products involving rice as an ingredient: highly puffable rice, crispness inducing agent in batters, hypoallergenic proteins and starches, and fermentable substrates (Kohlwey 1994). In each of these products, rice is used for a specific function. A recent study revealed significant growth in consumption of specialty rices including aromatic, elongating, waxy, sticky, dry cooking, quick cooking, and instant rices (Dziezak 1991).

Varietal differences and differences in methods of further processing are two of the most important factors that influence quality of rice and rice products. Some of the tests used in the U.S. to determine quality of rice include the alkali spreading value, amylography, amylose content, protein content, size, appearance and hardness of grain. Most of the tests are adapted from methods for evaluation of other cereals. The type of testing varies with the ingredient, and whether it is a whole grain or flour. Unfortunately, most of the quality control methods used in the industry today are based on subjective evaluation (Kohlwey 1994). Thus, there is a need to develop objective testing methods to evaluate rice varieties. Increase in consumption of rice in the U.S. justifies investigations on various properties of rice and rice products.

This study investigates the physicochemical properties of three Arkansas grown rice varieties with an objective of possible applications of these tests for identification of rice and quality control of rice and rice products. Textural properties of gels from La Grue, Bengal and S201 were investigated using a Texture Analyzer, and pasting characteristics of the rice varieties were evaluated by Brabender Visco/amylography. Studies were also conducted to investigate in-vitro starch digestibility of rice varieties using human salivary α-amylase.

MATERIALS AND METHODS

Samples

Rice samples from three grain sizes were selected for analysis. Fifty lbs each for varieties S201 (short grain), Bengal (medium grain), and La Grue (long grain), were obtained from the University of Arkansas Rice Research and Extension Center, Stuttgart, Arkansas. Rice samples were approximately six months old when the tests were conducted; they were stored at 4C until used. The samples were

obtained from one growing season only to avoid possible differences due to seasons and focus on the primary objective of the study which was to investigate the differences in physicochemical properties of three rice varieties as affected by grain size.

Preparation

Rough rice was dehulled in a Satake testing husker (model THU-35A), and debranned using a McGill no.2 mill. White rice was ground to flour through a 0.4-mm screen on a Udy cyclone mill.

Amylose Content

Amylose content of rice varieties was determined by a spectrophotometric method as described by Landers *et al.* (1991) .

Textural Properties

Textural properties and profiles of rice flour gels were evaluated using a Texture Analyzer (TA.XT2, Texture Technologies, NY). Rice flours were cooked in water (8% w/v in distilled deionized water) at about 99C for 2 min, the hot paste was poured into 50 mL beakers, covered, and cooled to room temperature. Gels formed were stored for 24 h at 4C. Beakers containing gels were secured on a steel plate fitted with a rubber gasket at the center to hold the sample container. A flat bottomed probe 3.5 cm long and 0.75 cm in dia. was used to measure fracturability, hardness, adhesiveness, cohesiveness, springiness, stringiness, gumminess, and chewiness (Bourne 1978).

Pasting Characteristics

A modified AACC (1991) procedure was used to measure pasting characteristics of the three varieties using a Brabender Visco/Amylograph. Rice flour, 45g was blended with 300 mL of distilled deionized water for 1.5 min. The remaining flour slurry was rinsed with 150 mL water into the viscometer bowl. The contents were heated at 95C for 20 min and cooled to 5C within 30 min. Peak, hot, and cool viscosities of the pastes were measured, and used to determine the consistency, breakdown and setback viscosities.

In-vitro Digestibility

In-vitro digestibility of whole, cooked rice grains were determined by a modified procedure of Yokoyoma *et al.* (1994). Rice samples were cooked in distilled, deionized water (dd) water (1 :3) for 20 min. Fifty grams of the whole, cooked rice was blended with 50 g of dd water in an 8 oz blender jar for 5 s.

Twelve grams of the slurry was weighed into a 250 mL erlenmeyer flask and 19 mL of dd water was added followed by 20 mL of 0.5 M phosphate buffer (pH 4.9) and 5 mL of 30 mM $CaCl_2$, and the flask was swirled for about 5 s to mix. A 5 mL sample was removed into a test tube, and 100 units of human salivary α-amylase solution in 1 mM $CaCl_2$ (α-amylase EC 3.2.1.1, Activity: One unit will liberate 1.0 mg maltose from starch in 3 min at pH 6.9 at 20C) was added and the flask swirled for about 2 s to mix. The flask was covered and placed in a shaking waterbath, 37C; a 5 mL sample was removed at 15, 30 and 60 min intervals. The 5 mL samples were dispensed into screwcap test tubes and placed in a beaker of boiling water for 8 min to inactivate the enzyme. After cooling to room temperature, the samples were centrifuged for 15 min at 25,000 × g. The supernatant was analyzed for maltose and the results were expressed as mg maltose equivalents per gram sample.

Statistical Analyses

Three replications of experiments were conducted in a completely randomized design. For studies on in-vitro digestibility, six replications were performed in a randomized complete block design with replications as blocks. Analysis of variance was performed and the least square means procedure was used to analyze differences in mean values when found significant (P<0.05) (SAS 1988). Pearson correlation coefficients were calculated for selected textural attributes (SAS 1988).

RESULTS AND DISCUSSION

Textural Properties

Textural properties of the rice varieties evaluated are presented in Table 1. Gels from the long grain variety, La Grue, generally were harder than medium (Bengal) or short (S201) varieties as indicated by a higher fracturability and hardness values. These gels were also more adhesive, and had higher values for gumminess and chewiness. Gels from S201 were harder and had higher fracturability values than those from the Bengal variety.

S201 gels were also more gummy and chewy than Bengal. While Bengal variety did not differ from S201 in adhesiveness scores, it had the lowest values for fracturability, hardness, gumminess, cohesiveness, and chewiness. No differences (P<0.05) were observed in stringiness, and springiness scores among the rice varieties.

Amylose content and gelatinization temperature are two of the most important factors that determine textural properties. Long grain varieties generally have higher amylose content and gelatinization temperature. Differences in the amylose

TABLE 1.
TEXTURAL PROPERTIES OF GELS FROM THREE RICE
VARIETIES (MEAN VALUES WITH STANDARD DEVIATION)

Textural properties	S201 S	Bengal M	La Grue L
Fracturability	0.045[b]	0.024[c]	0.14[a]
	0.02	0.005	0.01
Hardness	0.058[b]	0.038[c]	0.14[a]
	0.017	0.005	0.015
Adhesiveness	−0.57[b]	−0.59[b]	−1.13[a]
	0.21	0.10	0.12
Cohesiveness	0.70[b]	0.78[a]	0.51[c]
	0.05	0.05	0.04
Springiness	15.03	15.38	14.87
	0.36	0.42	0.63
Stringiness	12.82	12.45	12.46
	1.32	1.02	1.06
Gumminess	0.040[b]	0.03[c]	0.07[a]
	0.13	0.004	0.005
Chewiness	0.611[b]	0.46[c]	1.06[a]
	0.19	0.06	0.11

[a,b,c] Mean values with different superscripts across the rows are
significantly different ($P<0.05$)

content and gelatinization temperatures are attributed in part to the differences in the environmental conditions in which the crop is grown, particularly temperature (McKenzie 1994). The percent amylose content of varieties investigated in this study were 35.77 for La Grue, 25.57 for Bengal, and 21.60 for S201. Grain size or amylose content did not seem to influence the textural properties of the rice varieties. Positive correlations were observed between fracturability and hardness, hardness and gumminess, hardness and chewiness, and gumminess and chewiness (Table 2). Properties indicating gel hardness (fracturability and hardness) were negatively correlated to cohesiveness.

Grain evaluation methods need to be simple, involve small amounts of sample, and facilitate measurement of several texture parameters from the same test, and suitable for automation to facilitate reproducibility. The Texture Analyzer used in the present study was convenient, involves less sample size, and effectively offers an alternative method for texture analysis of rice.

TABLE 2.
CORRELATION COEFFICIENTS OF SELECTED TEXTURAL PROPERTIES[a]

	FR	HA	AD	CO	SP	ST	GU	CH
FR	1.00	0.99*	-0.89*	-0.91*	-0.33	0.31	0.96	0.93
HA		1.00	-0.89*	-0.91*	-0.33	0.31	0.97*	0.95*
AD			1.00	0.81	0.25	-0.08	-0.86	-0.85
CO				1.00	0.38*	-0.11	-0.81*	-0.78*
SP					1.00	0.06	-0.30	-0.16
ST						1.00	0.43	0.45
GU							1.00	0.99*

[a]FR, HA, AD, CO, SP, ST, GU, and CH are Fracturability, Hardness, Adhesiveness, Cohesiveness, Springiness, Stringiness, Gumminess, and Chewiness, respectively.

* Significant $(P < 0.001)$

Pasting Characteristics

Amylographic pasting properties obtained at a fixed sample concentration are used routinely in laboratories to measure cooking behavior of rice (Juliano 1982). Amylography is also considered to be a method familiar to all researchers (Juliano 1985a). However, investigations on pasting characteristics carried out at a fixed peak viscosity may be more justified since other parameters in an amylograph are dependent on peak viscosity (Bhattacharya and Sowbhagya 1979). This is true when closely related varieties are to be tested on a routine basis. However, in the present study, amylographic tests were conducted on a fixed sample concentration with an objective of evaluating apparent differences in the pasting characteristics of rice varieties (Fig. 1).

In general, the long grain variety was different from the other two varieties in their pasting characteristics (Table 3). The long-grain samples had a higher consistency and setback viscosity than S201 and had higher values for all attributes except breakdown viscosity when compared with Bengal variety. No differences were observed between La Grue (long) and S201 (Short) in peak, hot, and breakdown viscosities (P<0.05).
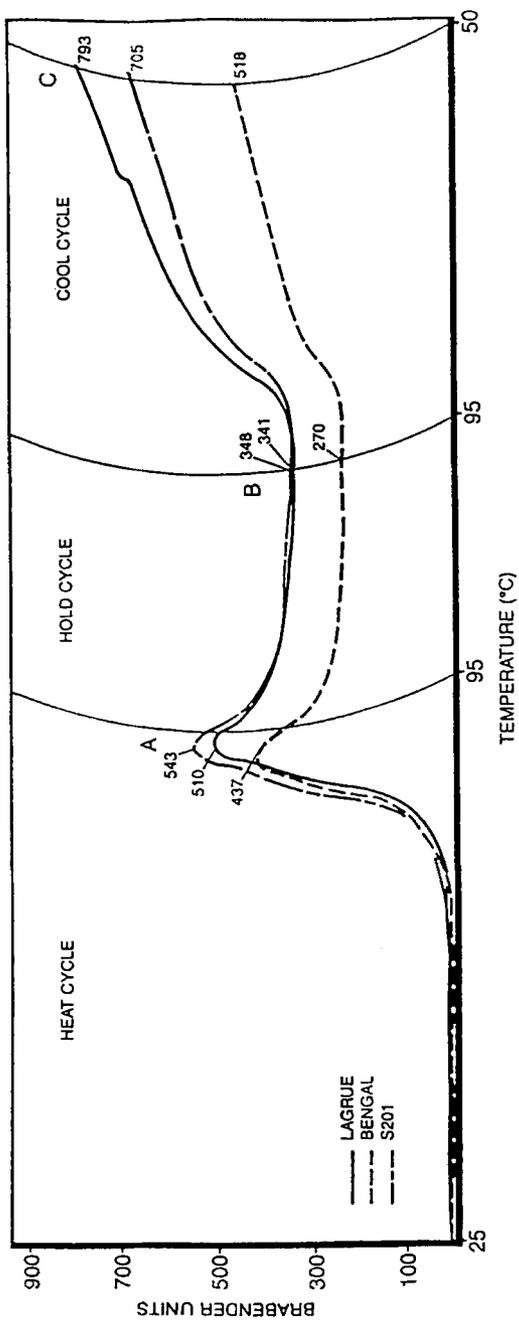
FIG. 1. PASTING CHARACTERISTICS OF RICE VARIETIES

Differences among rice types in the pasting characteristics were somewhat similar to textural properties of gels as measured by texture analysis. Bengal, a medium variety had the lowest values for almost all of the pasting characteristics studied, more notably the setback viscosity (a measure of difference between cool viscosity and peak viscosity).

TABLE 3.
AMYLOGRAPHIC PASTING CHARACTERISTICS OF THREE RICE VARIETIES
(MEAN VALUES WITH STANDARD DEVIATION)

Pasting Characteristics	S201 S	Bengal M	La Grue L
Peak viscosity	543.33[a]	436.67[b]	510.00[a]
	16.07	28.87	10.00
Hot viscosity	348.33[a]	270.0[b]	341.67[a]
	10.41	51.96	2.89
Cool viscosity	705.00[a]	518.33[b]	793.33[a]
	27.84	79.74	15.28
Consistency	356.67[b]	248.33[c]	451.67[a]
	18.93	28.43	12.58
Breakdown viscosity	195.00[a]	166.67[a]	168.33[a]
	15.00	23.01	12.58
Setback viscosity	161.67[b]	81.67[c]	283.33[a]
	32.15	51.07	25.17

[abc] Mean values with different superscripts across the rows are significantly different ($P<0.05$).

Amylography was developed primarily for distinguishing high-amylose varieties and thus may not be effective for low and intermediate amylose varieties at a paste concentration of less than 12% (Juliano 1985). This factor makes it difficult to evaluate in an objective manner differences between closely related varieties. In the present study, at a fixed sample concentration, although S201 and La Grue had similar peak viscosities, La Grue had significantly higher setback viscosity ($P < 0.05$) perhaps due to its higher amylose content. Bengal is characterized as a low amylose and low gelatinization type (Linscome 1992). A significantly lower setback viscosity refers to lower retrogradation tendency (Mazurs 1957).

In-vitro Digestibility

In vitro digestibility of cereal starches has been well correlated with glycemic response of starches (Bornet *et al.* 1989). Attempts were made to utilize this biochemical property to differentiate rice cultivars. Differences were observed in the digestibility of starches (Fig. 2). The long grain variety, La Grue, showed slower maltose release than the short and medium varieties during first 15 and 45 min of hydrolysis, as indicated by a significantly lower amount of maltose released (P<0.05). However, no differences among varieties in the amount of maltose released were observed at the end of 90 min of hydrolysis. Although long varieties have higher amylose content, they have been observed to have a lower susceptibility to human salivary (α-amylase. Rice varieties with similar amylose content differ in their starch digestibility and glycemic response in humans (Panlasigui 1991). Apart from amylose content, physico-chemical properties of starch, more particularly gelatinization, can influence starch digestibility. Accessibility of amylose by the enzyme is also dependent on the presence of amylose-lipid and amylose-protein complex. Besides, formulation and processing conditions also affect in-vitro digestibility of cereal product (Yokoyoma *et al.* 1994). In the present study, under similar conditions of processing, La Grue showed slower release of maltose than S201 and Bengal during the first 45 min of hydrolysis due to its lower susceptibility to the enzyme or perhaps due to its higher gelatinization temperature.

CONCLUSIONS

Differences in textural properties and pasting characteristics of different varieties of rice starch were observed. Tests developed to measure the textural properties might be useful to monitor rice starch gels from different varieties. These tests might be useful for purposes of identification of different varieties of rice, for quality control and to establish specifications for rice and rice products. Testing methods based on biochemical properties inherent to rice varieties might also be useful for varietal identification and quality control purposes. Differences in in-vitro starch digestibility might be used to differentiate rice varieties.

ACKNOWLEDGMENT

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data points with different superscripts at each time interval across X axis are significantly different (P < 0.05)
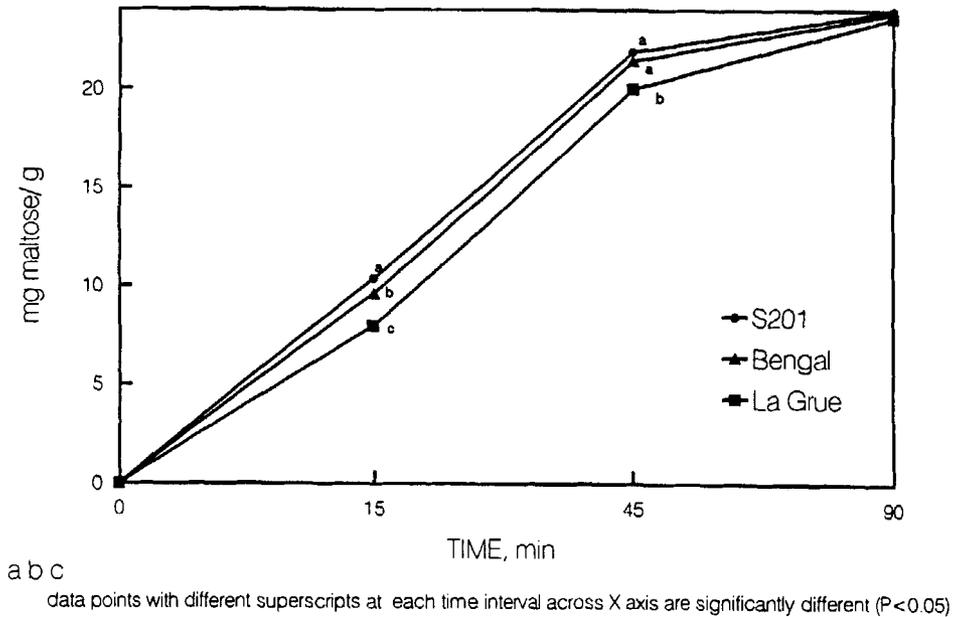
FIG. 2. IN-VITRO DIGESTIBILITY OF RICE VARIETIES

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