Detection of Differences in Corn Quality for Extrusion Processes by Rapid Visco Analyser

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Extruded cereal products are the result of the interaction of the extrusion process and the ingredients in the formula. Consequently, the product qualities are significantly affected by extruder operation and the quality and functional aspects of the ingredients. Many extruded snack and cereal products in the United States are predominantly composed of corn. Degermed, dry milled corn is used in the form of various-sized grits and flours (1). Particle size distribution of these ingredients is an important factor in achieving desired product qualities and extmder performance (2,3). However, changes in the quality of the corn meal or flour can result in product that is not acceptable. The scenario is further complicated when suspect corn meal or flour is examined and found to be well within all known specifications. Variations in quality pose a particular challenge to snack food and cereal processors because of the large quantities of corn processed. Differences in corn may result from variations in individual lots as well as from differences between suppliers.

The issue of inconsistent corn performance is complicated. The corn may meet all known specifications, and the varying performance may be random. Research on this problem is difficult for several reasons. First, the problem shows up during extrusion processing, and the processor must determine that the corn is actually causing the problem, not the processing parameters or other ingredients. Second, the problem may be randomly cyclic and not necessarily associated with seasonal or other coinciding factors. Extrusion processors may not have information about the corn source, variety, storage conditions, age, or milling (1,4), which may be factors in the performance of the extruder (3). Third, the expectations of the corn mill (in terms of quality, specifications, and yield) may not necessarily match the extrusion processor's requirements for consistent performance, product quality, and efficient production.

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For the extrusion processor, the issue is down time in production as well as the expense of making unacceptable product. For large extrusion processors, corn meal or flour lots may cycle for as little as a few hours or through a shift or for as long as a full day or days, and then the issue disappears as other lots enter the system. Small processors may see the same transient cycle, and the economies of scale may afflict them with more dire consequences.

The work discussed here was performed in response to this scenario. Two processors identified samples of "good" performing vs "poor" performing corn meal and corn flours. Corn meal samples were obtained from an snack extruder manufacturer and samples of flours from a contract extrusion company producing a corn-based RTE cereal. The corn meal and flour had been purchased by the processors as stock items from two different suppliers, and both met the individual processor's specifications.

Samples of both "good" and "poor" performing corn were identified by extrusion processing. In each case, inferior or unacceptable product (product outside the specifications) resulted from the "poor" corn lot. Samples of "good" performing corn consistently resulted in the desired product quality. Our objective was to attempt to distinguish between the "good" and "poor" performing lots of corn using the Rapid Visco Analyser (RVA).

RVA Analysis

Viscosity was measured using an RVA 4 (Foss North America, Eden Prairie, MN, and Newport Scientific, Pty, Ltd., NSW, Australia). The profile used for the standard analysis was included as part of the Thermocline for Windows program for the RVA 4. For the standard profile, 3.00 g of sample (dry weight basis) plus a total of 25.00 g of water were used. Both the scan profile and the paste profile had a 10-sec initial mix cycle at 960 rpm, then decreased to 160 rpm for the remainder of the profile. For the scan profile, the temperature increased from 58 to 75°C in 12 min. The paste profiles ramped from 25°C to the target temperature of 62 or 65°C (as determined by the scan profile) in 5 min and held for 10 min (total program = 15 rain). The corn meal samples were prepared for RVA analysis by milling through a Cylcotech laboratory mill with a l-mm screen. The corn flour samples were used as received with no milling or sieving.

The differences in performance of the corn meal or flours were observed during relatively low-moisture, high-solids extrusion. Examining either the meal or the flour samples using the standard RVA protile did not allow differentiation of the samples relative to performance. Figure 1 shows the standard RVA profiles for the corn samples used in snack extrusion. The "poor" corn meal shows a tendency toward a lower overall profile (Fig. 1A), but the corn flours are virtually identical by this method (Fig. 1B). A similar result was observed for peak paste profiles for nixtamalized corn flour using the RVA (5). Because peak viscosity differences in the above work were small, the differences in corn flour are not as obvious. These potential differences are expanded upon here.

To obtain resolution, two approaches were combined. First, the corn samples were run by the critical paste method, which involves determining the viscosity while holding the lowest pasting temperature. Samples were therefore scanned by the RVA to determine the critical initial pasting temperature, the lowest temperature at which an increase in viscosity is observed. This was done by focusing on the well-known pasting range (4). Second, because the properties of the corn seemed to be borne out at high-solids, low-moisture extrusion, absorption was thought to be a factor in how the corn experienced the thermal and mechanical inputs of the extrusion process. Therefore, the solids level in the RVA test was increased from 3.00 g to 8.00 g per 25.00 g water to amplify the differences.

Extruded Snack Products

The degermed corn meal samples were obtained from the American Extrusion Corporation, South Beloit, Il. A direct expanded corn collet intended for frying was the product made using this corn meal. Both samples were run on a model 700 F "random" or rotary head extruder (American Extrusion Corp., South Beloit, IL). The meal was adjusted to 15.5-16% moisture and fed at a rate of 470 lb/hr. No differences in torque were noted for "good" or "poor" performing corn meals. The product was fried and evaluated via sensory testing.

The snack food product made with "poor" quality corn meal had defects such as weak or fragile cell walls, which allows excessive oil absorption in frying. The product texture was deemed inferior to that of products made with the "good" corn meal.

Figure 2 shows the profile for the two corn meals run by the critical paste method. The initial paste temperature was shown to be 65-66°C. The profile in Figure 2 was obtained by programming the temperature to ramp up from an initial temperature of 25 to 65°C in 5 min and hold at 65°C (ending at 15 min). The "good" performing corn in the snack extrusion showed a tendency to absorb water and paste more readily than the "poor" corn. The viscosity for the "good" corn was threefold higher than that for the "poor" corn.

The behavior reflected in the paste profile reflects some features related to water absorption that would be crucial to the performance in the extruder. In snack processing, the meal is usually tempered for a short time with a small amount of added water. During extrusion, water uptake is dependent upon the properties of the starch-protein matrix of the corn endosperm. Factors that can affect the endosperm include the variety, growth conditions, and any damage during drying, storage, or milling (4). For example, corn of a vitreous nature tends to absorb water less readily. Also, heat damage may affect the starch-protein matrix, and annealing can change the properties of the corn.

The higher absorbing characteristics of the "good" corn are beneficial, given the short extrusion time (5-6 sec) and high solids during extrusion processing.

Extruded RTE Cereals

The corn flour samples were supplied by Custom Food Processors, Inc. (Blue Earth, MN). Corn flour was used to make a direct-expanded RTE corn product in a twin screw extruder (APV, MPF-100, L/D = 25) with a 300 hp drive using a moderate shear profile. Total feed moisture was 20% at a feed rate of 2,000 lb/hr. No torque differences were noted between the "good" and "poor" corn flour. Die pressure was -500 psi, and die temperature was 300-310°F.

The RTE cereal product using the "poor" quality corn flour resulted in excessive puff with large cell size. The product density decreased beyond the specifications for acceptable product. "Poor" corn caused an increase in temperature at mid-barrel. The operator response was to correct for both the product and the temperature issues. Regardless, acceptable product could not be made from this corn lot.

The flour was scanned by the RVA to determine its critical pasting temperature. In this case, the profile temperature was determined to be 62°C. The pasting temperature was probably influenced by the much smaller particle size (>80% through a U.S. 100-mesh sieve) commonly used in twin-screw extrusion processes. The "good" performing flour samples had lower pasting profiles, while the "poor" performing corn flour showed a 30% higher viscosity compared to the "good" flour (Fig. 3). The tendency to absorb water reflected in the RVA profile by the higher-pasting "poor" performing corn flour would allow a more advanced transformation during extrusion. In the twin-screw extruder, the residence time is measured in minutes, and this may allow the transformation of higher-pasting material to be too extensive. This theory was confirmed by production of acceptable product upon decreasing the shear profile. This is the reverse of the snack process, in which both mixing and time for absorption must occur in a matter of 5-6 sec. The corn qualities affect the extrusion process in different ways, depending upon the type of extmsion process and the absorption characteristics of the corn.

Strategies for Improving Products

The differences observed for the corn samples are not unique--virtually all corn millers encounter this issue. The issue becomes even greater worldwide because of the differences encountered as one moves away from the U.S. varieties of yellow dent corn. The ability to identify differences in the corn can help both the processor and the supplier meet their respective customers' needs. As demonstrated by the different absorption characteristics of the snack and RTE corn material shown by RVA analysis, the type of cooking process is fundamental to determining what corn is preferred. While the ability to screen the corn is useful, being able to adjust the process is more desirable. Depending upon the process, several approaches to formulation and process may be employed to obtain acceptable product.

The snack producer screened several processing aids and found one with emulsifying ability and soluble fiber components (Ribus, Inc., St. Louis, MO) that resulted in improved extruder performance, as well as consistent product quality and characteristics. The mechanism for this process aid appears to rest with its polar lipids and xylan content (6). Adding the processing aid to the corn meal resulted in a lower RVA profile. This is consistent with emulsifier effects on starch (7,8) but not necessarily predictive of the response in the extruder. The potential for the more polar lipids to function in a hydrophilic fashion may be responsible for the type of emulsifying effect. This can be contrasted to the effects of mono- and diglycerides for starch complexing and inhibition of gran-

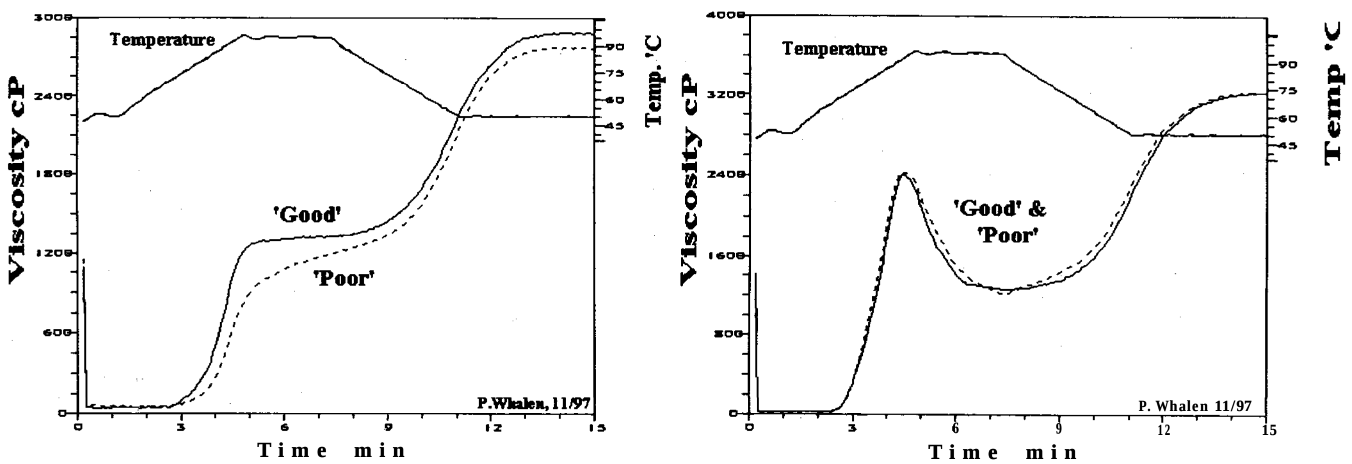

Fig. 1. Standard RVA profiles for "good" vs. 'poor" corn samples. A, corn meal used in snack extrusion; B, corn flours used in ready-to-eat cereal extrusion.

ule swelling, in which the extruded product is more severely affected, with increased density and smaller cell size.

Conclusions

In both the RTE and snack production systems, acceptable product could not be obtained by correction at the extruder. In the instance of the snack, the addition of a processing aid alleviated the condition. In the case of the RTE cereal, only changing the screw profile to a lower shear resulted in achieving product requirements. In either case, both the supplier and the extrusion processor could benefit from identification of the performance capabilities of the corn.

Differences in corn quality for extruded snacks and cereals are affected by the corn's inherent physical and chemical qualities. These appear to be related to the manner in which water is absorbed as a function of a critical pasting tempemture. The RVA can be used to screen for and reflect these factors as well as particle size effects for corn used in extrusion Processing aids may help the producer after the issue is identified. More work on the chemistry and interaction of potential processing aids in extrusion and corn processing is needed. However, identifying the cause of the response is in the interest of both the supplier and the user. The mechanism reflected here may apply to other aspects of corn processing such as extraction rates in corn wet milling, as it seems probable that absorption is a fundamental issue there as well. These issues may be addressed using the RVA with other techniques to examine corn dry milling factors such as corn varieties, storage, and crop year.

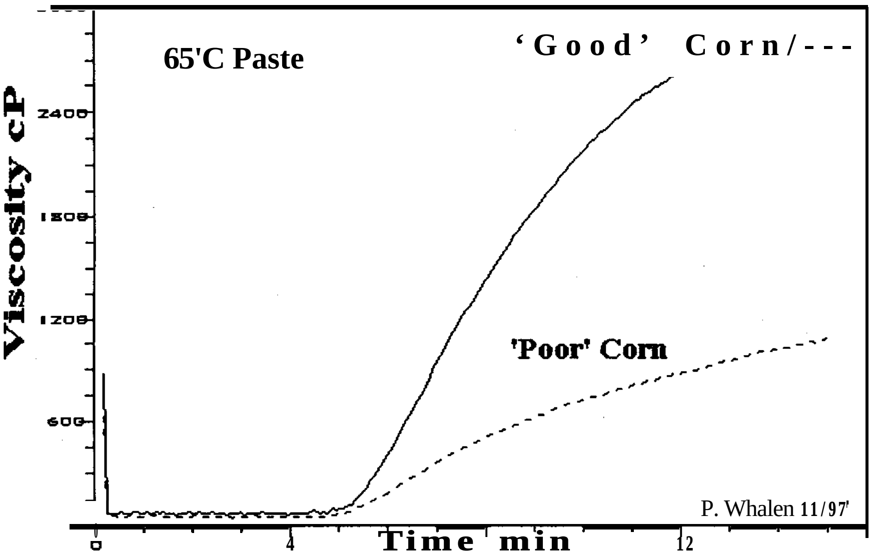

Fig. 2. Paste **profiles at critical temperature (65%) for "good" vs. 'poor" corn meal.**

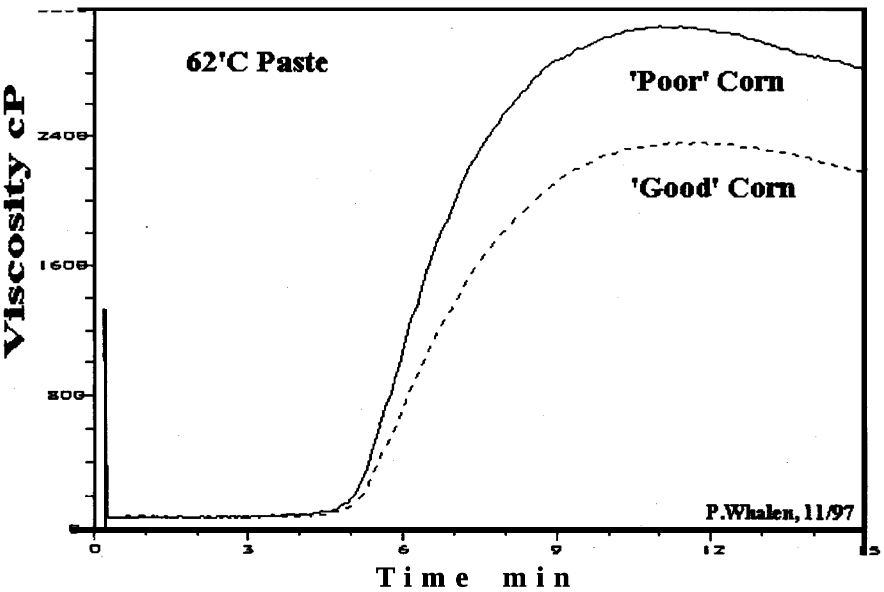

Fig. 3. Paste **profiles at critical temperature (62°C) for 'good" vs. "poor" corn flours.**

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