Water Absorption and Solubility and Amylograph Characteristics of Roll-Cooked Small Grain Products[1]

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ABSTRACT

For many years, cereals and cereal products have been gelatinized or cooked on heated rolls to prepare specialty products. Corn and grain sorghum grits or flours have been the raw materials used most frequently. Examination of the roll cooking of several other cereal derivatives (ie, grits from wheat, barley, rye, and oats) has shown that rheological characteristics differ when the various products are processed under like conditions. Comparisons made of water absorption (WAI), water solubility (WSI), and Brabender amylograph patterns of the resulting products revealed not only many similarities between the different cereals but also some interesting differences. Cooked grits from oats had considerably lower WAI and WSI values than the other grains under study; the WAI peaked about 100° F (37° C) lower than that of grits from wheat, barley, rye, corn, and sorghum. Oat products gave amylograph patterns similar to those of corn, sorghum, and wheat, whereas cooked barley grits gave atypical viscosity patterns, with elevated values at all critical points.

Gas- or steam-heated rolls have been used for many years to prepare partially or completely gelatinized starches, flours, and meals (Powell 1967, Whistler 1970). The degree of cooking of the product generally depends on moisture content, particle size, temperature, roll pressure, and duration of heating. By varying the operating parameters, cooked products can be made that exhibit a range of rheological properties. Products may be altered to provide materials with different water absorption and solubilities and with different viscosity properties, as shown by Brabender amylograph patterns. We studied the roll cooking of corn and grain sorghum grits (Anderson et al 1969a, 1969b, 1970) and include in this work similar studies on grits prepared from wheat, barley, rye, and oats.

MATERIALS AND METHODS

Materials

Barley, rye, hard wheat, and oats were obtained through commercial channels. Grits were prepared from barley, rye, and wheat by passing each grain several times through an abrasive dehulling machine to remove the bran, aspirating to recover bran, and then reducing the dehulled grains on a roller mill to obtain grits that would pass a no. 12 screen. Oats were dehulled in a scourer, aspirated, and then milled in a coffee mill to make grits that would pass a no. 12 screen. Chemical analyses of these materials, and of corn and grain sorghum are shown in Table I.

Equipment and Experimental Methods

For these tests, the GF pilot-plant gas-fired roll drier having a 12-in. diameter (General Food Package Equipment Co., Benton Harbor, MI) was used. Grits from the various grains were cooked on the gas-fired drier at temperatures ranging from 250 to 570° F (121–299° C) and at moisture levels of 15 and 25%. Roll clearance was set cold at 0.001 in. (0.025 mm), and roll speed was 3 rpm.

Analytical Methods

Rolled-cooked grit products were evaluated by measuring their water-absorption index (WAI), water-solubility index (WSI), and Brabender viscosity patterns.

The water-absorption index is the weight of gel obtained per gram of dry sample through a modification of the method described by Kite et al (1957) for measuring swelling power of starch. A 2.5-g sample of ground product (<60 mesh) was suspended in 3 ml of water at 30° C in a 50-ml tared centrifuge tube, stirred intermittently for 30 min, and centrifuged at 3,000 × g for 10 min. The supernatant liquid was poured carefully into a tared evaporating dish. The remaining gel was weighed and the WAI calculated from its weight.

As an index of water solubility, the amount of dried solids recovered by evaporating the supernatant from the water-absorption test was expressed as percentage of dry solids in the 2.5-g sample.

The amylograph test was done in the standard manner, with 500 g of 9% (db) suspension of the sample (<60 mesh), heated from 29 to 95° C in 44 min, held at 95° C for 16 min, and then cooled to 50° C in 30 min.

Chemical analyses of the grains and their grit products were conducted according to AACC methods (1962). Moisture was determined in a Brabender moisture tester.

RESULTS AND DISCUSSION

Only two of the operating factors were varied during the experimental work: the moisture content of the grits and the roll-surface temperature. The other operating conditions, such as roll pressure, duration of heating, and particle size of the grits, were

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TABLE I
Chemical Analysis of Whole Grain and Prepared Grits Used in Cooking Experiments

	Wheat		Barley		Rye		Oats		Corn	Grain Sorghum
	Grain	Grits	Grain	Grits	Grain	Grits	Grain	Grits	Grits	Grits
Moisture, %	12.7	12.2	10.9	12.0	11.8	11.9	9.9	10.0	14.0	12.0
Nitrogen, %	2.4	2.2	1.5	1.4	1.8	1.5	1.9	2.6	1.3	1.5
Crude fat, %	1.4	0.9	1.6	0.9	1.5	0.6	4.9	6.7	0.5	0.8
Crude fiber, %	1.7	0.8	4.7	0.6	1.8	0.6	10.6	1.2	···	0.3
Ash, %	1.6	1.1	2.4	1.1	1.7	1.3	3.1	1.7	0.4	0.3

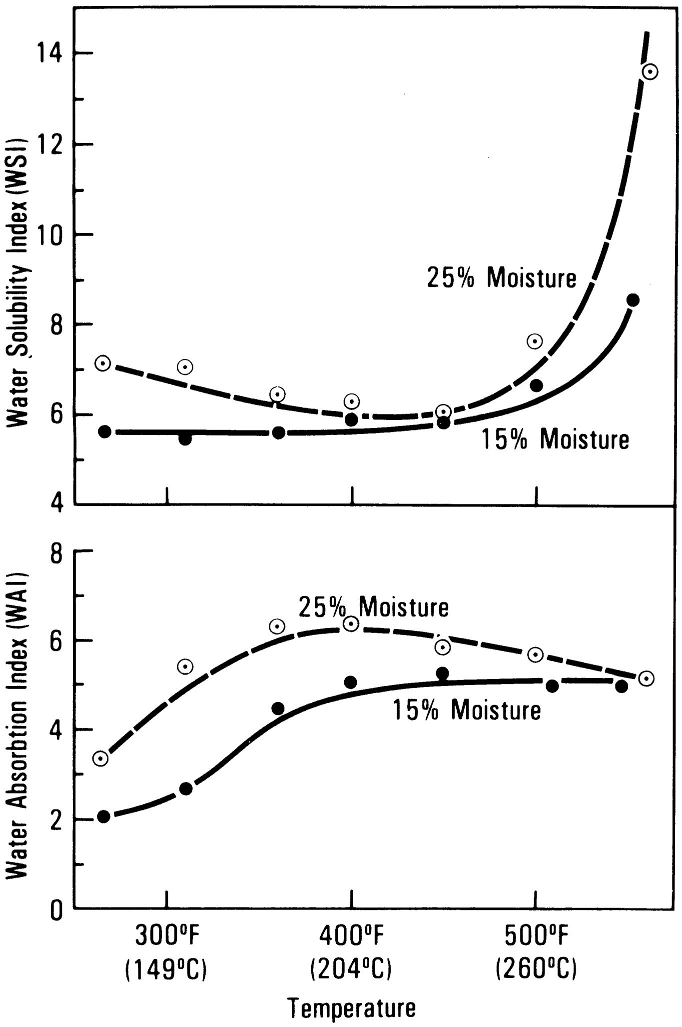

Fig. 1. Roll cooking of wheat grits: Effect of temperature and moisture on water-absorption index (WAI) and water-solubility index (WSI).

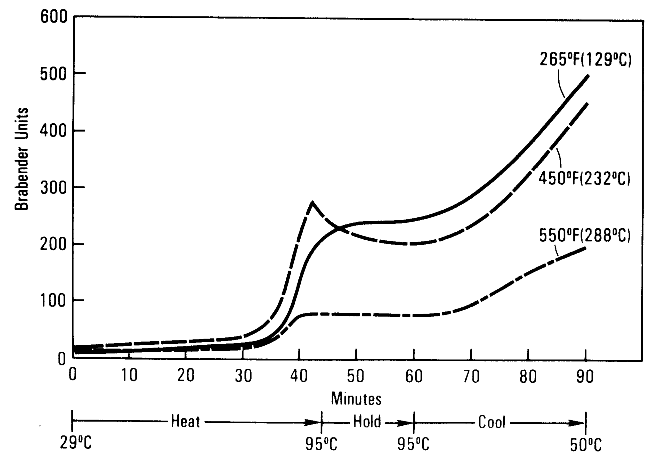

Fig. 2. Roll cooking wheat grits: Effect of temperature on viscosity (15% moisture).

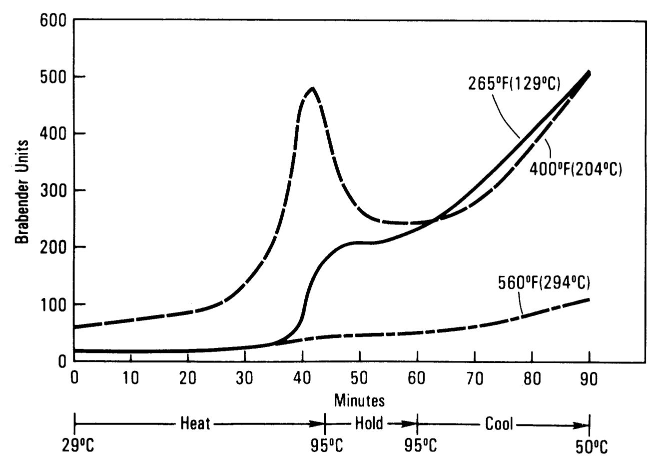

Fig. 3. Roll cooking of wheat grits: Effect of temperature on viscosity (25% moisture).

constant throughout the study.

In Figs. 1–3, results are given for the roll processing of wheat grits. Peak WAI appears to be about 6, occurring at 25% moisture and 400° F (204° C); this peak was not reached with the 15% moisture sample. The WAI of the 15% sample leveled off at the higher temperatures because starch degradation was occurring, evidenced by toasting and by the viscosity patterns (Figs. 2 and 3). The WSI decreased slightly as temperature was increased at both moisture levels to 400–425° F (204–218° C), then rose rather rapidly. Characteristic viscosity patterns were obtained, with initial paste viscosity (29° C) increasing with an increase in temperature of roll cooking, and the final cooked paste viscosity (50° C) decreasing. Degradation occurred in both the 15 and 25% moisture samples that were roll cooked at 550° F (288° C), as evidenced by lower peak and final cooked paste viscosities. At maximum WAI, peak viscosity was 280 Brabender units (BU) at 15% moisture and 450° F (232° C) and 480 BU at 25% moisture and 400° F (204° C).

Figures 4–6 show the results obtained from the roll cooking of barley grits. As shown in Fig. 4, the WAI follows a typical curve at both moisture levels. In the 25% moisture sample, the maximum WAI of 8 is reached at about 425° F (218° C), after which it decreases. At 15% moisture, WAI never reaches the maximum, peaking at about 7 at 460° F (238° C) and then falling off. The WSI remains level at 5 until about 425° F (218° C) and then progressively increases, with the 25% moisture sample increasing at a slightly greater rate.

Figure 5 shows viscosity curves for barley grits processed at 15% moisture at three different temperatures. The initial paste viscosity (29° C) increases as temperature of roll cooking increases; this also occurs with the 25% moisture samples (Fig. 6). Viscosity peaks at maximum WAI occurred at 460° F (238° C) for 15% moisture sample and at 410° F (210° C) for the 25% moisture sample. These viscosity peaks are the highest we have seen for any of the grains studied, varying from about 1,500 BU for the 15% moisture sample at 460° F (238° C) to 1,800 BU for the 25% moisture sample at 410° F (210° C). Final cooked paste viscosities (50° C) decreased characteristically as the roll cooking temperatures were increased.

As with wheat, some starch degradation occurred with samples that were roll cooked at 550°F (288°C), as shown by lower peak and final cooked paste viscosity for both tempering treatments.

Results of the processing of rye grits are given in Figs. 7–9. The WAI and WSI obtained from these studies gave patterns similar to those obtained from wheat grits, except at a slightly higher level (Fig. 7). Peak WAI was about 7 and, as with wheat, a similar dip in WSI appeared. Characteristic viscosity patterns again were obtained from the products of roll-cooked rye grits. Peak viscosities at maximum WAI were higher than wheat but lower than barley. These peaks occurred at 450 BU for the 15%, 450°F (232°C) sample and at 990 BU for the 25%, 405°F (207°C) sample. Starch degradation occurs at 550°F (288°C) in both samples.

The WAI for cooked oats does not follow the usual pattern observed with the other cereals tested (Fig. 10). Maximum WAI is about 4, occurring at 375°F (191°C) for the 15% moisture sample and at 325°F (163°C) for the 25% moisture sample. In the other

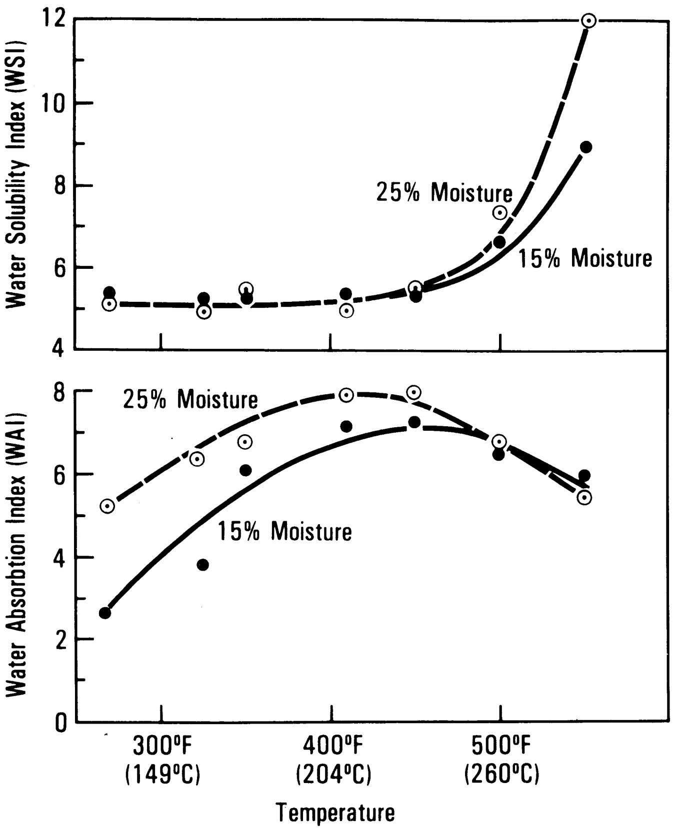

Fig. 4. Roll cooking of barley grits: Effect of temperature and moisture on water-absorption index (WAI) and water-solubility index (WAI).

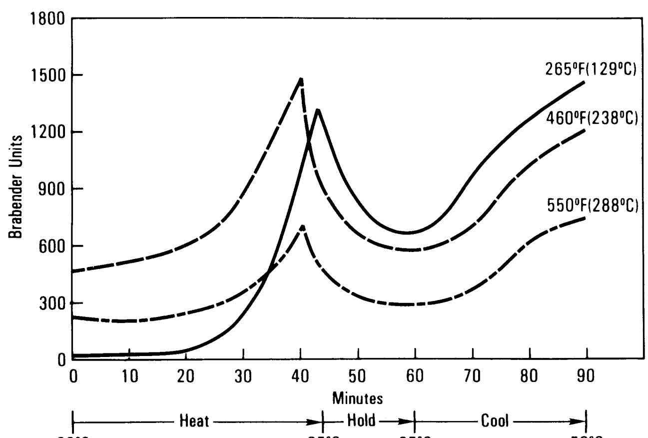

Fig. 5. Roll cooking barley grits: Effect of temperature on viscosity (15% moisture).

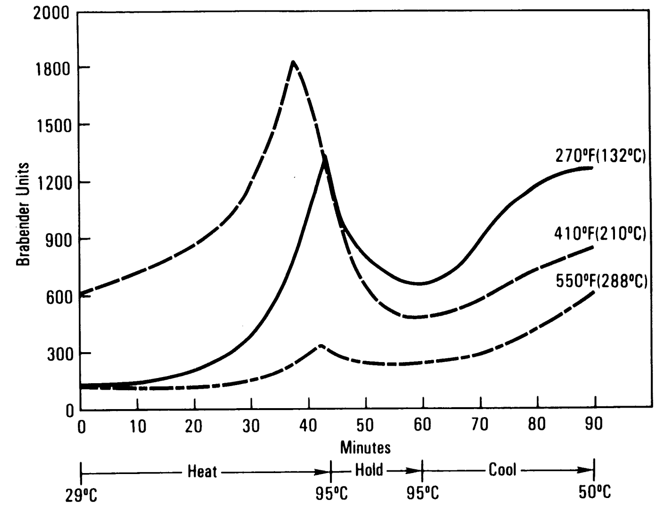

Fig. 6. Roll cooking barley grits: Effect of temperature on viscosity (25% moisture).

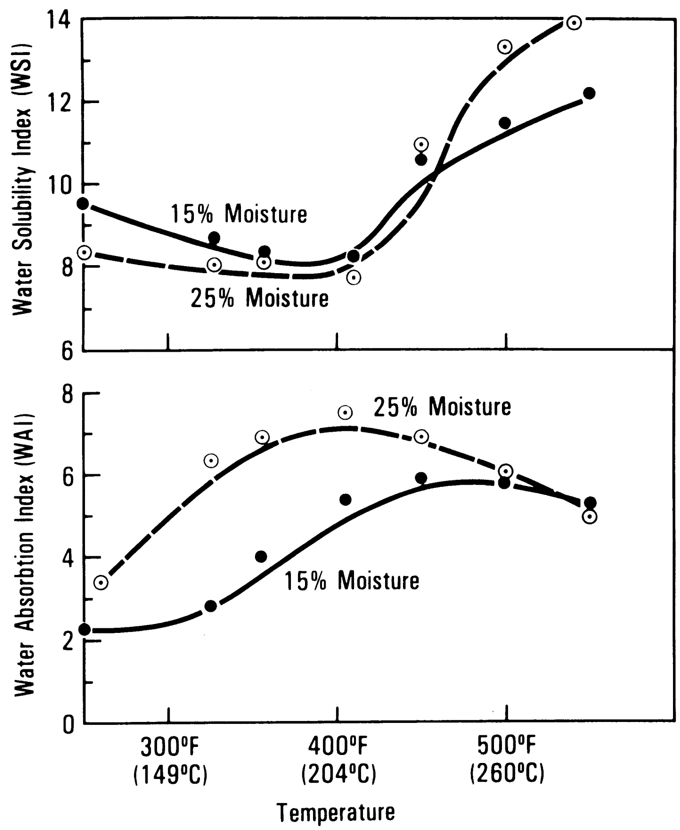

Fig. 7. Roll cooking of rye grits: Effect of temperature and moisture on water-absorption index (WAI) and water-solubility index (WSI).

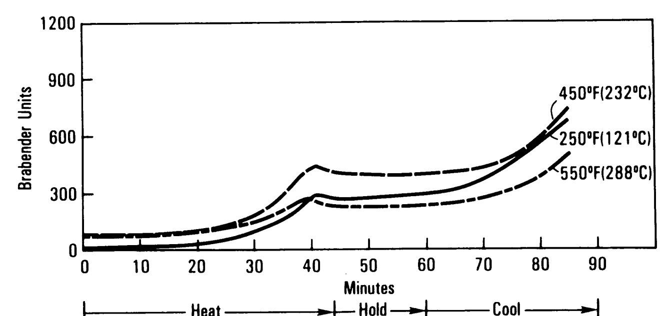

Fig. 8. Roll cooking of rye grits: Effect of temperature on viscosity (15% moisture).

cereals, maximum WAI generally occurred from 410° F (210° C) to 450° F (232° C), and WAI was 6 or higher. For the cooked oats, WAI increased at high cooking temperatures after showing a slight decrease. This phenomenon did not occur with WAI of other cereals, in which WAI declined after reaching maximum. Oat grits cooked at 500° F or higher (260° C) started browning and exhibited other appearance characteristics similar to those noted with the other cereals cooked at temperatures exceeding 500° F (260° C). Water-solubility index curves indicate rather atypical patterns

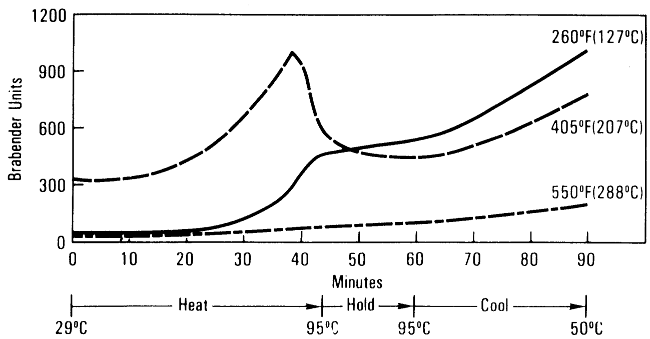

Fig. 9. Roll cooking of rye grits: Effect of temperature on viscosity (25% moisture).

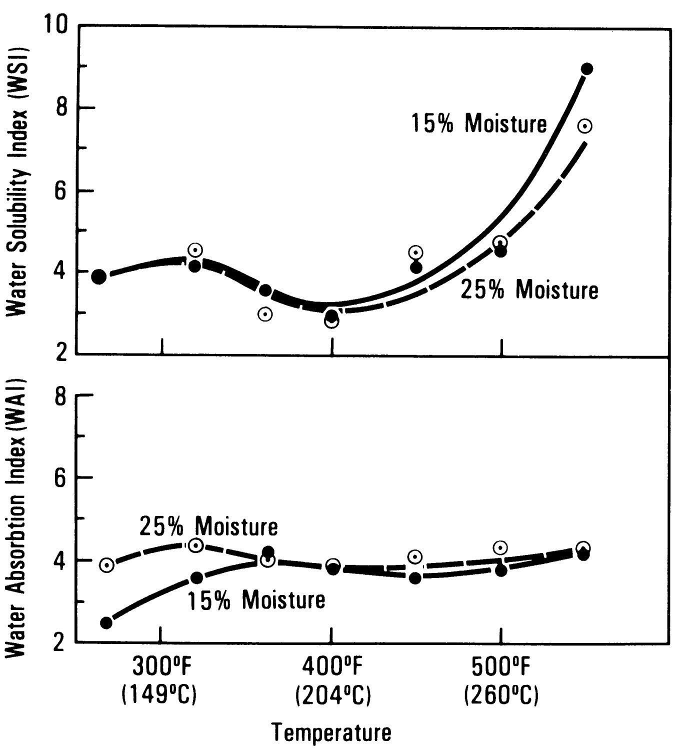

Fig. 10. Roll cooking of oat grits: Effect of temperature and moisture on water-absorption index (WAI) and water-solubility index (WSI).

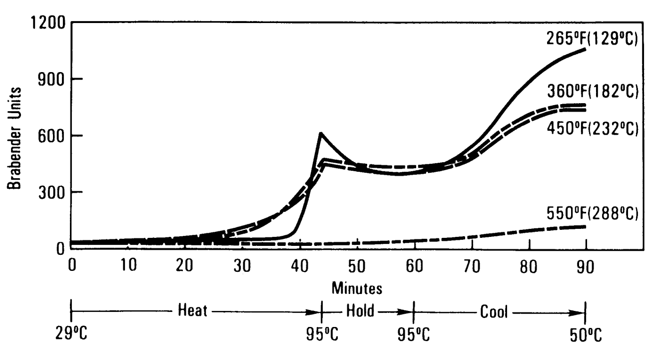

Fig. 11. Roll cooking of oat grits: Effect of temperature on viscosity (15% moisture).

when compared to the other cereals. After a slight increase, peaking at about 300° F (149° C), the WSI decreased to a minimum at 400–425° F (204–218° C) and then rose sharply as temperatures were increased. Figure 11 shows viscosity curves for oat grits processed at 15% moisture and at four different temperatures. Initial paste viscosity (29° C) was the same for samples cooked at 25% moisture (Fig. 12). In both moisture series, peak viscosity occurred in samples cooked at 265° F (129° C). With the exception of the 25% moisture sample cooked at 320° F (160° C), final cooked paste viscosity (50° C) decreased as temperature increased in a manner similar to that observed with viscosity patterns of the other cereals roll cooked under like conditions.

Comparisons of WAI values of grits from different grains cooked at 25% moisture over a range of temperatures are given in Fig. 13. Data for corn and sorghum are from Anderson et al (1969a, 1969b). Characteristic WAI curves were obtained from all the grains except oats, with WAI peaking for all but oats at temperatures from 400° F (204° C) to 450° F (232° C). The curve for oats showed very little change over the complete range of temperatures used. The peculiar behavior of oat grits perhaps can be attributed to the considerably greater amount of oil and crude fiber present in oats. Although not shown, the water solubility of cooked grits from the different grains was similar, ie, with little or no change in WSI until about 400° F (204° C), then increasing as the temperature of cooking was increased. Wheat and rye showed the highest WSI, which was attained at 550° F (288° C). A small peak at about 300° F (149° C) on the WSI curve for oat grits was not noted on the others, but the remainder of the curve followed the characteristics of the other grains. However, the value at 550° F (288° C) was somewhat less than those from the other grains under study.

Table II gives comparative amylograph data for selected samples of roll-cooked grits from the different grains studied. Except for corn, all samples were cooked at 25% moisture content and at approximately 400° F (204° C). The corn sample was cooked at

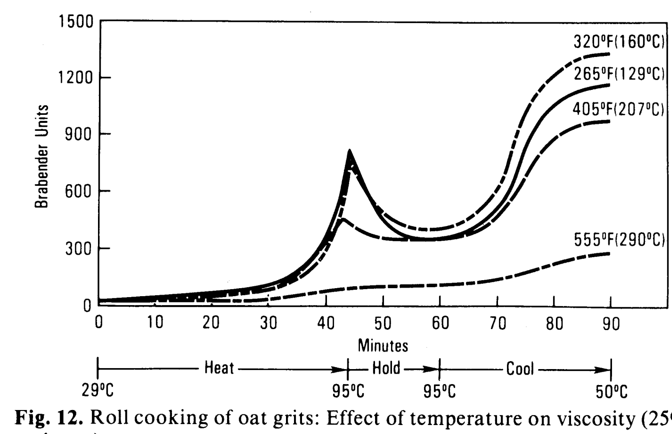

Fig. 12. Roll cooking of oat grits: Effect of temperature on viscosity (25% moisture).

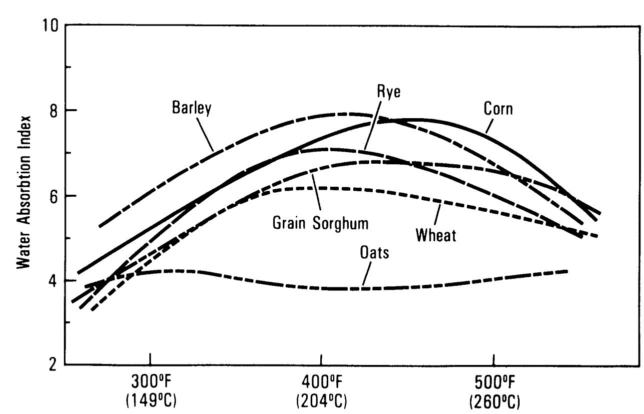

Fig. 13. Roll cooking studies: Water-absorption index of grits from different grains roll cooked at 25% moisture.

TABLE II
Amylograph Data for Roll-Cooked and Uncooked Cereal-Derived Grits

Sample Identification	Viscosity[a] at 29°C	at 95°C	Peak	at 95°C for 16 min	Final Cooked Paste Viscosity (50°C)
Barley					
Cooked[b]	605	1,200	1,820	470	850
Uncooked	10	1,140	1,140	580	1,240
Rye					
Cooked[b]	330	575	1,100	450	780
Uncooked	20	200	230	210	540
Wheat					
Cooked[b]	60	420	480	240	505
Uncooked	0	180	180	180	390
Oats					
Cooked[b]	30	420	450	360	960
Uncooked	20	380	405	280	850
Corn[c]					
Cooked[d]	320	260	490	210	450
Uncooked	30	280	280	330	730
Sorghum[c]					
Cooked[b]	170	240	330	240	330
Uncooked	20	300	300	280	700

[a] In Brabender units.
[b] Cooked at ~400° F (204° C) at 25% moisture.
[c] Anderson et al (1969a, 1969b).
[d] Cooked at ~465° F (240° C) at 20% moisture.

465° F (240° C) at 20% moisture. Amylograph data for uncooked grits from the grains are also included. The viscosity data followed the amylograph patterns expected from both the cooked and uncooked grits. Viscosity developed slowly as the temperature of the material was being increased to the point of gelatinization, at which viscosity peaked, often dramatically. It decreased when material was stirred at 95° C for 16 min, and once again increased during the cooling cycle to the final cooked paste viscosity at 50° C. Uncooked wheat, oats, rye, corn, and sorghum grits had similar amylograph patterns, with some minor variations. Uncooked barley grits, on the other hand, gave unusually high values for both peak and final cooked paste viscosity. Viscosity values that were higher than usual also were obtained from the cooked barley grits. Cooked rye grits gave a somewhat higher viscosity pattern than did the wheat, oats, corn, or grain sorghum.

These studies show that a broad range of products possessing different viscosity characteristics can be made by roll cooking cereal grits under different conditions of temperature and moisture. Furthermore, the various cereal grains, either cooked or uncooked, can exhibit viscous properties that differ from one another.

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