Degree of Milling Effects on Rice Pasting Properties[1]

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Cereal Chem. 78(2):205–209

ABSTRACT

The effects of degree of milling on pasting properties of medium-grain (cv. Bengal and Orion) and long-grain rice (cv. Cypress and Kaybonnet) were quantified using a Brabender ViscoAmylograph and a Rapid Visco Analyser. For all the cultivars tested, surface and total lipid contents decreased as the degree of milling increased. The peak viscosities for all rice increased with the degree of milling and the rates of increase were higher for medium-grain than long-grain cultivars. Degree of milling did not have a consistent effect on final viscosity for all the cultivars tested.

Rice is used for various food processing applications such as breakfast cereals, snacks, and package mixes, and as a thickener for baby food and sauces. However, rice functionality can affect its processability and the quality of the final product. As a result, tests for rice functional properties that are important in specific food processing applications have been established. Among these, determining rice pasting properties with the amylograph has been widely used (Halick and Kelly 1959; Juliano 1982). The Rapid Visco Analyser (RVA), which is faster and requires smaller sample size, is gaining acceptance, especially among breeders working with limited sample size (Blakeney et al 1996; Juliano 1996). Numerous studies have been published on the effect of cultivar and storage conditions on rice amylograph properties (e.g., Hamaker et al 1993; Chrastil 1994; Perdon et al 1997). In contrast, the effect of milling conditions on rice pasting properties, specifically the degree to which the bran layers have been removed, has received little attention.

Rice is commonly used as milled or white rice which is produced by removing the hull and bran layers of the rough rice kernel in the dehulling and milling processes, respectively. Rice protein and lipids are located mainly in the bran, while starch is mostly in the endosperm. The removal of bran during milling increases the starch level and lowers the lipid and protein content of the remaining kernel. The proximate composition and corresponding amylograph properties of milled rice will depend on the degree of bran removal during milling.

A measure of how much bran was removed during milling is referred to as the degree of milling. The USDA Federal Grain Inspection Service has designated four qualitative degree of milling categories: well-milled, reasonably well-milled, lightly milled, and undermilled. Several methods have been used to objectively measure rice degree of milling. The most common method is calculating the mass lost during milling. Determinations of the amount of surface and total lipids have also been used. Additionally, the Satake milling meter (MM1-B) offers a quantifiable method of determining the degree of milling by using the transmittance and reflectance properties of the milled rice samples. Well-milled rice has more of its bran removed and has a higher starch and lower lipid and protein content compared with undermilled rice. Within the same cultivar, a sample with higher starch content, which corresponds to a more well-milled sample, would be expected to have a higher paste viscosity than an undermilled sample. The presence of lipids can also lower rice paste viscosity (Ferrel and Pence 1964; Reece and Blakeney 1996). However, these studies did not quantify the relationship between the level of lipids and paste viscosity.

Studies have been published on measuring the degree of milling and its effect on the nutritional and sensory attributes of cooked milled rice (Roberts 1979; Piggott et al 1991). However, limited results have been published on the effect of degree of milling on rice pasting properties. The objective of this study was to quantify the relationship between the degree of milling and milled rice pasting properties.

MATERIALS AND METHODS

Two medium-grain cultivars, Bengal and Orion, and two long-grain cultivars, Cypress and Kaybonnet, were harvested in 1995 and 1996 from the University of Arkansas Rice Research and Extension Center at Stuttgart, AR. The 1995 samples were aged at 20°C for at least a year while the 1996 samples were kept at 4°C before analysis. Immediately after harvest, the rough rice samples from each cultivar were cleaned in a Carter-Day Dockage Tester (Carter-Day Co., Minneapolis, MN). After cleaning, the samples were conditioned to 12–12.5% moisture content (MC) inside a chamber set at 21°C and 53% relative humidity (RH). [Unless otherwise specified, all MC values are reported on a wet basis.] The air conditions inside the chamber were controlled by a temperature and RH control unit (PG&C 300 CFM Climate-Lab-AA Model No. AA-5460A, Parameter Generation & Control Inc., Black Mountain, NC).

Two 150-g portions of rough rice from each cultivar were dehulled in a McGill sample sheller (Rapsco, Inc., Brookshire, TX). The resulting brown rice was milled in a McGill #2 mill (Rapsco, Inc., Brookshire, TX) operated with a 1.5-kg weight that was positioned on the mill lever arm 15 cm from the mill saddle centerline. Milling durations used were 15, 30, 45, or 60 sec. Head rice were separated from brokens with a sizer (Seedburo Equipment Co., Chicago, IL) and weighed to obtain head rice yield. The head rice fractions from the two milling samples were combined and used for subsequent testing.

The degree of milling (DOM) of each milled rice sample was measured with a milling meter (MM-1B, Satake USA Inc., Houston, TX). Also, surface lipid contents were determined in duplicate following the petroleum ether extraction method of Chen et al (1997).

To measure total lipid content, milled rice samples were ground in a Cyclotec mill (Udy Corp., Fort Collins, CO) fitted with a 0.5-mm screen. Total lipid content of each ground sample was determined with a Soxtec fat extractor using petroleum ether as solvent (Approved Method 30-20, AACC 2000). The MC of the ground rice was measured by drying 2–5 g samples for 1 hr in an oven at 130°C (Juliano et al 1985). The MC values were used to calculate the amount of rice flour needed to prepare the rice flour slurry for pasting properties measurements. Pasting properties of each sample were separately analyzed (Viscograph-E, C.W. Brabender

[1] Published with the approval of the Director, University of Arkansas Agricultural Experimental Station. Mention of a commercial name does not imply endorsement by the University of Arkansas.

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Publication no. C-2001-0208-06R.

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Instruments, South Hackensack, NJ; and a Rapid Visco Analyser RVA-4, Foss North America, Eden-Prairie, MN) following Approved Methods 61-01 and 61-02 (AACC 2000). The properties measured from each pasting profile were peak viscosity (PV) and final viscosity at 50°C (FV). Two treatments were used to determine the effect of inactivating amylase on brown rice pasting properties. The first treatment consisted of dissolving 200 mg of mercuric chloride ($HgCl_2$) in the deionized water to be used for amylography. The solution was added to the flour, producing a slurry with a final concentration of 0.04% $HgCl_2$. Amylography was conducted on this slurry as previously described. In the second treatment, the slurry was briefly acidified as described by Meredith (1970). The calculated amount of rice flour was placed in a 1-L Erlenmeyer flask and 210 g of deionized water was added. After the flour was uniformly suspended, 20 mL of 1*N* HCl was added with stirring. The suspension was stirred for 20 min at room temperature before adding 20 mL of 1*N* NaOH to neutralize the suspension. The suspension was transferred to the amylograph bowl and the flask was rinsed with enough deionized water to obtain a total slurry mass of 500 g. Amylography was conducted as before.

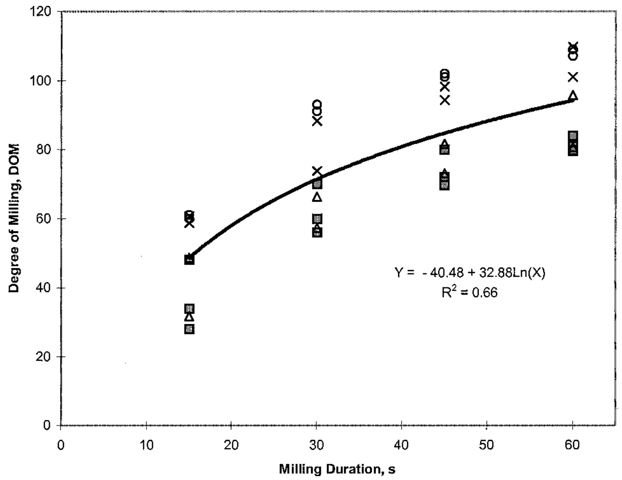

Fig. 1. Effect of milling duration in a McGill No. 2 laboratory mill on degree of milling, measured with a Satake MM-1B milling meter, of milled rice from Bengal (■), Orion (○), Cypress (Δ), and Kaybonnet (×) cultivars harvested in 1995 and 1996.

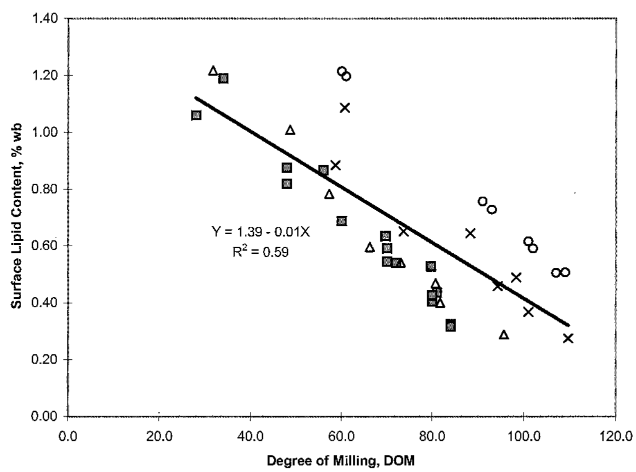

Fig. 2. Effect of degree of milling, measured with a Satake MM-1B milling meter, on surface lipid content of milled rice from Bengal (■), Orion (○), Cypress (Δ), and Kaybonnet (×) cultivars harvested in 1995 and 1996.

Regression equations were developed using JMP and SAS procedures (SAS Institute, Cary, NC) to relate the pasting properties (PV and FV) of samples within the same cultivar and year to degree of milling. Contrasts were performed to compare the regression coefficients within the medium- and long-grain rice cultivars tested. For relationships that were not significantly different from each other, common slopes and intercepts were estimated. Results with $P < 0.05$ were considered to be statistically significant. An analysis of variance was performed with SAS general linear model (GLM) procedure at $\alpha = 0.05$ to determine the significance of the differences observed in the paste viscosity values after the $HgCl_2$ and HCl-NaOH treatments.

RESULTS AND DISCUSSION

Rice degree of milling (DOM), measured with the Satake MM-1B milling meter, for all cultivars tested increased with milling duration (Fig. 1). Regression of DOM with milling duration showed a logarithmic relationship with the increase in DOM values tapering at longer milling durations. As expected, head rice yield decreased with milling duration. Head rice yield for all the cultivars tested decreased from an average of 68% after 15 sec of milling to 62% after 60 sec of milling, with the exception of Kaybonnet harvested in 1995, whose head rice yield decreased 59–53%. Surface lipid contents decreased accordingly with increases in DOM (Fig. 2). A similar trend was observed with the milled rice total lipid contents (data not shown). This result is consistent with previous observations (Sun and Siebenmorgen 1993; Chen et al 1997) and is expected because rice lipids are predominantly located in the bran layer, which is progressively removed during milling.

Individual regression equations were derived for relating the degree of milling (DOM, surface and total lipid contents) to peak and final viscosities (PV and FV, respectively) for each cultivar and harvest year combination (Tables I–III). Negative slopes were

TABLE I
Regression Coefficients for Linear Relationship Between Amylograph and RVA Paste Viscosities and Degree of Milling (DOM) Measured with Satake MM-1B Milling Meter

	Brabender Amylograph Paste Viscosity				RVA Paste Viscosity			
	Peak Viscosity		Final Viscosity		Peak Viscosity		Final Viscosity	
Cultivar	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept
Medium-grain								
Bengal 1995	6.16	195.79	3.92	307.96	1.42	230.82	0.02ns[a]	228.10
Bengal 1996	3.40	238.88	2.23	337.18	1.62	166.67	0.47	179.61
Orion 1995	2.86	392.20	–1.99	880.32	1.00	222.90	–0.90	336.25
Orion 1996	2.83	277.10	1.36	439.98	1.25	177.69	0.13ns	217.62
Long-grain								
Cypress 1995	1.26	487.05	–0.07ns	811.92	–0.25ns	248.91	–0.16ns	288.16
Cypress 1996	1.14	440.33	0.45ns	665.25	0.68	167.48	–1.30	343.66
Kaybonnet 1995	0.99	565.36	0.29ns	808.75	0.92	169.16	–0.25ns	322.52
Kaybonnet 1996	1.00	421.80	0.27ns	700.65	0.58	185.82	–0.72	347.29

[a] ns = Not significantly different from 0 ($P > 0.05$).

obtained for the regressions between paste viscosities and surface and total lipid contents because of the inverse relationships between degree of milling and lipid content (Fig. 2). Peak viscosities, measured with the amylograph and RVA, for all rice increased with degree of milling. The rates of increase were higher for medium-grain than long-grain cultivars. The regression relationships between PV and DOM were statistically significant for Bengal and Orion, the two medium-grain rice cultivars tested. Similar results were obtained with the long-grain rice cultivars, except for the RVA PV values of Cypress harvested in 1995, which did not show a significant relationship with DOM. Overall paste viscosities of the 1995 samples (aged one year) were generally higher than the 1996 samples which were not aged, as indicated by the intercepts of the regression equations in Tables I–III. This is consistent with previous research showing that paste viscosity of milled rice increased during storage (e.g., Hamaker et al 1993; Chrastil 1994; Perdon et al 1997).

In contrast with PV, the effect of DOM on final viscosity (FV), as indicated by the slopes given in Tables I–III was not consistent, and for half of the samples tested was not significant. Among the significant relationships, the amylograph and RVA FV values of Orion harvested in 1995 decreased with DOM. The same trend was observed with the RVA FV values of Cypress and Kaybonnet harvested in 1996.

The effect of DOM on Bengal FV was similar to that of PV using the amylograph and RVA. The amylograph FV increased with DOM for Bengal harvested in 1995 and 1996, while the RVA FV increased with DOM only for Bengal harvested in 1996 (Table I).

The increase in Bengal PV and FV with increased DOM may be explained by the higher amylase activity in Bengal. The effects of amylase inactivation treatments on amylograph paste viscosity of Bengal brown rice harvested in 1995 are shown in Fig. 3. Overall paste viscosities of Bengal after $HgCl_2$ and HCl-NaOH treat-

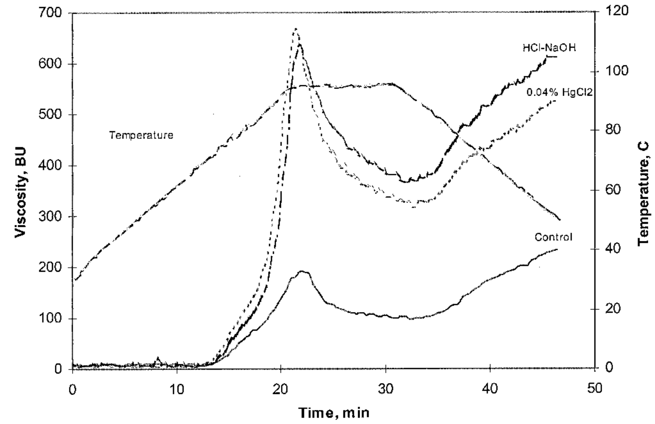

Fig. 3. Effect of amylase inhibition on paste viscosity of Bengal brown rice harvested in 1995.

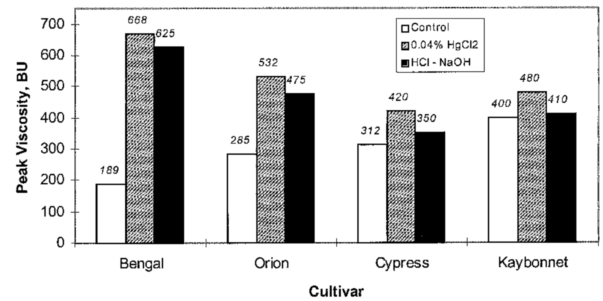

Fig. 4. Effect of amylase inactivation on amylograph peak viscosities of four brown rice cultivars harvested in 1995. LSD ($P < 0.05$) for comparing peak viscosities among treatments within each cultivar are 43 BU for Bengal, 50 BU for Orion, 43 BU for Cypress, and 59 BU for Kaybonnet.

TABLE II
Regression Coefficients for Linear Relationship Between Amylograph and RVA Paste Viscosities and Degree of Milling (DOM) Measured by Surface Lipid Content

	Brabender Amylograph Paste Viscosity				RVA Paste Viscosity			
	Peak Viscosity		Final Viscosity		Peak Viscosity		Final Viscosity	
Cultivar	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept
Medium-grain								
Bengal 1995	–521.55	921.71	–331.81	769.78	–120.03	397.96	–1.33ns	230.01
Bengal 1996	–234.86	604.72	–156.54	578.73	–116.27	343.77	–35.10	231.98
Orion 1995	–197.44	803.38	137.30	594.41	–68.63	366.11	62.39	206.46
Orion 1996	–190.01	677.62	–91.31	632.33	–83.98	354.54	–9.14ns	236.67
Long-grain								
Cypress 1995	–84.21	627.13	12.16ns	800.04	12.20ns	224.18	6.60ns	273.27
Cypress 1996	–72.18	563.96	–29.76ns	714.78	–43.00	240.82	83.57	201.78
Kaybonnet 1995	–80.11	694.00	–22.35ns	845.43	–88.67	297.26	17.37ns	291.59
Kaybonnet 1996	–60.54	548.64	–16.51ns	734.67	–35.00	259.28	43.52	255.95

[a] ns = Not significantly different from 0 ($P > 0.05$).

TABLE III
Regression Coefficients for Linear Relationship Between Amylograph and RVA Paste Viscosities and Degree of Milling (DOM) Measured by Total Lipid Content

	Brabender Amylograph Paste Viscosity				RVA Paste Viscosity			
	Peak Viscosity		Final Viscosity		Peak Viscosity		Final Viscosity	
Cultivar	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept
Medium-grain								
Bengal 1995	–356.37	863.06	–226.66	732.42	–82.99	385.28	–1.03ns	229.96
Bengal 1996	–158.76	582.92	–106.09	564.38	–79.35	333.48	–23.92	228.85
Orion 1995	–146.54	790.84	102.19	602.84	–51.26	362.07	46.17	210.55
Orion 1996	–142.91	669.76	–69.89	628.76	–63.42	351.30	–7.22ns	236.62
Long-grain								
Cypress 1995	–73.84	623.34	13.48ns	798.88	9.63ns	225.62	4.88ns	274.28
Cypress 1996	–65.72	561.54	–27.52ns	714.12	–39.23	239.44	76.18	204.51
Kaybonnet 1995	–66.85	691.31	–19.26ns	845.08	–63.69	287.42	18.34ns	289.61
Kaybonnet 1996	–62.78	549.58	–16.67ns	734.65	–36.42	260.09	45.23	255.21

[a] ns = Not significantly different from 0 ($P > 0.05$).

ments increased significantly. Comparison of amylograph PV values among the samples tested (Fig. 4) showed that both medium-grain cultivars, had significant increases in PV after amylase inactivation compared with the two long-grain cultivars. Bengal brown rice had the highest increase after $HgCl_2$ and HCl-NaOH treatments, 253 and 231%, respectively.

These results suggest that the amylase activity of Bengal brown rice was higher than that of the other three cultivars. Similar results were observed with the FV values. This may explain the higher increase in the PV and FV of Bengal with increased DOM. Like lipids, amylase is located mainly in the bran layer, which is removed during milling. Rice with a higher DOM will have less amylase and, thus, have higher paste viscosity.

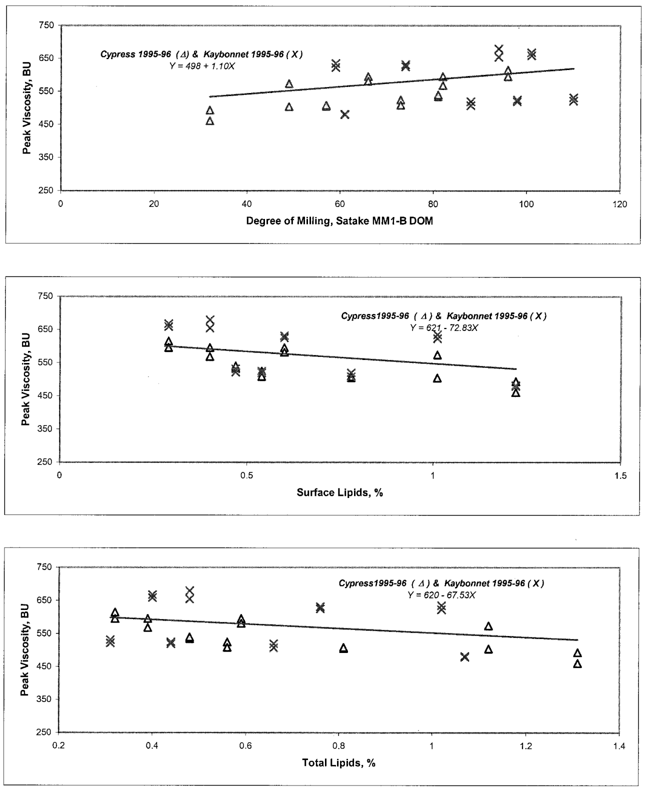

Fig. 5. Effect of degree of milling on amylograph peak viscosities of long-grain milled rice cultivars harvested in 1995 and 1996.

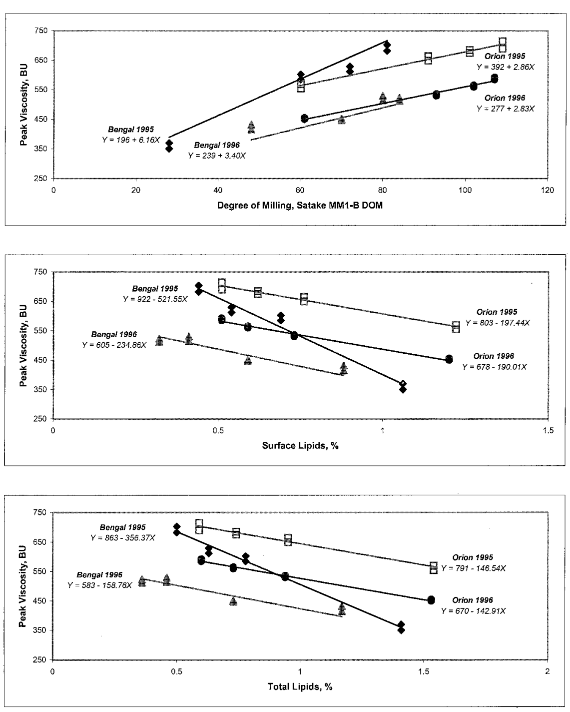

Fig. 6. Effect of degree of milling on amylograph peak viscosities of medium-grain milled rice cultivars harvested in 1995 and 1996.

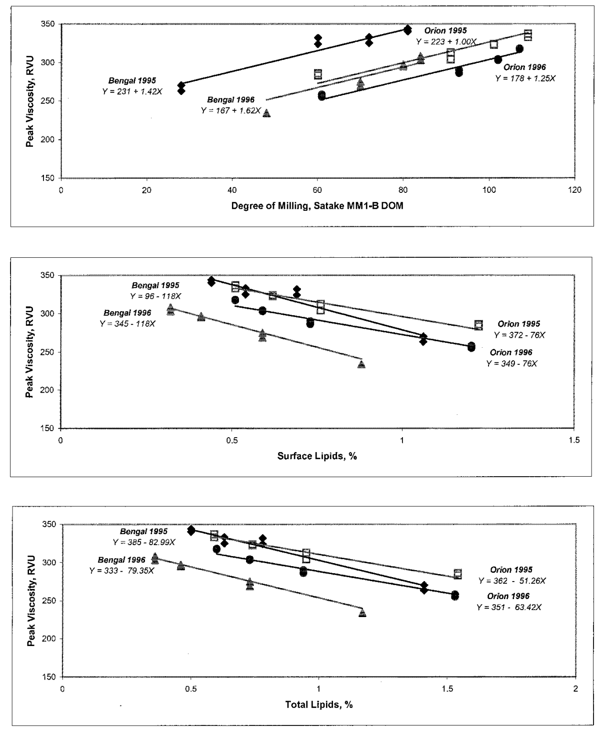

Fig. 7. Effect of degree of milling on RVA peak viscosities of medium-grain milled rice cultivars harvested in 1995 and 1996.

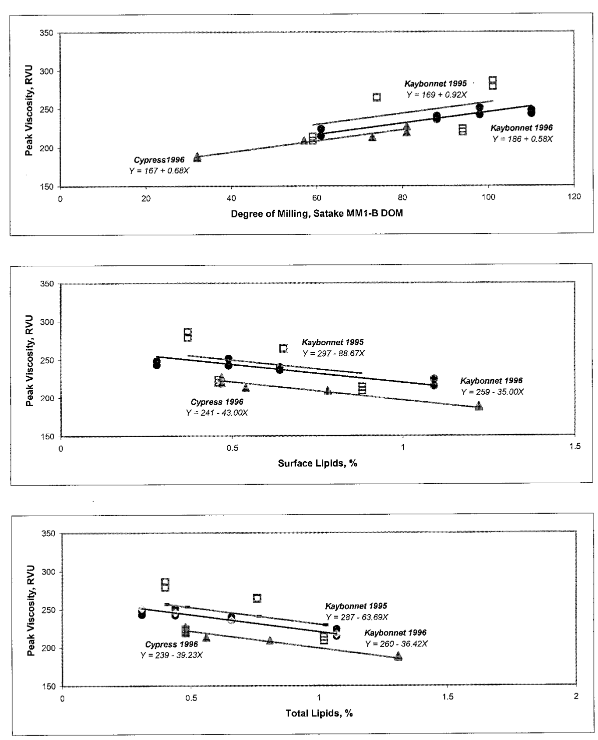

Fig. 8. Effect of degree of milling on RVA peak viscosities of long-grain milled rice cultivars harvested in 1995 and 1996. Data for Cypress harvested in 1995 were insufficient for statistical analysis and were not plotted.

Contrast tests on the significant regressions were done to determine whether common slopes and intercepts (Figs. 5–8) could represent the relationships between the DOM and paste viscosities. A common regression line could represent the relationship between the DOM and amylograph PV for Cypress and Kaybonnet harvested in 1995 and 1996 (Fig. 5). With the medium-grain rice, a common slope existed between DOM and PV for Orion harvested in 1995 and 1996, but not for Bengal (Fig. 6). As mentioned earlier, Bengal harvested in 1995 had a very high amylase activity, which could have altered its behavior relative to the 1996 sample. Bengal harvested in 1996 showed lower increases in paste viscosities after $HgCl_2$ and HCl-NaOH treatments suggesting that the rice harvested in 1996 had lower amylase activity than those harvested in 1995. With the RVA PV, a common slope could represent each cultivar, including Bengal, across 1995 and 1996 (Figs. 7 and 8). This result may suggest that amylography may be more sensitive than the RVA in measuring amylase activity. These results showed that for a given cultivar harvested in a given year, milled rice paste viscosity was linearly dependent on the DOM. Therefore, the DOM of rice should be considered when measuring paste viscosities.

CONCLUSIONS

The DOM of milled medium- and long-grain rice cultivars affected surface and total lipid content and pasting properties, specifically PV and FV. Milled rice surface and total lipid content decreased as DOM increased for all cultivars tested. Peak viscosity increased with DOM. Regression slopes of the relationship of PV versus DOM were greater with medium-grain than with long-grain cultivars. The DOM did not have a consistent or a highly significant effect on FV. The effect of DOM on PV and FV measured by amylograph or RVA across cultivars and harvest year could not be predicted by a single equation. The results suggest that, in general, the DOM (measured with the Satake milling meter or by surface or total lipid contents) significantly affected milled rice paste viscosity. It is, therefore, important to specify the DOM of a sample when comparing and specifying milled rice pasting properties.

LITERATURE CITED

American Association of Cereal Chemists. 2000. Approved Methods of the AACC, 10th ed. Methods 30-20, 61-01, and 61-02. The Association: St. Paul, MN.

Blakeney, A. B., Welsh, L. A., Martin, M., and Reece, J. E. 1996. Use of the RVA for flour and starch viscosity analysis. Pages 13-18 in: Applications of the Rapid Visco Analyser. C. E. Walker and J. L. Hazelton, eds. Newport Scientific, Pty. Ltd.: Warriewood, NSW, Australia.

Chrastil, J. 1994. Effect of storage on the physicochemical properties and quality factors of rice. Pages 41-49 in: Rice Science and Technology. W. E. Marshall and J. I. Wadsworth, eds. Marcel Dekker: New York.

Chen, H., Marks, B. P., and Siebenmorgen, T. J. 1997. Quantifying surface lipid content of milled rice via visible/near-infrared spectroscopy. Cereal Chem. 74:826-831.

Ferrel, R. E., and Pence, J. W. 1964. Use of the amylograph to determine extent of cooking in steamed rice. Cereal Chem. 41:1-9.

Halick, J. V. and Kelly, V. J. 1959. Gelatinization and pasting characteristics of rice varieties as related to cooking behavior. Cereal Chem. 36:91-98.

Hamaker, B. R., Siebenmorgen, T. J., and Dilday, R. H. 1993. Aging of rice in the first six months after harvest. Arkansas Farm Research 42(1):8-9.

Juliano, B. O. 1982. An international survey of methods used for evaluation of cooking and eating qualities of milled rice. IRRI Res. Pap. Ser. No. 77. International Rice Research Institute: Philippines.

Juliano, B. O. 1996. Rice quality screening with the Rapid Visco Analyser. Pages 19-24 in: Applications of the Rapid Visco Analyser. C. E. Walker and J. L. Hazelton, eds. Newport Scientific, Pty. Ltd.: Warriewood, NSW, Australia.

Juliano, B. O., Perez, C. M., Alyoshin, E. P., Romanov, V. B., Bean, M. M., Nishita, K. D., Blakeney, A. B., Welsh, L. A., Delgado, L. L., El Baya, A. W., Fossati, G., Kongseree, N., Mendes, F. P., Brillante, S., Suzuki, H., Tada, M., and Webb, B. D. 1985. Cooperative test on amylography of milled rice flour for pasting viscosity and starch gelatinization temperature. Starch 37:40-50.

Meredith, P. 1970. Inactivation of cereal alpha-amylase by brief acidification: The pasting strength of wheat flour. Cereal Chem. 47:492-500.

Perdon, A. A., Marks, B. P., Siebenmorgen, T. J., and Reid, N. B. 1997. Effects of rough rice storage conditions on the amylograph and cooking properties of medium-grain rice cv. Bengal. Cereal Chem. 74:864-867.

Piggott, J. R., Morrison, W. R., and Clyne, J. 1991. Changes in lipid and in sensory attributes on storage of rice milled to different degrees. Int. J. Food Sci. Technol. 26:615-626.

Reece, J. E. and Blakeney, A. B. 1996. Influence of free fatty acids on rice flour RVA profiles. Page 25 in: Applications of the Rapid Visco Analyser. C. E. Walker and J. L. Hazelton, eds. Newport Scientific, Pty. Ltd.: Warriewood, NSW, Australia.

Roberts, R. L. 1979. Composition and taste evaluation of rice milled to different degrees. J. Food Sci. 44:127-129.

Sun, H., and Siebenmorgen, T. J. 1993. Milling characteristics of various rough rice kernel thickness fractions. Cereal Chem. 70:727-733.

[Received November 19, 1999. Accepted November 30, 2000.]