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USE OF THE AMYLOGRAPH TO DETERMINE EXTENT OF COOKING IN STEAMED RICE[1]

R. E. FERREL AND J. W. PENCE

ABSTRACT

Slurries of rice flour heated in the amylograph bowl to 95°C. and held for 20 min. exhibit the marked reduction in viscosity common to starch materials held at this temperature. This difference in viscosity (ΔV) decreases as steaming or other cooking pretreatment of rice is increased, until it reaches zero. Visual and other examination of steamed grain indicates that when ΔV reaches zero, the rice is completely cooked, internal opacity is minimal, and actual or potential starch-granule collapse apparently is near a maximum. Neither the naturally occurring fatty materials in brown rice nor the differences in amylose content between long- and short-grain rice affect the proportionality between cooking treatment and ΔV values. The relationship between ΔV and degree of cooking was used to study steam-cooking of both brown and milled whole-grain rice prior to conversion to quick-cooking convenience products. Final extent of cooking appears to be principally a function of steaming time, whereas cooking rate seems to be primarily a function of rice moisture content.

Development at this Laboratory of several instant or quick-cooking rice products has involved a precooking step (1,2,3). To minimize kernel distortion and rupture and the cost of subsequent drying, cooking has generally been carried out by atmospheric steaming, with grain moisture content as low as possible. The degree of cooking affects the final product: excessive cooking may lead to undesirable side reactions such as browning; and insufficient cooking causes uneven textural and hydration characteristics in the finished products.

Traditional methods for determining adequacy of cooking in the rice industry, where processing conditions are similar to those mentioned above, have been visual examination of the finished product for a glassy, translucent appearance and absence of white centers, i.e.,

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small spots of uncooked starch. To meet these standards, excessive cooking has frequently been employed unknowingly, with the result that undesirable dark colors develop in the grain. Roberts *et al.* (4) found that the volume of rice expanded by hot air and the amount of soluble starch, as indicated by iodine blue value determination, were useful in evaluating the degree of parboiling.

Neither traditional methods nor Roberts' criteria are completely satisfactory when applied to processed materials. Drying of rice grains without the moderating influence of the hull, even under the mildest conditions, causes numerous cracks and fissures. These cracks exert a depressing influence on the volume of hot-air-expanded grain, with the result that direct comparison between expanded volume and processing treatment is impractical. Measurement of solubilized starch is not applicable to brown rice, because iodine blue value determinations on processed brown rice give a muddy yellow-brown color instead of the typical blue. In addition, Roberts and co-workers found no apparent maxima for soluble starch short of complete solubilization of the total amylose content of the rice, requiring extremely drastic treatment conditions. Further, the depth of iodine color obtained for a given treatment would be dependent upon the amylose content of the rice being used, which can differ by a factor of about 2 between short- and long-grain types and nearly as much between varieties within the long-grain type.

Viscosity measurements have long been used to characterize starch and starch-containing materials and the effect of modifications on the materials. When starch is heated above a critical temperature in the presence of water, the starch granules swell rapidly. If heating is continued, the granules rupture, or the starch material diffuses from the granule; either situation leads to a change in viscosity characteristics as measured on the amylograph. These changes, then, should be of use in determining the degree of cooking to which a sample has been subjected. In this paper we present a method for evaluating the extent of cooking in processed rice, utilizing the amylograph.

Materials and Methods

Rices used in these studies were U.S. No. 1 grade obtained through commercial channels. Both brown and milled short-grain rice were of the Japonica type of either Coloro or Colusa variety normally grown in California. The long-grain was Texas Patna variety.

Hydration. Rice was hydrated by submerging it in tapwater at room temperature for the length of time necessary for it to reach the desired moisture content, as determined from previously prepared moisture-uptake curves. Rice rapidly absorbs water to an equilibrium moisture content of approximately 31%, but only by going to temperatures above the gelatinization point can higher moistures be achieved. Since cooking should be avoided at this stage, and because low moisture content minimizes later drying requirements, we have confined our studies to rice having moistures at or below equilibrium.

Cooking. The soaked rice was drained quickly in cylindrical wire baskets with covers. Each basket was then placed on externally driven, rubber-covered rolls in an enclosed chamber. Live steam was introduced into the chamber through a series of horizontal jets along a distribution pipe below and parallel to the axis of the basket and rolls. Steam was exhausted through a small port in the center of the curved top of the steaming chamber. The steaming chamber was always preheated before use. The basket contained four longitudinal lifters equally spaced around its interior circumference so that the rice was continually lifted and cascaded in the steam atmosphere during the cooking period. The entire equipment was of stainless-steel construction.

Drying. Processed samples were dried by transferring the basket with its contents to a laboratory-built dryer, where the basket was rotated and the rice cascaded in a stream of ambient air. The dryer was operated through a cycle timer, so that the rice was alternately tumbled and aerated 10 min. and then allowed to rest and temper for 30 min. Drying was conducted for 16–20 hr. Final rice moisture was 10–11%.

Amylograph Technique. The Model AC8 Amylograph (Brabender Corporation, Rochelle Park, N.J.) was used in most of the studies, but some of the comparisons were run on a Model VAV1 Visco/amylo/graph (C. W. Brabender Instruments, Inc., South Hackensack, N.J.). Rice was ground to pass the 40-mesh screen of the Micro Wiley mill. A 10% slurry was prepared by placing 50.0 g. (adjusted to a calculated 13.5% moisture content) in a Waring Blendor, and approximately 300 g. of the required 450 g. (adjusted for the actual weight and moisture content of the rice) of distilled water was added. The mixture was slurried 1.5 min. and transferred to the amylograph bowl. The remaining water was used to rinse the blender and then transferred to the amylograph bowl. The slurry was immediately heated to 30°C. The chart was then adjusted to a zero-min. marking and the slurry heated to 95°C. at a rate of 1.5°C. per min. The paste was held at this temperature for 20 min., then cooled back to 50°C. at the rate of 1.5°C. per min.

Moisture Determinations. Moisture content of dry rice samples was determined by the official air-oven method (5) or in an infrared moisture analyzer calibrated against the air-oven method. High-moisture samples were analyzed by the official two-stage air-oven method for wheat and other grains (5).

Results and Discussion

Figure 1 is a tracing of five amylograph curves obtained on milled

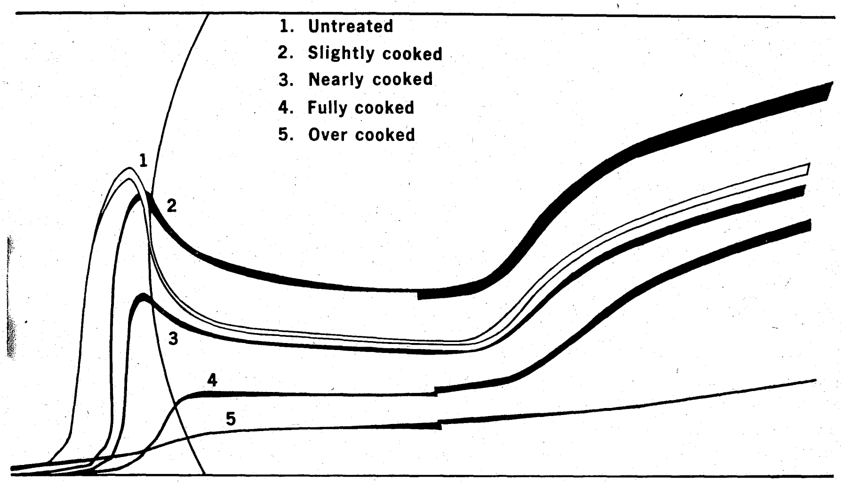

Fig. 1. Tracing of amylograph curves showing the effect of preprocessing on curve characteristics.

pearl rice previously subjected to different degrees of cooking, as evaluated by subjective visual examination. The curves have been so positioned that the 95°C. points coincide. The curve characteristic that appears to correlate best with subjective evaluation of the degree of cooking is the difference (ΔV) between peak viscosity and viscosity after 20 min. of continuous heating at 95°C. ΔV decreases with the severity of pretreatment given the sample. Viscosity characteristics of rice are dependent on many factors such as age, storage conditions, and amylose-amylopectin ratios. To minimize the effect of these factors, we express ΔV of treated samples as a percentage of the value of ΔV obtained on the untreated rice.

While some of the drop in viscosity during the 95° heating period may be due to mechanical shearing action of the amylograph, at least a part is probably due to collapse of starch granules occasioned by the cooking. When the material is first subjected to cooking not involving a mechanical shearing force, as was done in our experiments, and then run on the amylograph, the curves obtained are similar to those obtained when slurry concentration is reduced. Since slurry concentrations were held constant here, a reasonable explanation seems to be that granule collapse, due either to rupture or to outward diffusion of the starch molecule from the granule, occurred during cooking. This results in an effective reduction in concentration of swollen granules and a corresponding decrease in structural viscosity. Further, if ΔV were due solely to mechanical shearing action in the amylograph, changes in ΔV should be more nearly proportional to lowering of peak viscosity than is evident in curves 1, 2, and 3 of Fig. 1. Supporting evidence that such granule collapse has occurred is the increasing amounts of soluble starch found in the cooked samples, by iodine blue value determination by the method of Roberts *et al.* (4) (data not shown).

Curve 5 of Fig. 1 represents severe treatment conditions (processed twice as long as the sample represented by curve 4), and the character of the cooling portion of the curve indicates that excessive cooking leads to degradative changes.

Milled Pearl Rice. ΔV measurements have been used to study the steam cooking of milled pearl rice. The effect of steaming time and grain moisture content on ΔV is shown in Fig. 2. As the data clearly indicate, steaming time is the principal factor controlling the degree of cooking, while to a lesser extent moisture content controls the rate of cooking.

Brown Rice. Brown rice contains approximately 2% of naturally occurring oil in its bran and germ. Unless the rice is fresh or has been stored under excellent conditions, the oil portion may contain appreciable proportions of free fatty acids. Additional amounts of mono- and diglycerides may also be present, particularly if any significant amount of immature rice is present. Since both fatty acids and monoglycerides are known to react with amylose (6), it was important to find whether the natural oil content would interfere with the application of this method to brown rice.

To determine this, samples of brown and milled rice were each split into two equal portions. One portion of the brown rice was extracted four times by decantation with a low-boiling petroleum ether fraction (30°–60°C. boiling range), and the extract was concentrated under vacuum at 30°C. and added to a portion of the milled rice. Solvent was evaporated under vacuum at 30°C. Amylograph curves were then run on all four samples. Curves in Fig. 3 have been traced

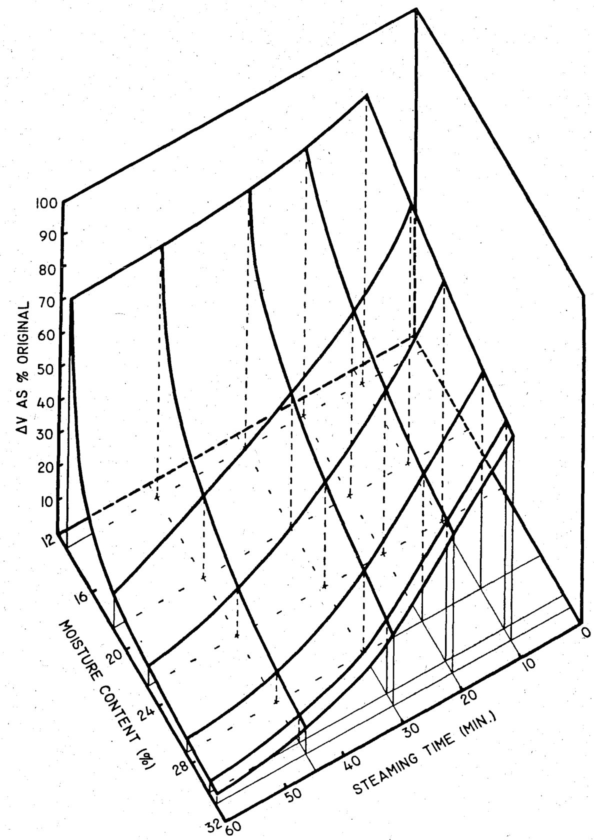

Fig. 2. Effect of steaming time and moisture content of rice on ΔV expressed as a percentage of ΔV for untreated rice. Milled pearl rice.

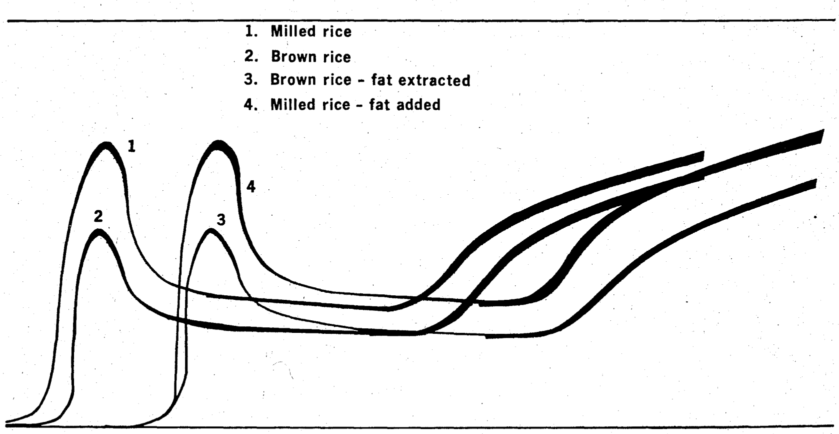

Fig. 3. Amylograph curves showing the effect of rice oil on viscosity characteristics.

so that the important points of comparison can be seen clearly. All four samples gave normal responses, and the pairs of curves for brown and milled rice are identical within the limits of the instrument. While the fat extraction was not exhaustive, it was complete enough so that the above results indicate that any inhibitory effect contributed by the oil in brown rice is relatively minor.

A limited study of the effect of moisture content and steaming time on ΔV was carried out on brown rice. The results were, in general, the same as those found with milled pearl rice (Fig. 4). Since

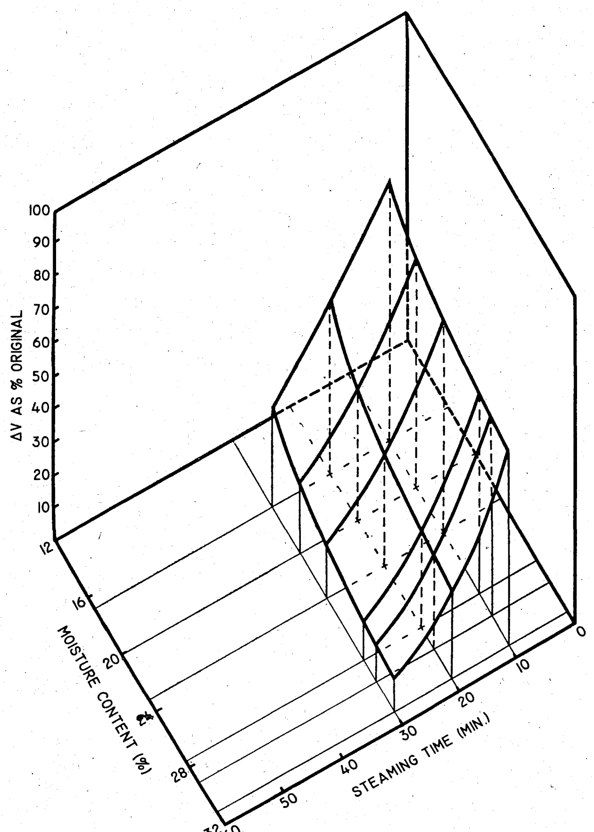

Fig. 4. Relationship of steaming time and moisture content to ΔV for brown pearl rice.

the milled and brown rice did not come from the same lot of rough rice, it would be expected that change in ΔV as a result of varying moisture content and steaming time would differ slightly for the two materials.

Long-Grain Rice. The amylose content of long-grain rice, which is much higher than that of short-grain rice, has been associated by Williams *et al.* (7) with its superior cooking and processing characteristics. Halick and Kelly (8) found marked differences in pasting characteristics between short- and long-grain rice varieties, differences which were likewise associated with cooking quality and amylose content. Since much of the rice processed in this country is of the long-grain variety, it was important to establish that the proposed method would be applicable here also. Accordingly, the effect of moisture at two different steaming times on ΔV was determined (data not shown). The same general relationships were observed, with slight differences in rates again apparent. The differences in rate, however, are not nearly as great as might be expected, if consideration is given to differences in amylose content and in processing characteristics.

Standardization of Amylograph. While it is usually general practice to standardize all amylographs within a laboratory and frequently between laboratories, there might be occasions when comparison of results on nonstandardized instruments is necessary or desirable. Having recently purchased a new instrument, we made such comparisons before the instruments were standardized. Results are shown in Table I. Even with rather large differences in the response of the two instruments as measured in Brabender Units, results are comparable when expressed as percentage of value for untreated rice, determined on the same instrument. For purposes of this method, standardization of instruments is not necessary.

TABLE I

Comparisons of ΔV Obtained on Two Nonstandardized Amylographs

Sample Moisture	ΔV on Old Instrument		ΔV on New Instrument	
	B.U.	*% of original*	*B.U.*	*% of original*
Original	215	100	175	100
18.5	90	42	75	43
22.5	75	35	60	34
27	60	28	50	29
30	45	21	40	23
31	50	23	45	26

This method of evaluating extent of cooking, although empirical, appears to be superior to the purely subjective visual examination used in the past, and should be useful in both study and evaluation of any rice-processing involving a cooking step. Application of the technique to the processing of wheat and other cereal grains is planned.

Acknowledgments

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