Effect of Gluten on the Cooking Quality of Spaghetti[1]

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ABSTRACT

The effect of different types of gluten on spaghetti cooking quality was studied. Gluten characteristics were measured using the farinograph, alveograph, and the Kosmina gluten stretching test. Cooking quality was assessed by measuring spaghetti tenderness with an apparatus designed in our laboratory. Gluten of medium strength as assessed by the physical tests appears to produce spaghetti of optimum cooking quality. Reconstitution studies indicate that gluten quality is the major factor determining cooking quality.

The importance of cooking quality of macaroni products as a major factor in the assessment of wheat and/or semolina quality has been long recognized in some parts of Europe. It has only been within recent years, however, that sufficiently sensitive objective measurements have been possible on cooked spaghetti to permit investigation of the chemical and physical parameters of wheat and semolina which are principally involved in determining cooking quality. In the past, cooking tests have been made and such factors as cooking water residue and degree of swelling (water uptake) have been measured; these measures, however, have never been found to be clearly related to the quality of cooked spaghetti as judged organoleptically.

Holliger (1) investigated the influence of the amount of gluten on the cooking quality of spaghetti with the Buhler bending stress tester. He isolated gluten from a grade of Canadian HRS wheat and added increments of this to starch or to soft wheat flour to give a protein range from 5 to 26%. Increasing the amount of gluten in spaghetti decreases the amount of residue in the cooking water and increases the force required to produce a given extension in cooked spaghetti as measured on the bending stress tester. In these tests, however, different gluten types were not investigated.

Matweef (2), using a balance which was adapted to measure the strength of both dry and cooked macaroni, investigated a similar problem, that of the influence of gluten on cooking quality. He studied two U.S. durum varieties and one French durum variety grown in two locations in France. At one location the protein content was 16.0%; at the other it was 11.0%. Higher protein content was reported to produce better cooking quality.

Sheu et al. (3) studied the effect of interchanging various components of HRS and durum wheats on macaroni quality. Differences in cooking quality in terms of cooked weight, residue, and firmness were attributed primarily to the gluten fraction. Macaroni color was affected by gluten and water-soluble fractions.

Recently we have described an apparatus that measures the tenderness of cooked spaghetti (4). With organoleptic tests it is not feasible to assign a numerical index for tenderness, but with this apparatus such designation is possible. Spaghetti samples processed in Switzerland and in Italy and considered *al dente* were tested to determine the range of tenderness indices associated with good cooking quality.

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On this basis a tenderness index in the range from 35 to 45 was taken to represent good cooked spaghetti. For a large number of samples tested, it has been found that samples with firm, good bite have low tenderness index values and soft ones, higher values (4).

Since gluten largely determines the rheological properties of dough, a study was undertaken to assess the effect of different types of gluten on spaghetti cooking quality. The criterion of cooking quality used in this work is the tenderness of the cooked product. Color of the product either before or after cooking was not considered.

The differences in gluten types are defined here as those differences in rheological properties that are characterized by the farinograph curves (5).

MATERIALS AND METHODS

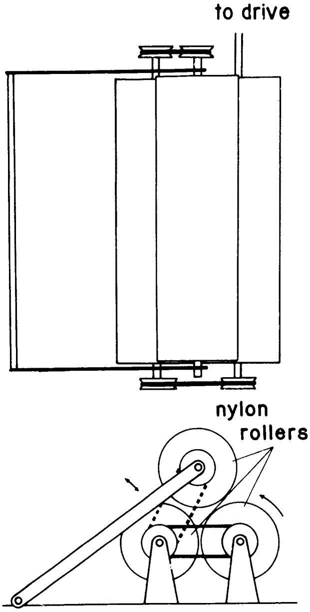
Spaghetti samples were processed by a slightly modified micro macaroni method (6) from semolina or flour milled from several types of vulgare wheats and a number of durum wheat varieties. Doughs were mixed for 1.5 min., the last 30 sec. under vacuum. A four-strand, 1/16-in. Teflon spaghetti die was used for extrusion. Processing absorption varied from 31.5 to 35% so that the samples were extruded with a pressure of about 600 lb. per sq.in.

For the cooking test, a ratio of 1 g. of spaghetti to 10 g. boiling water is used. During cooking a strand is removed at intervals from the cooking water and cut with a sharp edge or squeezed between two glass plates. The cooking time is taken as the time required for the white core in the strand to disappear; this time varies from 12 to 15 min. Tenderness indices were calculated as described previously (4).

The method originally described by Kosmina (7) for studying the stretching characteristics of gluten was modified for better reproducibility in weaker durum glutens. The test is carried out on a cylindrical-shaped test piece formed by a moulder and held by a specially designed holder. The moulder, similar in design to that for test baking described by Kilborn and Irvine (8), was constructed as shown schematically in Fig. 1. The rolls are made from a piece of nylon rod 1 3/8 in. in diameter and 4 in. long and driven by a 1,600-r.p.m. motor with a 30:1 reduction gear. The rolls are set to mould a test piece about 3/8 in. in diameter. Figure 2 shows the design of the dough holder. B and C are split rings in which the test piece is placed. When assembled, the four pieces are rigidly held by a spring clamp. D is a cap to hold split ring C together during the test and to prevent the test piece from slipping out by pinching a small piece of gluten between it and C. A is a bar to hold B together and to suspend the unit on top of a glass cylinder. The total weight of C and D is 12.5 g.

Gluten was washed out on a Theby gluten washer using a salt-phosphate buffer, pH 6.7. The resulting gluten was worked between the fingers until it became sticky and 6.0 g. was weighed out. The test piece was allowed a rest period of 25 min. in water before it was shaped on the moulder. After it had rested in the holder for 20 min., an extensibility test was carried out with readings taken every minute.

The Chopin Alveograph was adapted to study the sheeting characteristics of gluten. Freshly washed gluten from 20 g. semolina or flour was formed into a ball and flattened between two plates separated by 1/8-in. spacers. A disc of gluten of uniform thickness was thus prepared. For most of the samples the rest period was 1 hr.; for the two spring wheats the rest period had to be increased to 2 hr. The



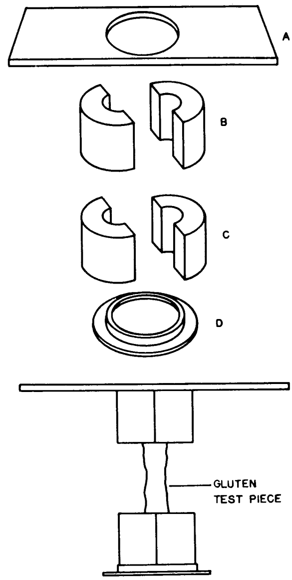


Fig. 1 (left). Design of gluten moulder.

Fig. 2 (right). Gluten test-piece holder.

gluten disc was coated with mineral oil to prevent drying and to decrease stickiness. The aperture through which the bubble is blown was decreased to 1 in. The height of the curve was calibrated with a water manometer in terms of dynes per sq.cm.

Farinograms were obtained by the method described by Irvine et al. (5). The absorption for all samples was 31.5%.

For reconstitution studies, semolinas from two varieties of durum wheat, Stewart 63 and Pelissier, were separated into four fractions: starch, gluten, water-solubles, and insoluble pentosan-rich fraction (9). Gluten was hand-washed in tap water. All fractions were freeze-dried. Spaghettis were made from various combinations of the fractions and tested for tenderness.

RESULTS AND DISCUSSION

Figure 3 shows the farinograms of the wheats investigated. As reported by Irvine et al. (5), protein content has a marked effect on the maximum consistency, dough development time, and tolerance index. Some of the differences here can be attributed to protein content, particularly for the soft wheats, which had about 8% protein. The differences in dough development time and tolerance index noted in the others are attributed to type of gluten.

Figure 4 shows the alveograms of glutens from the same wheats. Since glutens from HRS wheats were tougher than those from other wheats, a bubble could not be blown after a 1-hr. rest period but it was possible after a 2-hr. rest period. The curves are not shown since they would not be comparable. North American durum glutens produced smaller bubbles, as shown by a smaller area under the curve.

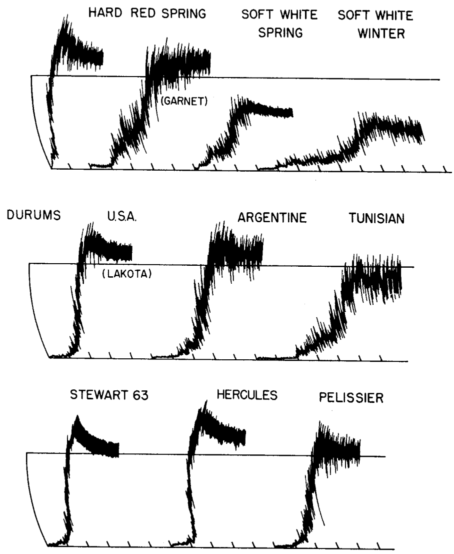
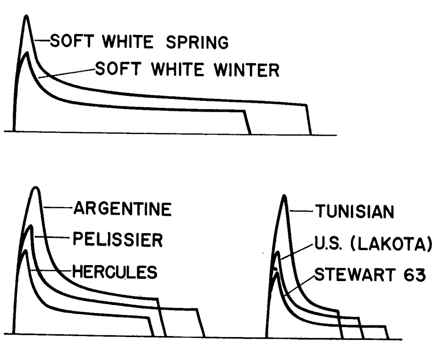


Fig. 3. Farinograms of different wheat varieties at 31.5% absorption.

Reproducibility of the alveograms for maximum height was fairly good; the average of triplicate runs is reported.

The stretching curves for six of the glutens are presented in Fig. 5. The curve for HRS gluten was superposable on that of Garnet. Argentine gluten gave a curve slightly higher than that of Garnet, while the curve for Tunisian was similar to that of Pelissier. Lakota yielded a curve very similar to that of Hercules. Reproducibility of the curves was excellent for the strong glutens, but for the weaker ones the scatter was ±0.5 cm. All tests were done in triplicate.

Table I and Fig. 6 summarize these results along with the results of the tenderness test. The tenderness indices are multiplied by a factor of 1,000 and the units are mm. per sec. Each of the physical tests has been characterized by a



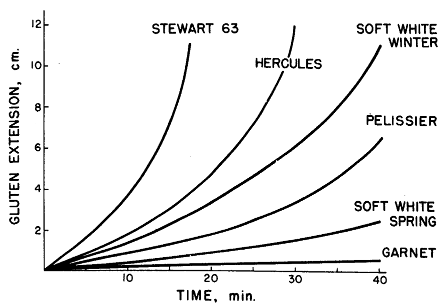


Fig. 4 (left). Alveograms of wheat gluten.

Fig. 5 (right). Gluten extensibility curves.

TABLE I. SUMMARY OF FARINOGRAPH, ALVEOGRAPH, GLUTEN EXTENSIBILITY, AND COOKING TESTS

Sample	Tenderness Index mm./sec. X 10^3	Farinograph Dough Development Time min.	Gluten Stretching Test Slope at 10 min.	Alveograph Maximum Pressure dynes/cm.^{2}	Protein Content %
Vulgare wheats					
Hard red spring	53	2.75	0.1	[a]	13.0
Soft white spring	49	6.00	0.6	6.9 X 10^3	8.4
Soft white winter	56	12.00	1.5	4.7	8.4
Garnet	45	9.50	0.1	[a]	11.0
Durum wheats					
Lakota	43	6.00	2.1	5.1	11.8
Argentine	35	8.00	0.3	8.6	12.7
Tunisian	36	11.25	1.4	8.3	10.6
Stewart 63	55	4.50	5.1	3.9	12.0
Hercules	45	4.50	2.1	5.9	12.6
Pelissier	41	8.00	0.7	6.4	11.6

[a]Not measurable after 1-hr. rest period.

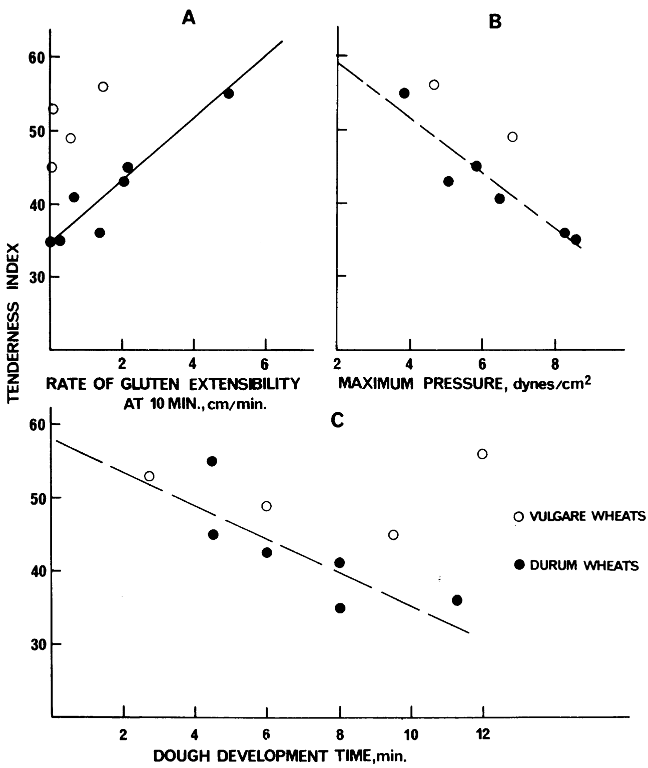


Fig. 6. Correlation coefficients of tenderness index and gluten characteristics.

TABLE II. CORRELATION COEFFICIENTS OF TENDERNESS INDEX AND GLUTEN CHARACTERISTICS

	All Samples n = 10	Durum Wheat Only n = 6
Tenderness index vs. gluten extensibility	0.37 n.s.	0.93**
Tenderness index vs. alveograph maximum pressure	−0.84**	−0.94**
Tenderness index vs. farinograph dough development time	−0.30 n.s.	−0.79 n.s.

single parameter. For the gluten stretching test the slope of the curve at 10 min. was chosen; the slope, in units of cm. per min., gives a measure of the rate of extension at a fixed time and therefore is a measure of the flow characteristics. For the alveograph test, the maximum height of the curve measured in terms of dynes per sq.cm. was taken as an indication of the strength of sheeted gluten. For the farinograph test, the dough development time, i.e., the time required to reach maximum consistency, is taken to represent the mixing characteristics.

Protein content of the flour or semolina is given to show that protein quantity is not necessarily related to firmness in cooked spaghetti.

Data in Table I are presented graphically in Fig. 6 when tenderness index is plotted against gluten extensibility (A), alveograph maximum pressure (B), and farinograph dough development time (C). It is interesting to note that for durum wheat there appears to be a relation between firmness of cooked spaghetti and gluten strength, whereas for vulgare wheat there appears to be none. This is indicated in Table II where correlation coefficients have been calculated for all samples (n = 10) and those for durum wheat only (n = 6). The regression lines are those for durum wheat only.

The high correlation coefficient ($r = -0.84$) for tenderness index and alveograph pressure is due to the omission of two HRS samples. If the maximum pressure were measurable, the points on Fig. 6, B, would fall at higher pressure and therefore lower the correlation coefficient to the point where it would probably not be significant.

As mentioned earlier, a tenderness index in the range from 35 to 45, which includes six of the ten samples tested, would be considered *al dente*. Of the varieties tested, Stewart 63 gluten is the weakest in terms of extensibility, sheeting, and mixing characteristics, and has the highest tenderness index.

It is generally accepted in Europe that Argentine and Tunisian durums have the best cooking quality of the wheats available to this market. These two types show the lowest tenderness index, and of the durum wheats tested they are among the strongest in terms of extensibility, sheeting, and mixing characteristics.

This relationship of softer cooked product and weak gluten has been found in our studies of a wide range of durum varieties grown by plant breeders. Conversely, stronger gluten has been generally associated with firmer cooked product. The type of gluten, therefore, is an important factor in determining tenderness in cooked spaghetti.

Table III shows the effect on the tenderness of spaghetti made from reconstituted Stewart 63 and Pelissier semolina and with various components interchanged. As interchanging starch, water-soluble fraction, and the insoluble

TABLE III. TENDERNESS INDEX OF RECONSTITUTED SAMPLES

Sample	Tenderness Index mm./sec. X 10^3
Reconstituted Stewart 63	55
Reconstituted Pelissier	39
Stewart 63 with Pelissier gluten	41
Pelissier with Stewart 63 gluten	54

pentosan-rich fraction had very little effect on the tenderness, indices are not included in the table. However, there is a marked effect on the tenderness when the gluten is interchanged. Pelissier with Stewart 63 gluten becomes quite soft whereas Stewart 63 with Pelissier gluten is quite firm. Freeze-drying appears to have a slight effect, as indicated by a slightly lower tenderness value for the reconstituted sample as compared with the original semolinas in Table I. There seems little doubt that gluten is the component which primarily affects the tenderness of cooked spaghetti.

The rate and extent of dough development in processing during mixing, kneading, and extrusion are dependent on the dough development time and dough stability (tolerance index). These parameters are readily measurable on the farinograph and are characteristic of a variety. The farinograph curves in Fig. 2 were run at a constant absorption of 31.5% to compare the mixing characteristics. The processing absorption, however, was varied for optimum extrusion pressure and good handling properties of dough. As absorption affects dough development time (4) and, to some extent, the tolerance index, the mixing curve for HRS wheat, in particular, is affected at the higher processing absorption. Although HRS wheat gluten is the strongest of samples tested, in terms of extensibility and sheeting, the dough development time was the shortest and the tolerance index was the poorest at this low macaroni dough absorption. These characteristics could conceivably result in overdevelopment of the dough during processing, with accompanying gluten breakdown. The extent of breakdown then could affect the cooking quality. Although the glutens of Stewart 63 and HRS are entirely different, the mixing characteristics are similar both in terms of dough development time and tolerance index, and in tenderness of cooked spaghetti. On the other hand, the mixing characteristics of Pelissier or Argentine are stronger (longer dough development time, lower tolerance index). Thus, under normal processing conditions, it is possible that for doughs from stronger gluten types, the work input for dough development is optimal with little gluten breakdown, so that spaghetti of good cooking quality is produced.

The structure of dough can be envisaged as starch and other minor components enveloped by a three-dimensional network of gluten. The sheeting characteristics and the strength of the membrane would then play a significant role in the rheology of the system and would surely influence the behavior during processing, the rigidity of the strands during and after drying, and the properties upon cooking. A gluten of fairly strong characteristics, such as gluten in Pelissier or Argentine durum, gave lower tenderness values which were considered more desirable as far as tenderness in the cooked product was concerned.

Although color is considered as an important quality factor, only the tenderness in the cooked product as affected by different gluten types was studied. Holliger

(1) found that the amount of protein affected the quality as measured on his stress binding tester. For the samples studied here, the kind of gluten has a more pronounced effect than the amount of gluten. Undoubtedly there are a number of factors which play some role in cooking quality, but the most important constituent is gluten and the quality of the gluten is at least as important as the quantity.

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