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Some Rheological Properties of Crude Gluten Mixed in the Farinograph[1]

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ABSTRACT

Farinograph mixing curves for gluten were successfully obtained with the use of the small bowl but with the sensitivity linkage set as for the large bowl. The curve for minimum mobility of gluten *vs.* water content showed that water plays a greater role in determining gluten mobility in the range of higher water content. Addition of salt increases the mobility of gluten. Glutens from a lower grade of HRS wheat and from winter wheat were slightly weaker, and glutens from durum were considerably weaker than glutens from top grades of HRS wheat. Addition of urea (a hydrogen bond-dissociating reagent) decreased the consistency of gluten and made it sticky. This effect was counteracted by addition of $MgSO_4$. Acetamide and guanidine hydrochloride had an effect similar to that of urea. Addition of acetone (a hydrophobic bond-dissociating reagent) produced a phenomenological effect similar to that of urea, also counteracted by $MgSO_4$. Butanone-2, dimethylformamide, and dioxane produced similar effects, butanone-2 being most effective on an equimolar basis. Other factors examined for effect on the mixing behavior of gluten included iodate, NEMI, pH, and heat. Heat-treated glutens and glutens washed from urea- and acetone-treated doughs were examined by the gluten-stretching test of Kaminski and Halton.

Ordinary flour-water dough consists of three distinct phases—a gas phase of occluded air cells, a solid phase of starch granules and endosperm fragments, and a viscoelastic phase essentially of hydrated proteins. This last phase may be regarded as a matrix in which the gaseous and solid phases are contained. One feature of such a system is the rather large surface area of the interface between the viscoelastic phase on the one hand, and the gas cells and the particulate solid phase on the other. This large interface would, however, not be expected to be a feature of crude gluten, which consists of one phase only. Obviously, it should be of interest not only to study the mixing properties of flour proteins as part of the complex dough system, but also to examine the mixing behavior of flour proteins more directly.

A technique for studying the mixing properties of crude gluten with the farinograph has been described recently (1). This report presents a study, based on that technique, of some rheological properties of crude gluten when mixed in the farinograph. The effect of water content, salt, urea, acetone, and other reagents or factors has been examined and the results are summarized.

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MATERIALS

Six samples of crude gluten were used in this study. Four of them, designated as HRS-1 to 4, were from hard red spring wheat, one (AW) was from winter wheat, and one was from durum wheat. Specific details are summarized in Table I.

TABLE I
DATA ON GLUTEN PREPARATIONS

GLUTEN SAMPLE	SOURCE	ANALYTICAL DATA		
		Moisture	Protein (Dry Basis)	Ash (Dry Basis)
		%	%	%
HRS-1[a]	Commercially-milled, straight-grade flour from Canadian hard red spring wheat	11.1 11.2	85.3 84.0	0.28 0.32
HRS-2	Laboratory-milled flour from No. 2 Manitoba Northern wheat	11.6	86.7	0.30
HRS-3	Laboratory-milled flour from No. 4 Manitoba Northern wheat	13.0	84.8	0.25
HRS-4	Commercial gluten, Ogilvie Flour Mills Co.	6.3	80.0	0.74
AW	Laboratory-milled flour from No. 2 Alberta Winter wheat	13.1	81.1	0.32
Durum	Laboratory-milled flour from 2 C.W. amber durum wheat	12.2	85.1	0.90

[a]Two samples.

METHODS

Preparation of Dried Gluten

Three hundred grams of flour, and 240 ml. of 0.001*M* sodium chloride solution for the HRS and AW flours and 300 ml. for the durum flour, were mixed in the GRL mixer for 5 min. in air, at 30°C., to make a batter. The batter was rested for 5 min., then 600 ml. of the salt solution was poured into it. Mixing was continued for 5 min., the bowl was scraped down by hand, and the mixing carried on 5 min. longer. At this time a glutenlike mass was consolidated in the slurry. This was taken off from the bowl, and washing by hand was continued under a slow stream of the 0.001*M* salt solution for about 20 min. until the gluten started to be weak and "porous" and the appearance of foam was noticed in the washing solution.

The washed gluten was relaxed in dilute salt solution and dried by evacuation in a freeze-dryer overnight; the sample was not frozen first. The mass of puffed-up, dried gluten, which was very friable, was ground to pass through a 72 GG standard grits-gauze bolting cloth and humidified to 11 to 14% before use.

Maximum-Swelled Gluten

When gluten is placed in water it swells until it reaches an equilibrium, or maximum swelling volume. To extend the experiments to a higher range of water content, maximum-swelled gluten was used. To prepare such gluten, dough was mixed in the GRL mixer; 0.001*M* sodium chloride solution equivalent to 60% absorption was used. This dough was rested for 1 hr. and gluten was washed by hand from the dough under a slow stream of the same solution. The gluten thus obtained was rested in the solution for

30 min. After relaxation, excess water was expressed from the gluten by hand, and the required amount was then scaled off and used directly in experiments. The mean moisture content (dry gluten basis) of 10 replicates of maximum-swelled HRS-1 gluten was 218% and ranged from 205 to 225%; for durum gluten it was 206% and ranged from 202 to 211%.

Farinograph Mixing Curves for Gluten

The bulk of the data used in the present study was derived from mixing curves obtained with the farinograph in which the small bowl was used but with the sensitivity linkage set in the position normally used with the large bowl (1:5 ratio). This procedure is used routinely with macaroni doughs (2) and was used in a preliminary study with one sample of commercial gluten (1).

A constant wet gluten weight method (80 g.) was adopted. When larger amounts were used, portions of the wet gluten remained on top of the gluten mass without participating in the mixing process. When smaller amounts were used, the gluten mass separated into two portions wrapped around each blade and merely rotated in a manner similar to that of a clothes wringer and no effective mixing took place. With maximum-swelled gluten alone it was not possible to obtain a mixing curve in our farinograph, because the wet gluten mass divided around each blade and simply rotated without mixing as already described.

Starting from dried gluten, it was relatively easy to obtain farinograph mixing curves. A calculated amount of water to make a total wet-gluten weight of 80 g. was added to a weighed amount of dried gluten in the mixing bowl, and the mixing curve was obtained when mixing was continued in the usual manner.

In this way a range of 80–130% water content (dry gluten basis) was covered for HRS-1 gluten, and 70–90% for durum gluten. However, in the higher water content part of the range some difficulty was encountered, as the gluten began to wrap around each mixing blade and rotated without mixing. To obviate the difficulty the farinograph was stopped, the gluten was consolidated into one mass with a pair of large forceps, and the mixing was restarted. This was repeated several times until proper mixing behavior was obtained.

The range for water content in the gluten, over which farinograph curves could be obtained, was extended considerably by the following method. A calculated amount of dried gluten was added to a predetermined amount of maximum-swelled gluten which was scaled off and placed in the mixing bowl. Again some help with forceps, as noted above, was required. In this way not only was the range of water content extended but a portion of the data could be duplicated by both methods. This common range showed that dried gluten did not differ in rheological behavior from wet gluten prepared directly.

All farinograph curves were obtained by mixing in air. No successful method was found for mixing these materials in a closed system in an atmosphere of nitrogen, because of the necessity of scraping down and of consolidating the wet gluten in the initial stages of mixing.

The various reagents (sodium chloride, urea, acetamide, guanidine hydrochloride, acetone, butanone, etc.) were dissolved or suspended in the amount of water normally used and added to the gluten in the mixing bowl.

Heat-Treatment of Dried Gluten

Dried gluten was heat-treated as follows: 60 g. of HRS-1 or 65 g. of durum gluten was weighed into a tin (9 cm. in diameter × 3.2 cm. deep) and covered with a lid. The sample was heated in an air-circulating oven at 70°C. for 1, 2, 3, and 4 hr.; at 80°C. for 1, 1.5, 2, and 2.5 hr.; at 90°C. for 0.5, 1, 1.5, and 2 hr.; and at 100°C. for 1 and 2 hr. (Not all data are shown in Fig. 9.) After this heat-treatment, the tin was sealed with masking tape and cooled overnight.

Heat-treatment caused the gluten to cake, and its hardness increased with increasing temperature or heating time. Each sample of heat-treated gluten was ground and sifted through a 72 GG sieve, the moisture determination was repeated, and the gluten was used as necessary for obtaining farinograph mixing curves.

Gluten-Stretching Tests

The rate of stretching of gluten under constant load was measured by the method of Kaminski and Halton (3) with slight modifications.

Heat-treated gluten and glutens from the flour dough treated with urea and acetone were subjected to this test. When heat-treated gluten was to be used for this test, the sample was prepared by adding to the dried gluten twice its weight of water, and mixing. Excess water was squeezed out of the wet gluten by hand. Duplicate 5-g. portions of this wet gluten were shaped into a ball and rested in distilled water for 1 hr. and then subjected to the stretching test under 10-g. weight; (8.6 g. in water because of buoyant force).

Preparation of Wet Gluten

Wet gluten was prepared from flour dough mixed with urea or acetone as follows: 8.4 g. of urea or 8.1 g. of acetone (1.66×10^{-3} moles/g. dry flour) was dissolved in the water to be added and placed in the bowl of the GRL mixer, then 100 g. of flour was added and the contents were mixed for 2.5 min. in air at 30°C. The dough was rested in distilled water for 30 min. and the gluten was washed out under a slow stream of distilled water. Quadruplicate 5-g. balls of gluten were shaped and relaxed for 1 hr. in distilled water and then subjected to the stretching test.

RESULTS AND DISCUSSION

For the purpose of a systematic presentation of the results obtained in this study, the data are presented in six parts. The first part describes representative farinograph mixing curves for gluten. These curves represent the bulk of the primary data on which later results are based. The second part discusses the relation between the water content and minimum mobility of gluten. In the third part, the effect on gluten of some common reagents is examined. Urea- and acetone-treated glutens are further examined in the presence of magnesium sulfate which counteracts the effect of these reagents. Then, the Kaminski-Halton gluten-stretching test is used to examine further the effect of urea and acetone. The final section groups experiments on the

effect of heat-treatment, of pH, and of iodate and N-ethylmaleimide.

Farinograph Mixing Curves for Gluten

Illustrative farinograph mixing curves for gluten are shown in Fig. 1. In examining these curves, it should be remembered that there is a factor of 5 in the sensitivity setting of the farinograph lever linkage. This setting is necessary because the consistency of the wet gluten mass is several times as high as that of normal doughs and is therefore outside the usual range of the kymograph.

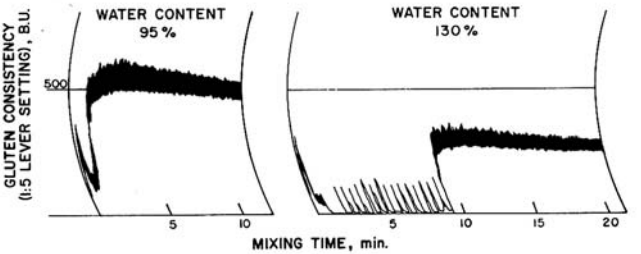

Fig. 1. Representative farinograph mixing curves for gluten at two levels of water content.

The curve on the left shows a mixing curve for gluten (HRS-1) at a water content of 95% (dry gluten basis), which is in the lower part of the range that was studied. Except for the sensitivity setting, the curve has an appearance similar to that of an ordinary farinogram for flour. Upon addition of water and mixing, gluten consolidates into a strong, smooth mass which mixes well in the farinograph.

The curve on the right, Fig. 1, shows a mixing curve for the same gluten but at a water content of 130%. The consistency is, of course, lower. But the main feature is the initial difficulty encountered in consolidating the wet gluten into one mass. As has already been noted in the section on methods, under certain conditions the gluten consolidates first around each mixing blade and rotates separately without mixing. It is necessary to stop the mixing at intervals to consolidate the gluten mass with the aid of large forceps, and then to restart the mixing. Some 15 such assists are indicated in the right-hand mixing curve before effective mixing was achieved. This initial difficulty in mixing is considered to arise from the known observation that two portions of wet gluten when placed together do not knit readily to form one piece until the surface water is incorporated into the interior and the gluten becomes sticky. Such sticky gluten knits together without difficulty. This behavior is also a function of the mixing bowl. The small stainless-steel-clad bowl which was available to us was especially prone to this behavior. This may be related to the highly polished surface of the bowl. Another solid stainless-steel bowl, which became available later, gave a much more effective consolidation of the gluten.

Mixing curves of the type illustrated in Fig. 1 were obtained to provide data for further examination of the rheological behavior of various glutens under conditions described below.

Relation between Minimum Mobility of Gluten and Water Content, and Effect of Sodium Chloride

Farinograph mixing curves were obtained for a representative hard red spring wheat gluten (HRS-1) over a range of water content of 80 to 130% (dry gluten basis) starting from dried gluten and water, and extended above 130% starting from maximum-swelled and dried gluten. For comparison, a durum gluten was also included. Starting from dried durum gluten, only the range of 69–90% water content could be covered; above this range maximum-swelled gluten with the addition of dried gluten was used.

Figure 2 summarizes the results as a plot of minimum mobility of gluten against water content. The initial solid portions of each line represent data obtained in experiments starting from dried gluten and water, and dashed portions represent data starting from maximum-swelled and dried gluten.

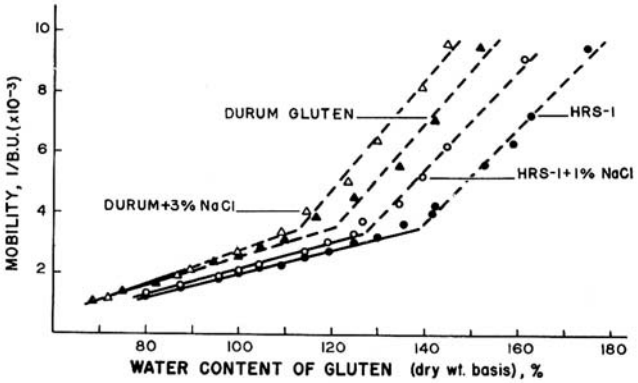

Fig. 2. Relation between gluten mobility and percent water content for HRS-1 gluten with 0 and 1% sodium chloride added and for durum gluten with 0 and 3%.

A question may arise about the validity of apposition of data obtained by the two variants of the method used in obtaining mixing curves. However, data for the durum gluten show a regular continuation of the line through 90% water content, even though two different methods are represented. With HRS-1 gluten several points were replicated in the range about 124% water content, and the results by either method were essentially the same.

Figure 2 shows that each of the four lines may be considered as consisting approximately of two essentially linear portions of different slope. In the initial portion of the curve the change in mobility, per unit change in water content, is much less than in the upper portion of the graph. This suggests that water plays a greater role in gluten mobility at higher water content levels.

The figure also shows that, for the same water content, HRS-1 gluten has lower mobility (higher consistency) than durum gluten. This is in agreement with the common knowledge that HRS wheat gluten is stronger than durum gluten.

The addition of salt in obtaining mixing curves increases the mobility of both types of gluten, consistently with the effect of salt in regular farin-

ography (4). Durum gluten appeared to be less sensitive to salt; 3% in durum gluten produced approximately the same effect as 1% salt with HRS gluten.

Finally, it may be of practical interest to indicate approximately the range of water content in which bread doughs and macaroni doughs may be considered to lie. Our estimates of water bound by gluten were 175% for bread doughs and 115% for macaroni doughs, well below the water content of 200% in maximum-swelled gluten; neither appears to attain its maximum swelling volume, according to our estimates.

Figure 3 brings together, for comparison, data on mobility *vs.* water content for five glutens of varying quality. The data have been adjusted to bring all glutens to the same protein level as that of HRS-1 gluten.

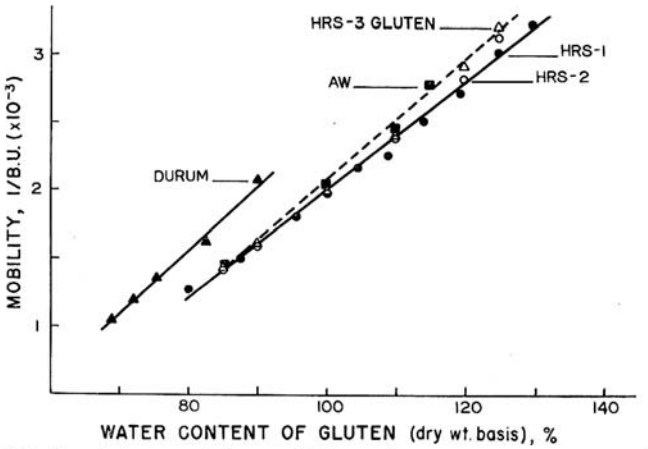

Fig. 3. Relation between gluten mobility and percent water content for HRS-1, -2, -3, AW, and durum glutens.

The data show that these two glutens are very similar and in fact may be represented by the same line. Again, glutens from the lower grade of spring wheat and from winter wheat (HRS-3 and AW) are slightly weaker, as was expected. They too have been arbitrarily represented by a common line. The durum gluten is in a class by itself and is considerably weaker than the other glutens. Here a "weak" gluten is defined as having a lower resistance to shear (lower consistency in mixing) at a given water content; a strong gluten would then be defined as one with a high resistance to shear when compared at the same water content.

Effect of Urea, Acetamide, Guanidine Hydrochloride, and Some Organic Solvents on Gluten

Urea is commonly employed as a reagent in the study of proteins. There has been renewed interest in protein chemistry in the study of the effect of urea and of some related substances in relation to hydrogen and hydrophobic bonding in proteins (5,6,7,8). In this study the effect of some of these substances on the farinograph mixing curves for crude gluten was examined. In general, the addition of urea decreased the consistency of gluten and made it more sticky. Above a concentration of 5.0% for durum gluten

and above 7.5% for other glutens (dry gluten basis), the presence of urea increased the time to reach maximum consistency.

Figure 4 summarizes the data on maximum consistency *vs.* urea concentration for HRS-1 gluten at 90, 100, and 110% water content, and for a durum gluten at 82, 88, and 90% water content. For both glutens the urea concentration was varied from 0 to 10%.

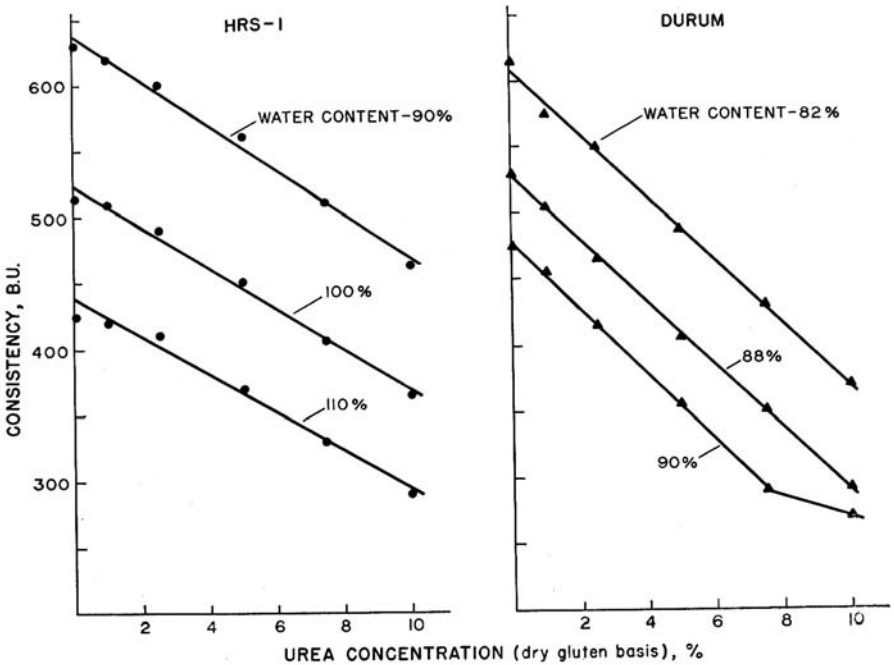

Fig. 4. Plot of consistency in Brabender units against percent urea concentration.

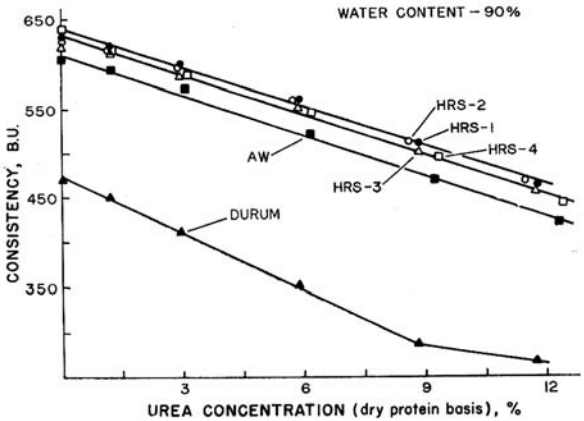

Fig. 5. Plot of consistency in Brabender units *vs.* percent urea concentration for HRS, AW, and amber durum glutens at a water content level of 90%.

Taking the 90% water content level which is common to both glutens, we see once again that the durum gluten is considerably weaker. In addition, the slope which represents the decrease in maximum gluten consistency per unit increase in urea concentration is greater for the durum gluten.

Figure 5 presents a comparison of plots of maximum consistency *vs.* urea concentration for six different glutens, all at the same water content of 90%. The data have been adjusted to the same protein basis as HRS-1 gluten. The results in the presence of urea parallel those already shown for gluten and water alone in Fig. 3.

Both acetamide and guanidine hydrochloride had an effect similar to that of urea, i.e., lowering the maximum consistency of gluten mixing curves. Data for these substances with HRS-1 gluten are summarized in the upper

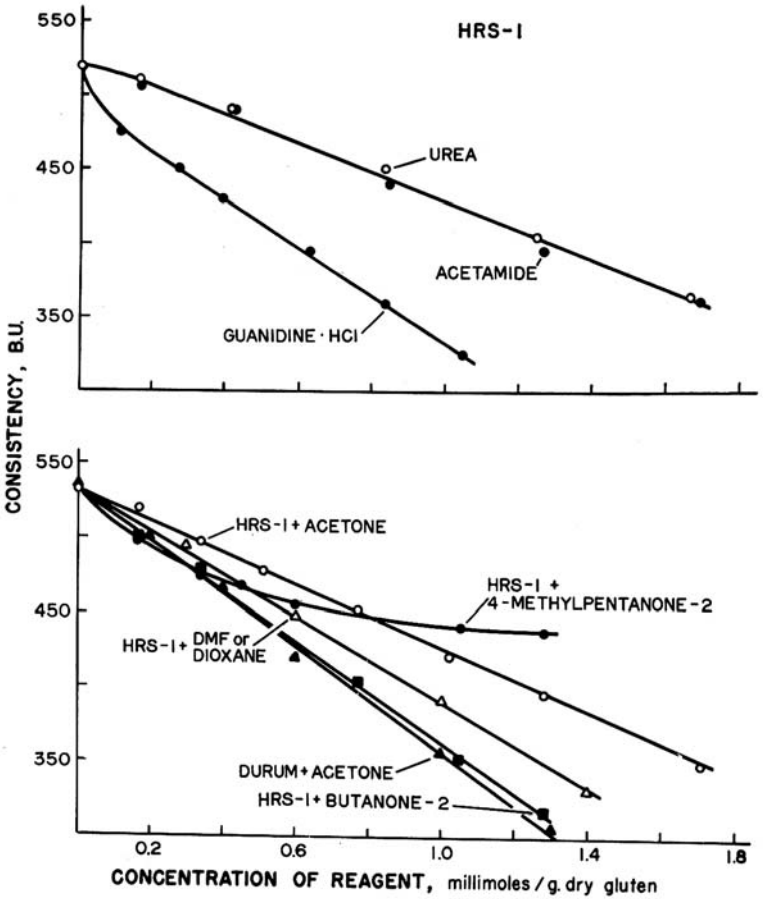

Fig. 6. Upper graph shows effect of urea, acetamide, and guanidine hydrochloride concentration on the consistency of HRS-1 gluten. Lower graph shows effect of acetone, dioxane, dimethylformamide, 4-methylpentanone-2, and butanone-2, concentration on the consistency of HRS-1 gluten and of acetone on the consistency of durum gluten.

half of Fig. 6. The concentrations are expressed on an equimolar basis and the water content of the gluten for the mixing curves was 100%, dry gluten basis. Guanidine had the most pronounced effect.

Equally interesting is the effect of organic solvents (5,6,7,8) such as acetone, butanone-2, dimethylformamide, dioxane, and 4-methylpentanone-2. When added to HRS-1 gluten mixed in the farinograph they produced an effect similar to that of urea. The lower half of Fig. 6 shows the maximum gluten consistency at 98% water content plotted against molar concentration of each of the reagents. Additionally, the curve obtained with durum gluten at 85% water content, treated with acetone, is also shown.

Acetone produced the least effect in decreasing the consistency of HRS-1 gluten; dioxane and dimethylformamide were somewhat more effective; and butanone-2 was the most effective. 4-Methylpentanone-2 was somewhat different, and this may perhaps be associated with its low miscibility with water and with its predominantly hydrophobic character. The greater slope for the effect of acetone on durum gluten, of course, not only is the result of the effect of acetone, but reflects the lower strength of durum gluten.

Interest in these reagents is not casual. It arises from the fact that recent researches in protein chemistry have attributed to these reagents the role of dissociating hydrophobic bonds. These chemicals may be considered to possess both a hydrophobic and a hydrophilic group in the same molecule. Viewed in this way, the similarity between urea, traditionally considered as a hydrogen bond-breaking reagent, and acetone, a hydrophobic bond-breaking agent, becomes understandable. Both dissociate the secondary bond structure of proteins, whether these bonds are hydrogen or hydrophobic bonds, and hence change the secondary structure of gluten. This, of course, is only one view. It is realized that the subject of hydrogen and hydrophobic bonds in proteins is an active one and that other interpretations of our results may be made. In addition, there is the possibility that the protein-lipid interaction may be involved.

Effect of Magnesium Sulfate on Mixing Curves of Urea- and Acetone-Treated Glutens

Jankiewicz and Pomeranz (9) reported the effect of urea as a hydrogen bond-dissociating reagent in dough as reflected by farinograms. The effect was counteracted or reversed by the addition of magnesium sulfate. It was of interest to extend the observations of these workers to the mixing curves for gluten. In addition to urea, acetone has also been included as an interesting reagent. Both were used at a level of 1.66×10^{-3} moles/g. dry flour. The concentrations of urea and magnesium sulfate were based on the work of Jankiewicz and Pomeranz.

The results are summarized in Fig. 7. The left-hand column shows the mixing curves for the control gluten (A), and for gluten with magnesium sulfate (B), urea (C), and acetone (D). The right-hand column shows a curve for control gluten, a urea-treated gluten, and an acetone-treated gluten, to each of which 0.8 g. solid magnesium sulfate was added, after 3 min. of initial mixing.

The first part of each curve on the right is, of course, identical with

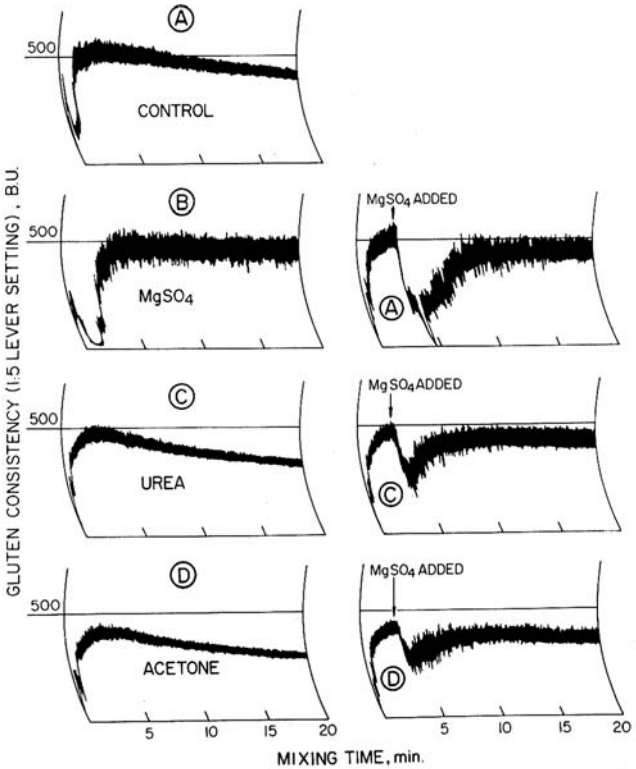

Fig. 7. Farinograph mixing curves showing changes in consistency during 20 min. of mixing for control, and for gluten with urea and acetone, with and without magnesium sulfate.

that of the corresponding part of the curve in the left-hand column. The addition of the salt produces an immediate drop in stability and consistency. An exudation of water from the gluten upon the addition of salt can actually be noted. It may be considered that the presence of an electrolyte upsets the ionic equilibrium. However, as mixing continues, the exuded water is again incorporated into the gluten. A compatible balance between water and the electrolyte in the gluten is re-established.

The remainder of the gluten mixing curve past the initial dip indicates that stability of urea- and acetone-treated glutens in the presence of the salt is mostly regained. The curve assumes an appearance more like that of the control gluten than that of the curve for urea- or acetone-treated gluten.

An explanation for the effect of magnesium sulfate on urea- and acetone-treated gluten may be suggested. Pomeranz suggests that the salting-out effect on the hydrated gluten protein system counteracts the dispersing effect of urea in dissociating the hydrogen bonds. Kauzmann (5) states that electrolytes tend to strengthen the hydrophobic bonds by decreasing the solubility of nonpolar groups in water. Thus, magnesium sulfate would counteract the effect of acetone in dissociating the hydrophobic bonds and produce an effect analogous to that obtained with urea-treated gluten.

Stretching Test on Gluten from Urea- and Acetone-Treated Doughs

The Kaminski and Halton (3) gluten-stretching test was used to study further the similarity of the effect of urea- and acetone-treated glutens. For this test, doughs were mixed from flour and water with added urea or acetone at a level of 1.66×10^{-3} moles/g. dry flour. The glutens were washed out and subjected to the stretching test.

Figure 8 shows the increase in length of the gluten sample with stretching time. Gluten washed from urea-treated and from acetone-treated dough showed a definite decrease in the rate of extension, acetone producing the greater effect.

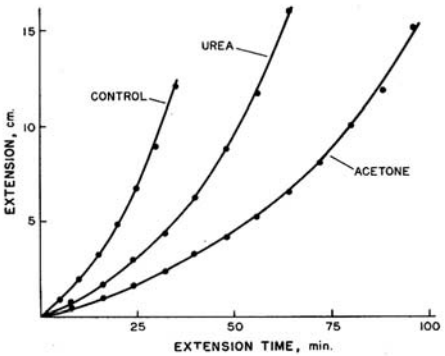

Fig. 8. Curves for extension *vs.* extension time relations for gluten hand-washed from control flour-dough, and flour-dough containing urea or acetone.

In connection with these results, it is of interest to cite the work of Huggins, Tapley, and Jensen (10) and others (11), who showed that urea could induce the formation of intramolecular –SS– bonds from intermolecular –SS– bonds through the mediation of –SH bonds, i.e., by a sulfhydryl-disulfide interchange mechanism.

In the same way the effect of urea and acetone on gluten, whether they dissociate hydrogen or hydrophobic bonds, may be visualized as opening up the protein structure; the inaccessible –SH and intramolecular –SS– groups then become available to increase the interchain cross-linking through the disulfide-sulfhydryl interchange mechanism.

Miscellaneous Experiments with Gluten

In this section are grouped a number of less closely related but nevertheless interesting experiments on the rheological properties of gluten. These experiments include a preliminary look at the effect of heat-treatment, pH, and iodate and N-ethylmaleimide (NEMI).

Effect of Heat-Treatment of Gluten on Mixing Curves and Stretching Characteristics

Heat-treatment under comparatively moderate conditions, such as 70°C. for 1–4 hr., or 80°C. for 1 hr., did not produce significant changes in the farinograph mixing curves for HRS-1 gluten. More drastic heating, e.g. at 80°C. for 2.5 hr., produced a rough, irregular, and wide curve in the initial mixing stages, but eventually the curve appeared normal. At still higher temperatures, or at longer heating times, the gluten lost its cohesiveness and

stickiness, and a meaningful mixing curve could not be obtained. The addition of urea to heat-treated glutens produced a smaller decrease in consistency as compared to the decrease obtained when urea was added to unheated gluten.

Heat-treated durum gluten showed recognizable changes in the farinograph mixing curves more readily. The maximum consistency was slightly higher and the band width wider, with a tendency to an increase in mixing tolerance.

However, because of the lack of adequate sensitivity for more than qualitative observations, the farinograph technique was abandoned in favor of the more sensitive (for this purpose) Kaminski-Halton gluten-stretching technique. The results of gluten stretching tests are summarized in Fig. 9.

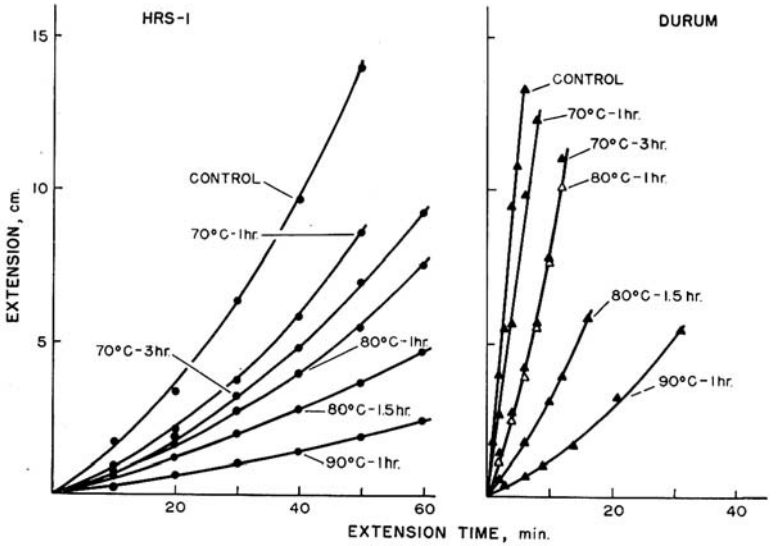

Fig. 9. Graphs showing extension *vs.* extension time relations for HRS and durum gluten prepared by mixing vacuum-dried gluten with water. Dried glutens were heated at different temperatures.

It is obvious from the graph that the stretching test is more sensitive in indicating changes produced by heat-treatment of gluten. The left-hand part of Fig. 9 shows that heating HRS-1 gluten at 70°C. for 1 hr. results in a definitely slower rate of stretching. The change in stretching properties increased with higher temperature or longer time.

The right-hand portion of the figure shows corresponding data for gluten from durum wheat. It will be noticed from the steepness of the curves that durum gluten is very much more extensible than gluten from HRS wheat. If one were to superpose the two graphs, the curve for HRS-1 control gluten, which was given no heat-treatment, would fall between the curves for durum gluten that was heated at 80°C. for 1.5 hr. and at 90°C. for 1 hr.

Relation between pH and Maximum Consistency of Gluten

When HRS-1 gluten was acidulated by addition of acetic acid, a de-

crease in maximum consistency and an increase in stickiness were observed, but no recognizable change in maximum development time was shown. Figure 10 summarizes the data. No further comment appears to be necessary at this time.

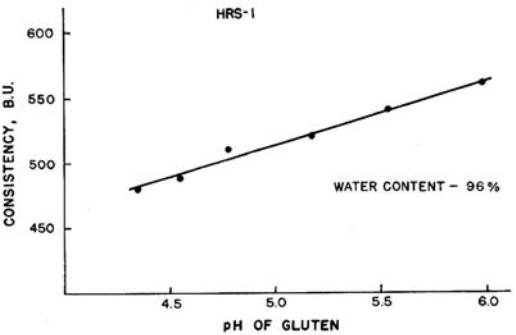

Fig. 10. Relation between consistency in Brabender units and the pH of HRS-1 gluten at a water content of 96%.

Effect of Iodate and NEMI on Mixing Curves for HRS-1 and Durum Gluten

Sulfhydryl reagents, iodate and NEMI, have been used extensively in the study of the chemistry of flour proteins (12). The results of a few preliminary experiments with these reagents on two types of gluten are summarized briefly.

Over a concentration range of iodate from 2.5 to 100 μeq. per g. dry gluten, no significant change in maximum consistency or development time was observed in the mixing curves of either gluten. The rate of decrease in consistency past the maximum (MTI) was reduced with 2.5 to 50 μeq. iodate. Addition of more iodate did not appear to produce any further effect.

Treatment of both glutens with NEMI over a range from 0.5 μeq. per g. reduced the development time and markedly increased the rate of decrease in consistency past the maximum up to 4 μeq. per g. Further addition increased the breakdown rate more slowly. Treatment with NEMI made the glutens sticky and fluid.

In general, treatment of gluten with iodate or NEMI yielded results analogous to those obtained for dough as described by Meredith and Bushuk (12).

CONCLUDING COMMENT

It is of some significance that hydrated crude gluten lends itself to mixing studies with the farinograph under a fairly broad range of experimental conditions. In general, the results of the present study indicate that the mixing behavior of gluten is what might be predicted on the basis of indirect evidence derived from experiments with dough. They support the view that the physical properties of dough are, in large measure, attributable to its gluten which provides a matrix for the other constituents.

There is an interesting suggestion in the results that the strength of

glutens from various sources taken at the same protein content and at the same water content may be assessed by their mobility in the farinograph. However, further work is necessary. It would have been of some interest to measure the mobility of gluten at its maximum swelling volume, but for this purpose a further study of the mixing action of the farinograph bowl, or a mixer of another design, would be required.

The comparative effects of urea and acetone on the mixing characteristics of gluten proteins suggest a method for a further study of the role of hydrogen and hydrophobic bonds in the structure of gluten. Other selected reagents may be tested in a similar way to provide at least some of the answers to the perplexing questions about the physical and chemical nature of gluten.

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