RHEOLOGY OF DURUM WHEAT PRODUCTS[1]

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ABSTRACT

The use of a farinograph for assessing the rheological properties of pasta doughs has proven useful for quality evaluation of durum semolinas. Characteristics measured are the dough development time, maximum consistency, and tolerance index but little attention has been given to the band width and "wildness" or irregular mixing patterns of some durum varieties. Farinograms have been analyzed taking into account the mixing action of the farinograph blades and the flow characteristics of doughs of varying quality. Rheology of extrusion is examined in terms of farinograms. Differences in mixing curves are related to spaghetti and gluten quality.

A technique for using the farinograph in the characterization of durum semolinas was introduced by Irvine *et al.* (1) in 1961. With this procedure dough development time, maximum consistency, and tolerance index can be measured at absorption levels corresponding to those used in commercial processing. The influence of various factors such as variety, environment, particle size, temperature, and salt were discussed in the original publication.

In our plant breeding program for durum wheats, one of the important tests for assessing gluten quality has been and still is, the farinograph. All varieties under test must exhibit farinograph characteristics indicative of strong gluten because strong gluten is related to good cooking quality (2).

Generally, the mixing characteristics of durum semolinas at low absorption can be classed into three types as shown in Fig. 1. Curve A is typical of varieties with weak extensible gluten; dough development time is short and tolerance index is high. Curve B with longer dough development time, lower tolerance

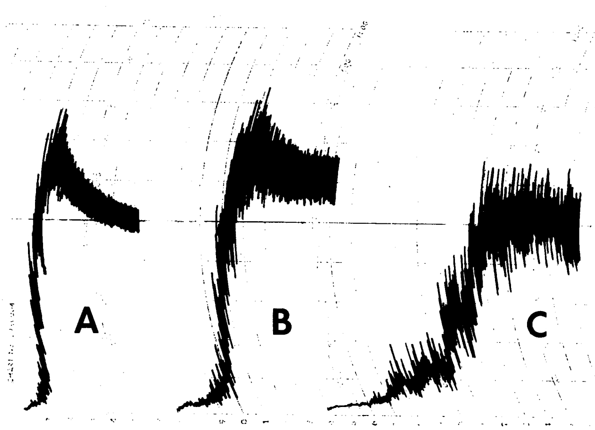

Fig. 1. Farinograms of durum semolina at 31.5% absorption. **A)** weak gluten variety, **B)** medium strength gluten variety, **C)** strong gluten variety.

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index, and wider band width is typical of medium strength gluten. Varieties with very strong inextensible gluten exhibit long dough development time, very low tolerance index, and wildness as in curve C.

Doughs with properties that produce farinograms such as curve A are generally quite sticky and adhere to the bowl and to the mixing blades. The slack and flowy nature of the dough gives rise to a smooth curve and narrow band width. On the other hand, doughs that produce farinograms as curve C are not sticky and very easy to remove from the mixer. Wildness is related to this factor of stickiness.

The shape of the farinogram can be analyzed in terms of the behavior of dough in the mixing bowl. In the course of mixing, maximum shear is imparted when the shearing edges of the blades coincide, *i.e.*, on every second rotation of the slower moving blade and every third rotation of the other. This is illustrated in Fig. 2 where the chart speed was increased to four times the normal speed to 4 cm/min. Curve A is a weak gluten variety and when expanded one can clearly see a comb-like pattern on the curve. Each line above the median curve represents maximum shear, *i.e.*, when the shearing edges of the blade coincide. Since the mixing speed used was 59 rpm one can count 30 lines per 4 cm. This type of dough forms essentially a continuous phase in the bowl so that there is always some dough being sheared to maintain uniform consistency.

Curve B in Fig. 2 is an expanded farinogram of a strong gluten variety. As mentioned, this type of dough is not sticky and tends to form lumps of dough rather than a smooth homogeneous phase. Thus as the blades rotate dough is not sheared at all times; at such instances the consistency drops. When dough is

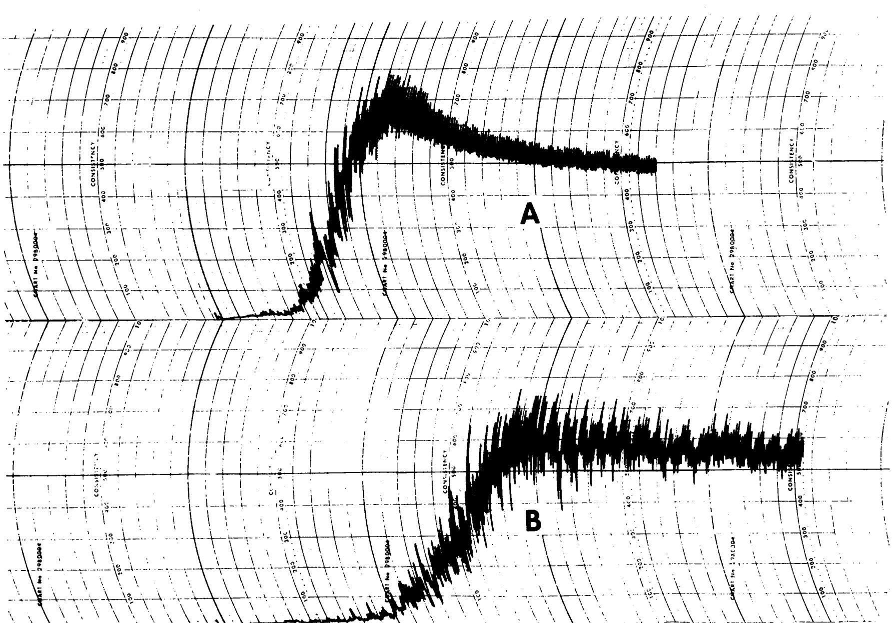

Fig. 2. Farinograms of weak gluten variety **A**), and strong gluten variety **B**), run at chart speed of 4 cm/min.

sheared, the consistency increases. This irregular action gives rise to wildness and the curve lacks the comb-like pattern of curve A.

The behavior of semolina doughs in the farinograph cannot really be considered analogous to the behavior of dough in a continuous extrusion press. The major difference is that in the extrusion worm, dough development takes place in a confined space, whereas, in the farinograph dough is not restricted to a fixed volume. In order to study the behavior of dough in a confined space, a plunger was machined out of aluminum to fit the farinograph bowl as illustrated in Fig. 3. It was found that approximately 100 g of dough was required to fill the space around the blades. To simulate the conditions in a continuous extrusion press 75 g of semolina and 23.6 ml of water (31.5% absorption, 14% moisture basis) were mixed until little lumps were formed. The mixer was stopped and the plunger clamped into position. This would be analogous to the lumps of semolina-water mixture passing from the mixing unit into the extrusion worm. When mixing is resumed, dough is formed immediately as indicated by the curve reaching maximum consistency. The consistency is very high so that 3.6 kg of weight had to be placed on the lever arm to attenuate the curve. With the 5:1 ratio setting on the lever system, this weight corresponds to lowering the curve by 720 Brabender Units. Figure 4 shows four sets of curves; curves on the left are normal farinograms and those on the right are mixed with the plunger.

The behavior of the dough, regardless of the type of durum semolina, is similar when mixed with a plunger. Maximum consistency is reached immediately and the consistency drops very quickly. Differences can be seen in the band width and the height of the curve. Strong gluten type, like curve D, on the basis of band width and consistency appears to be much more tolerant to severe mixing than weak gluten type like curve A. The very narrow band width and rapid drop in consistency of curve A indicate severe breakdown of the dough structure. Such instability may well be a factor that affects the cooking quality. Another factor associated with instability is the stickiness and softness of the dough which may lead to a well known processing problem, uneven extrusion pattern. Stickiness could give rise to a more pronounced laminar flow in the walls of the conduits leading from the extrusion worm to the die. For short goods this presents no

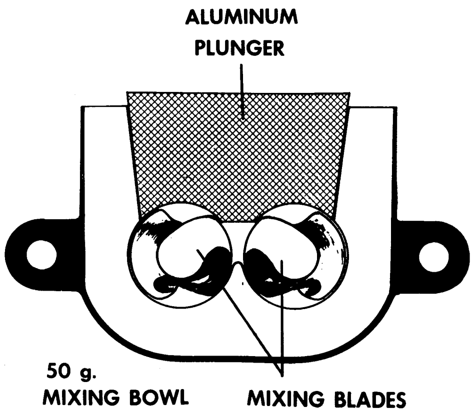

Fig. 3. Diagram of plunger constructed for the 50-g farinograph bowl.

problem, but for long goods an extrusion pattern much like a sine wave results. Stronger gluten varieties may give a more even extrusion pattern and thereby reduce the amount of trim after extrusion.

Another factor that has been investigated and reported to be important is the role of SH:SS system. Fabriani (3) stated that the ratio of reactive SH to total SH is related to cooking quality; the higher this ratio, the better is the cooking quality. The SH:SS interchange reaction would then play a role during mixing and Fig. 4 may be interpreted on this basis. Varieties with strong gluten have more reactive SH groups and, therefore, a greater probability of an interchange reaction. This reaction may then be responsible for higher consistency and wider band width in curves C and D.

Assessment of rheological properties of semolina doughs gives a good indication of the quality of spaghetti that might be expected from the semolina. However, it does not necessarily follow that the cooking quality of the spaghetti will be good because of desirable rheological properties. The ultimate test of cooking quality is still the judgment of the consumers. Instrumental measurements of textural properties of cooked spaghetti are very useful but it is not possible to measure characteristics such as starchiness, stickiness, or flavor.

One of the most important measurable characteristics in cooked spaghetti is firmness. This can be objectively determined on a number of instruments—the Instron Universal Testing machine, the Brabender Texturometer, or laboratory designed apparatus like our spaghetti tenderness tester (4)—where the rate of shear is measured. With our apparatus the rate of shear is represented by a parameter, *tenderness index,* which is related to gluten strength (2), to sensory

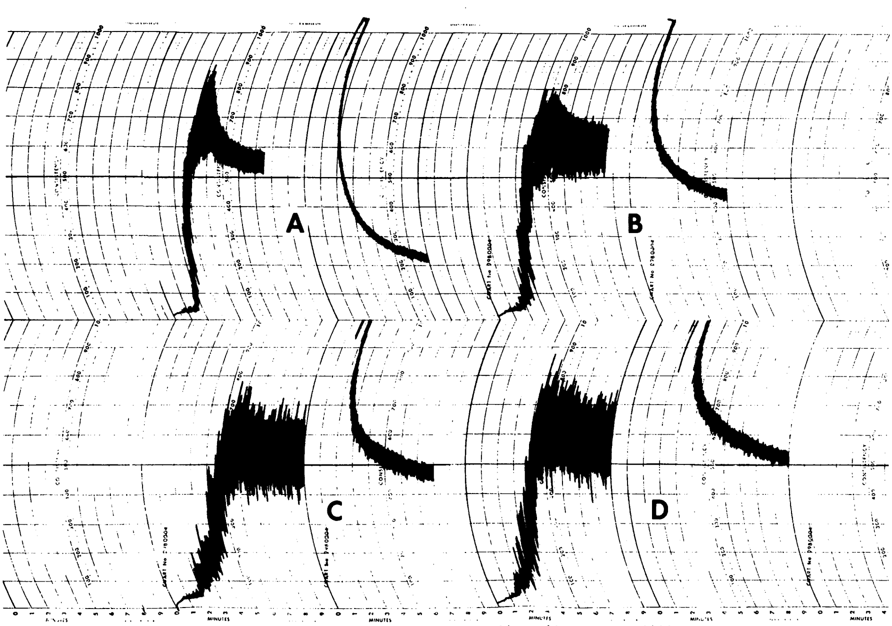

Fig. 4. Farinograms of weak gluten **A**), medium-strength gtuten **B**), strong gluten **C**) and **D**) durum varieties. Left, normal curve; right, with plunger.

evaluation of firmness, and to shear stress as determined on the Instron (5). Two other parameters (6) for describing texture are *compressibility,* which is related to chewiness and *recovery,* which is a measure of the elastic component. Both of these parameters are related to the shear force measured on the Instron and to sensory evaluation of firmness and chewiness (5). On the basis of numerous tests, good quality in cooked spaghetti should have low tenderness index (0.035 to 0.040 mm/sec), low compressibility (60 to 70%) and high recovery (45 to 60%).

Good cooking quality in spaghetti is related to gluten quality but this is only one factor. The role of starch in spaghetti quality has so far received very little attention. The influence of starch on the rheological properties during processing, during drying, and during cooking requires study. The role, if any, of minor constituents like soluble and insoluble pentosans, lipids, and mineral matter on the rheological properties is unknown. Much more research is necessary in this area; hopefully, in the not too distant future we will be able to answer the question: What constitutes quality and how can it be best measured?

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