Roll and Extrusion-Cooking of Grain Sorghum Grits

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DRY-MILLING OF GRAIN sorghum is being carried out in about six plants in the United States. Each of these plants produces a number of milled products, including grits, flour, and feed (1). For many industrial and food applications, it is necessary to alter the properties of sorghum endosperm fractions by cooking them to various degrees of gelatinization. A wide range of products with different water absorptions and solubilities, and with different viscosity properties as shown by Brabender amylograph patterns, can be made by varying cooking conditions. Cooking or gelatinization of sorghum grits can be done rather simply by adding moisture to the grits and then passing the moistened grits through either heated rolls or an extrusion cooker. For many applications, gelatinized sorghum products can be utilized in place of corn, and these products are finding increased usage in the building material, oil well drilling, foundry, and other industries. We have recently studied the gelatinization of corn grits by roll- and extrusion-cooking (2), and have now applied these techniques to the cooking of sorghum grits.

Materials and Equipment

In these studies we used commercial grain-sorghum brewers' grits milled from sorghum grown in the Texas-Oklahoma area. The grits contained 12% moisture, 9.2% protein, 0.34% ash, 0.84% fat, and 0.28% crude fiber.

Screen analysis was as follows:

<table>
<thead>
<tr>
<th>U.S. Standard Sieve Series (mesh)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>+12</td>
<td>0.1</td>
</tr>
<tr>
<td>+14</td>
<td>3.7</td>
</tr>
<tr>
<td>+20</td>
<td>84.1</td>
</tr>
<tr>
<td>+30</td>
<td>10.7</td>
</tr>
<tr>
<td>+40</td>
<td>0.7</td>
</tr>
<tr>
<td>-40</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Roll-cooking was carried out either on a laboratory Buflovak double-drum dryer (Fig. 1) or on a pilot-plant GF double-drum dryer (Fig. 2).

The Buflovak dryer has two chrome-plated rolls, each 6 in. in diameter and 7-5/8 in. long, with a total area of 2 sq. ft. The rolls were heated by steam under pressures up to 100 p.s.i.g. Grits were fed to the rolls by a vibratory feeder.

The GF dryer, manufactured by General Food Package Equipment Corp., Benton Harbor, Michigan, is gas-fired and capable of attaining roll temperatures up to 700°F. The rolls of the dryer are chrome-plated steel, 12 in. in diameter and 18 in. long. The dryer is fitted with automatic ignition and controlled burning. For both dryers, roll clearance was set at 0.001 in. cold, and the roll speed was maintained at 3 r.p.m. Roll temperatures reported here were measured with a surface pyrometer and are average values of surface temperatures taken in the particular area of the rolls used in the tests.

Extrusion cooking was carried out in a Killion K-100 standard plastics extruder having a 1-in. diam. barrel and a 20-in. effective screw length (Fig. 3). The screws with this extruder have an increasing root diameter over the last 10 in. of length, compress the feed. Two screws were used with compression ratios of 3:1 or 1.5:1. The extruder barrel was heated by electrical heaters controlled thermostatically to give temperatures up to 600°F. A separate thermostat and heater combination was applied to each half of the barrel.

Analyses

Each gelatinized product was evaluated by measuring its water-absorption index (grams of gel recovered per gram of dry sample used in test), water-solubility index (percent of dry sample in water layer), and Brabender amylograph viscosity pattern. These analytical determinations have been described in detail previously (2).

Procedures

In the roll-cooking studies, the following variables were investigated: Moisture content of grits over the range of 15 to 30%; steam pressure in the rolls of the Buflovak dryer of
30, 50, and 85 p.s.i.g., corresponding to actual roll-surface temperatures during operation at approximately 255°, 285°, and 300°F., respectively; and roll-surface temperatures on the GF dryer varying from 300° to about 550°F.

In the extrusion-cooking studies, the following variables were investigated: Moisture content of grits over the range 15 to 35%, barrel temperatures between 220° and 450°F., and screw compression ratios 1.5:1 and 3:1.

Moisture content of the grits to be treated was adjusted to the desired value by spraying water on them while mixing and then holding the tempered grits for at least 1 hr. These were then cooked under the conditions selected, dried to about 10% moisture, when necessary, and finely ground (100% -60 mesh) in a Mikro-Samplmill to obtain material for determination of water-absorption index, water-solubility index, and amylograph curves.

Results and Discussion

The results of tests in which sorghum grits were roll-cooked over a range of grit-moisture contents and roll-surface temperatures are given in the next four figures. Figure 4 shows the effects of roll-surface temperature and grit moisture on water-absorption index. Roll-surface temperatures were 300°F. or below on the steam-heated drum dryer and above 300°F. on the gas-fired dryer.

The maximum water-absorption index was slightly less than 7. This maximum was not reached with grits at the 15% moisture level, however. As moisture content of the grits was increased at a fixed roll-surface temperature there was an increase in water-absorption index. In samples of higher moisture content cooked above 425°F., the water-absorption index decreased, probably due to some degradation of the carbohydrate. Also, at temperatures above 500°F., there was browning of the final products, and above 520°F., the products scorched and some carmelization occurred.

The water-solubility index increased progressively with increasing roll-surface temperature at all grit-moisture levels (Fig. 5).

Selected amylograph curves for gelatinized sorghum grits processed at 25% grit moisture, over a roll-surface temperature range of 285° to 520°F., are shown in Fig. 6. Uncooked cold-paste viscosities (29°C.) increased as the temperature of cooking was increased to about 500°F., after which some degradation of product apparently took place, and the cold-paste viscosity decreased drastically from 220 B.U. at 495°F. to 60 B.U. at 520°F. Peak viscosities were of the same magnitude regardless of temperature, except for the 520°F. sample. The peaks occurred progressively sooner, however, as the temperature

Fig. 1. Steam-heated drum dryer used for roll-cooking studies on cereal grains.

Fig. 2. Gas-fired drum dryer.

Fig. 3. Extruder-cooker.
of cooking was increased, again with the 520°F-sample being the exception. The final cooked-paste viscosities (50°C) decreased as the roll-surface temperature was increased.

Similar curves for gelatinized sorghum grits processed at 460°F roll-surface temperature over a grit-moisture range of 15 to 30% are plotted in Fig. 7. Uncooked cold-paste viscosity (29°C) increased with increasing grit moisture. With the exception of the 15% sample, peak viscosities varied within a range of only 50 B.U. and occurred at approximately the same time.

**Fig. 4.** Water-absorption indices for roll-cooked sorghum grits.

**Fig. 5.** Water-solubility indices for roll-cooked sorghum grits.

**Fig. 6.** Amylograph curves for sorghum grits cooked at 25% grit moisture, 285° to 520°F roll-surface temperature.

**Fig. 7.** Amylograph curves for sorghum grits cooked at 15 to 30% grit moisture, 460°F roll-surface temperature.

**Extrusion-Cooking.** In preliminary tests the grain-sorghum brewers' grits used in these cooking tests (88% coarser than No. 20 U.S. Standard sieve) proved to be of suitable size for good feeding to the extruder and for adequate heat treatment during extrusion. A moderate feed rate was employed to give a retention time of about 30 to 45 sec.

Tests were carried out in which the moisture content of the grits was adjusted to levels from 15 to 35%, and the barrel of the extruder was held at various temperatures between 230° and 450°F. Screws having compression ratios of 1.5 and 3.0 were used, without a discharge die. Results of extrusion-cooking tests given in Fig. 8 show water-absorption index and water-solubility index as functions of barrel temperature for sorghum grits containing 15 and 25% moisture. The water-absorption index increased progressively with barrel temperature up to about 370° to 380°F, and then decreased as decomposition or degradation began to take place. The water-solubility index increased progressively with barrel temperature throughout the entire temperature range studied. At a fixed-barrel temperature the water-absorption index was always higher at the 25% moisture level, but the water-solubility index was always higher at the 15% moisture level.

The effect of moisture was demonstrated in studies, carried out at 250°F., in which the screw having 1.5:1 compression ratio was used, and moisture in the grits varied from 15 to 35% (Table I). As moisture of the grits was increased, there was an increase in the water-absorption index and a decrease in the water-solubility index of the cooked products.

Amylograph curves for grits extruded at 25% moisture at temperatures ranging from 230° to 425°F. are shown in Fig. 9. The uncooked cold-paste viscosity (29°C) increased with increasing extrusion temperature to a maximum at about 380°F. and then dropped off rapidly. Final cooked-paste viscosity (50°C.) was highest at the lowest extrusion temperature (230°F.), then dropped progressively as temperature increased to 425°F. Curves 1 and 2 in Fig. 9 represent results obtained at a barrel temperature of 230°F. but with screws having compression ratios of 1.5:1 and 3:1, respectively. Increased shear from the screw with the higher compression ratio (3:1) gave a lower final cooked viscosity (300 B.U. with the 3:1 screw, 400 B.U. with the 1.5:1 screw).

Amylograph curves for grits extruded at 15% moisture at temperatures ranging from 250° to 425°F. are given in Fig. 10. Comparison with curves of Fig. 9 reveals that starch degradation was much greater at the lower moisture level, resulting in lower cold-paste and cooked-paste viscosities at the same extrusion temperature.

**Fig. 8.** Water-absorption index and water-solubility index as functions of barrel temperature for sorghum grits containing 15 and 25% moisture.

**Table I.**

<table>
<thead>
<tr>
<th>Moisture (%)</th>
<th>Water Absorption Index</th>
<th>Water Solubility Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>3.0</td>
<td>45.0</td>
</tr>
<tr>
<td>20</td>
<td>3.5</td>
<td>40.0</td>
</tr>
<tr>
<td>25</td>
<td>4.0</td>
<td>35.0</td>
</tr>
<tr>
<td>30</td>
<td>4.5</td>
<td>30.0</td>
</tr>
<tr>
<td>35</td>
<td>5.0</td>
<td>25.0</td>
</tr>
</tbody>
</table>
TABLE I. EFFECT OF MOISTURE CONTENT ON PRODUCT
CHARACTERISTICS OF EXTRUSION-COOKED SOYGRUM
GRITS (Temperature, 250°F., 1.5:1 Compression Ratio)

<table>
<thead>
<tr>
<th>Moisture Content of Grits, %</th>
<th>Water-Solubility Index, g. Gel/g. Dry Sample</th>
<th>Water-Absorption Index, % of Dry Sample in Water Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>3.2</td>
<td>11.1</td>
</tr>
<tr>
<td>26</td>
<td>4.8</td>
<td>8.1</td>
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<tr>
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<td>7.8</td>
</tr>
<tr>
<td>35</td>
<td>5.8</td>
<td>6.0</td>
</tr>
</tbody>
</table>

Comparison of Roll- with Extrusion-Cooking. A comparison of some properties of roll- vs. extrusion-cooked sorghum meals, when each has been processed to about the same water-absorption index, is shown in Table II. The first three sets of processing conditions yielded materials having water-absorption indices near 4.5. This value is in the range of 4.0 to 5.3 considered suitable for processed corn meal to be used in CSM (2). CSM, a blended food product currently used in the Food for Peace Program, contains partially gelatinized corn meal, soy flour, nonfat dry milk, vitamins, and minerals. The last three sets of processing conditions yielded materials having water-absorption indices near 6.5. In each group, cooked-paste viscosity was higher for the roll-cooked product, but the water-solubility index was higher for the extrusion-cooked product.

Comparison of amylograph curves in Fig. 6 for roll-cooking at 25% moisture with those in Fig. 9 for extrusion-cooking at 25% moisture shows that shapes of curves at the higher temperatures are quite different for the two methods. With roll-cooked products, viscosity obtained during the amylograph cooking cycle increased with temperature to about 80°C., whereas with extrusion-cooked products processed at 350°F. or above, this increase did not take place. Apparently the 30 to 45 sec. time employed for extrusion-cooking, in combination with the increased shear inherent with extrusion, gelatinized and degraded the starch so that viscosity did not increase during the amylograph cooking cycle.

Summary and Conclusions

With both roll- and extrusion-cooking of sorghum grits at a given moisture level, the water-absorption index passed...
Fig. 10. Amylograph curves for sorghum grits extruded at 15% moisture, with barrel temperature ranging from 250°F to 425°F.

through a maximum as cooking temperature increased, dropping off as temperatures sufficient to produce degradation were reached. Water solubility increased progressively with an increase in cooking temperature.

With roll-cooking, the water-absorption index at a given cooking temperature up to 425°F increased with increasing moisture levels; at any cooking temperature the water-solubility index increased with increase in moisture level. With extrusion-cooking, the water-absorption index at a given cooking temperature was higher at high moisture levels, but the water-solubility index was higher at low moisture levels. This phenomenon is believed to be caused by greater shear degradation of starch during extrusion at low moisture levels.

In general, when sorghum grits were gelatinized by either roll- or extrusion-cooking to similar water-absorption levels, the amylograph cooked-paste viscosity was higher with the roll-gelatinized products. It is possible, however, to prepare extruder-gelatinized materials with higher amylograph cold-paste viscosities (29°C) than those of roll-gelatinized materials. Apparently the short heating time involved in roll-cooking is not sufficient to develop the maximum thickening potential, and at high temperatures starch degradation further reduces cold-paste viscosity.

Sorghum grits can be processed by either roll- or extrusion-cooking to materials having water-absorption properties and viscosity characteristics similar to those of processing corn meal satisfactory for use in CSM. Control of processing conditions used in roll- or extrusion-cooking of sorghum grits permits the preparation of products having a wide range of properties.

Acknowledgments

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Literature Cited


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