# Effects of Acid-Soluble and Acid-Insoluble Gluten Proteins on the Rheological and Baking Properties of Wheat Flours[1]

K. R. PRESTON and K. H. TIPPLES, Canadian Grain Commission; Grain Research Laboratory, Winnipeg, Manitoba R3C 3G9

## ABSTRACT

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Gluten, isolated from a hard red spring wheat flour, was fractionated into acid-soluble and acid-insoluble protein fractions. The effects of adding increasing levels of these fractions and of unfractionated and reconstituted gluten upon the rheological and baking properties of two base flours varying in baking quality were investigated. Results with the mixograph and farinograph suggested that the dough-strengthening effects obtained when gluten proteins were added to the base flours were mainly due to proteins present in the acid-soluble gluten fraction, whereas the acid-insoluble gluten proteins at higher levels had a slight dough-weakening effect. Addition of increasing levels of gluten to the base flours significantly increased loaf volume with both the Grain Research Laboratory's Chorleywood and remix baking procedures. Similar increases in loaf volume were also obtained by addition of the acid-soluble gluten proteins. Addition of acid-insoluble gluten proteins significantly reduced loaf volumes.

The baking quality of bread wheat flours has been shown to depend strongly upon both the quantitative and qualitative properties of their gluten proteins. Significant increases in dough strength and loaf volume associated with increasing levels of gluten proteins have demonstrated the importance of the quantitative aspect (Aitkin and Geddes 1939). Similarly, reconstitution studies by Finney (1943) have demonstrated the importance of gluten "quality" upon baking properties. Aitkin and Geddes (1938) have shown qualitative differences in the dough-strengthening

properties of glutens from different bread wheat varieties.

More recent studies have suggested that the solubility and molecular weight distribution of the gluten proteins are a major factor in determining gluten "quality." Pomeranz (1965) showed that the dispersibility of wheat flour proteins in $3M$ urea/phosphate buffer was negatively correlated with loaf volume. Orth and Bushuk (1972) and Orth et al (1972) studied the solubility distribution of 26 wheat varieties varying in quality, using a modified Osborne procedure. Remix loaf volumes were shown to be highly correlated ($r = 0.82$) to the proportion of insoluble glutenin flour proteins. The level of this protein fraction was also shown to be highly correlated with dough strength properties, as measured on the farinograph.

Using reconstitution techniques, MacRitchie (1972,1973) has shown that dough strength appears to be a function of the molecular weight distribution of the gluten proteins. The more

insoluble high molecular weight protein fractions were found to increase farinograph dough development time and extensigraph height and area and to reduce farinograph dough breakdown Reconstitution studies by MacRitchie (1978) have also suggested that differences in the baking response of bread wheat flours varying in quality may be closely related to the properties of the more insoluble high molecular weight glutenin proteins.

The present study was initiated to gain a better understanding of the relative effects upon rheological and baking properties of the high molecular weight acid-insoluble gluten proteins and the more soluble gluten proteins. For this purpose, gluten isolated from a Canadian hard red spring wheat of good baking quality was fractionated with $0.05M$ acetic acid into soluble and insoluble protein fractions. The effects of adding various levels of these fractions and of unfractionated and reconstituted gluten upon the rheological and baking properties of two base flours of similar protein content but of varying rheological and baking characteristics were studied.

## MATERIALS AND METHODS

Wheats used in the present study included a composite sample of the hard red spring wheat variety Neepawa, grown in 1976 at Agriculture Canada research stations across Western Canada, a commercially-grown sample of Canada western red spring wheat, grade No. 1 CWRS-11.5, and a Brazilian bread wheat obtained from the Canadian International Grains Institute (Winnipeg). All wheats were milled to straight grade flour (approximately 75% extraction) on the Grain Research Laboratory's (GRL) pilot mill. Selected properties of these flours are shown in Table I.

The two base flours had similar protein content but varying strength and bread-making quality. The Brazilian flour, which produces high quality "Pao Francaise" bread, had weak dough characteristics and low loaf volume potential for the production of the North American type of breads. The No. 1 CWRS-11.5 flour had medium-strong dough characteristics and good loaf volume potential.

### Fractionation of Gluten Proteins

Gluten was prepared from flour (Neepawa) by the method of Doguchi and Hlynka (1967). Following lyophilization, the gluten was ground to a flourlike consistency in a coffee grinder.

Extraction procedures were all performed at 4°C. Gluten (50 g) was stirred 6 hr in 5 L of $0.05M$ acetic acid with a Caframo overhead stirrer (Canadian Laboratory Supplies), then centrifuged at $5,000 \times g$ for 30 min. The pellet was resuspended in 2 L of $0.05M$ acetic acid and stirred for 12 hr. Following centrifugation at $40,000 \times g$ for 30 min, the resulting pellet was resuspended in 1.5 L of $0.05M$ acetic acid and stirred an additional 12 hr. After the third centrifugation at $40,000 \times g$ for 30 min, the pellets were dispersed in a minimum volume of $0.05M$ acetic acid $(1:1, v/v)$, stirred 1 hr, and centrifuged at $150,000 \times g$ for 30 min in an ultracentrifuge. The resulting lighter gel layer was carefully separated from the hard starch layer with a spatula. The starch layer was resuspended in acid solution and the above procedure repeated twice. The gel layers were combined, suspended in a minimum volume of $0.05M$ acetic acid, and lyophilized. This fraction was termed the acid-insoluble fraction.

The supernatants from the above procedures were combined and adjusted to pH 7.0 with $1.0M$ sodium carbonate. The sticky precipitate was removed with a spatula and added to the pellet obtained by centrifuging the remaining solution at $5,000 \times g$ for 15 min. The precipitated proteins were redissolved in a minimum volume of $0.05M$ acetic acid, and contaminating insoluble "gel" protein was removed by centrifugation. The solubilized protein was reprecipitated as described, then lyophilized. This fraction was termed the acid-soluble gluten proteins. The starch residue separated from the gel layer and a portion of the pH 7.0 soluble gluten fraction, following dialysis against $0.05M$ acetic acid, were also lyophilized in order to give protein recovery data. All samples were ground in a coffee grinder before use.

### Rheological Tests

All flour and gluten fractions were weighed on a 14% moisture basis. Samples were prepared by adding the various gluten fractions to a plastic beaker containing the preweighed base flours (Brazilian and No. 1 CWRS) and stirring by hand until thoroughly mixed. Gluten, reconstituted gluten (9:1 acid-soluble/acid-insoluble) and acid-soluble (pH 7.0-insoluble) gluten were added at three levels (0.5, 1.0, and 2.0%); acid-insoluble gluten was added at 0.5 and 1.0%.

Mixograms were obtained using a Swanson-Working mixograph (National Mfg. Co., Lincoln, NE). Control flours (35.0 g) and flours containing various levels of the gluten fractions were added to the mixing bowl pre-equilibriated to 30°C. After addition of 21.7 ml of water (62% absorption), mixing at 88 rpm was initiated, and curves were obtained with the spring index bar set in position 11.

Farinograms were obtained with the small Brabender farinograph bowl and the constant flour weight (50 g) procedure according to the AACC (1962) procedure.

Extensigrams were obtained with the procedure described by Holas and Tipples (1978) except that doughs were prepared from 50 g of flour in the small Brabender farinograph bowl. Curves were obtained for doughs at 45 and 135 min, with rounding and shaping at 90 min.

### Baking Tests

Two baking procedures were used. The GRL remix procedure with 15 ppm of potassium bromate and 1% salt was performed according to the general procedure of Irvine and McMullan (1960) and included a 2.75 hour (30°C) bulk fermentation period before remixing.

The GRL-Chorleywood procedure was carried out by a method similar to that of Kilborn and Tipples (1973). The baking formula included 200 g of flour, 2.5% sugar, 1% salt, 1.5% shortening, 3.0% yeast, 1% malt syrup (60°L), 0.1% monobasic ammonium phosphate, 37.5 ppm ascorbic acid, and 30 ppm potassium bromate. Doughs were developed slightly past peak consistency with a GRL mixer (160 rpm), scaled, rounded into two "pup-loaf" sized doughs, given an intermediate proof of 20 and 25 min, and panned. Loaves were then proofed at 35°C for 55 min and baked for 25 min at 430°F.

## RESULTS

### Fractionation of Neepawa Gluten

Protein contents and yields of fractions isolated from the Neepawa gluten are shown in Table II. Recoveries of gluten proteins averaged 90.4%. The acid-soluble fraction precipitated at

### TABLE I
#### Physical Properties of Flours

| | Neepawa | Brazilian | 1 CWRS-11.5 |
|---|---|---|---|
| Protein,[a] % | 14.2 | 11.1 | 11.4 |
| Ash, % | 0.36 | 0.50 | 0.40 |
| Starch damage, Farrand units | 20 | 4 | 28 |
| Gassing power, mm | 270 | 265 | 380 |
| Amylograph viscosity, BU | ... | 375 | 705 |

[a]14% moisture basis.

### TABLE II
#### Protein Content and Yield of Fractions from Neepawa Gluten

| Fraction | Protein[a] (%) | Protein Recovery (%) |
|---|---|---|
| Neepawa gluten | 84.4 | ... |
| HAc-insoluble | 67.1 | 9.8 |
| HAc-soluble, pH 7 insoluble | 88.6 | 69.4 |
| HAc-soluble, pH 7 soluble | 8.4 | 10.4 |
| Starch pellet | 17.3 | 0.8 |
| Total | ... | 90.4 |

[a]Dry weight basis.

pH 7.0 gave the highest recovery, averaging 69.4% of the total gluten protein. Polyacrylamide electrophoretic analysis with aluminum lactate buffers (data not shown) showed that this fraction contained both gliadinlike and gluteninlike components. By contrast, the pH 7.0 soluble proteins, which accounted for approximately 10% of the total protein, had components of high electrophoretic mobility. These proteins are normally considered to be impurities trapped during gluten formation (Hoseney et al 1969) and were not subjected to further studies.

As extraction progressed, the acid-insoluble gluten formed a highly hydrated gel, as previously described (Mecham et al 1962, Meredith 1961). Recovery of acid-insoluble protein, after removal of starch by ultracentrifugation, averaged 9.8%. However, the low recovery was probably because of the fragile characteristics of the gel pellet, which, even at ultracentrifugation speeds, resulted in losses during decanting of the supernatant.

### Effects of Gluten Fractions on Rheological Properties

*Mixograph.* Results with the mixograph are shown in Figs. 1A and B. Addition of increasing levels of unfractionated gluten to both base flours increased dough strength, as evidenced by higher peak heights, increased dough development times, and increased dough stability. These effects were more pronounced with the stronger No. 1 CWRS flour than with the Brazilian flour. Addition of reconstituted gluten gave mixograph characteristics similar to the corresponding level of added unfractionated gluten.

Addition of increasing levels of acid-soluble gluten also increased dough strength relative to that of the two base flours but, again, to a much more noticeable extent with the No. 1 CWRS sample. Mixograph curves were only slightly weaker than were those for corresponding levels of added unfractionated gluten. In contrast, the addition of increasing levels of acid-insoluble gluten gave similar or slightly weaker mixograph curves compared to those of the base flours.

*Farinograph.* As with the mixograph studies, results with the farinograph (Figs. 2A and B) showed that both the Brazilian and No. 1 CWRS flours were strengthened by addition of unfractionated gluten, reconstituted gluten, or acid-soluble gluten. Increased levels of unfractionated and reconstituted gluten had almost identical effects upon farinograph properties. With 2% of either gluten

added, absorption increased approximately 1% for both the Brazilian (control flour absorption = 55.5%) and the No. 1 CWRS (control flour absorption = 61.2%) flours. Farinograph dough development times were also significantly increased. For the Brazilian and the No. 1 CWRS flour, addition of 2% unfractionated gluten increased dough development times from 2.50 to 3.25 min and from 3.50 to 4.50 min, respectively. Dough stability was also increased, the effects being more pronounced with the stronger No. 1 CWRS flour.

The acid-soluble gluten fraction also strengthened the farinograph properties of the flours and increased absorption, although effects were less pronounced than with the unfractionated and reconstituted glutens. Addition of increasing levels of this fraction to the Brazilian flour increased dough development time only slightly (0.25 min) and gave little increase in dough stability. However, with the No. 1 CWRS flour, addition of increasing levels of the acid-soluble fraction had a marked effect on both dough development time and stability. Addition of 2% acid-soluble protein increased dough development time from 3.50 to 4.25 min, and dough stability increased by approximately the same extent as when unfractionated or reconstituted gluten was added.

Addition of 1% acid-insoluble gluten to either flour increased farinograph absorption by approximately 0.6%. However, this fraction decreased dough development time and stability compared to those of the control flours. With the Brazilian flour, dough development time decreased from 2.50 to 2.25 min and with the No. 1 CWRS flour, from 3.50 to 3.00 min. Thus, in contrast to the effects of unfractionated gluten, reconstituted gluten, and acid-soluble gluten, addition of acid-insoluble gluten appeared to cause weakening of dough characteristics as measured by the farinograph.

*Extensigraph.* Figures 3A and B show the effects of the gluten fractions upon extensigraph properties for doughs rested a total of 135 min. The Brazilian flour gave a fairly weak extensigraph curve characterized by a low resistance to extension (maximum height)
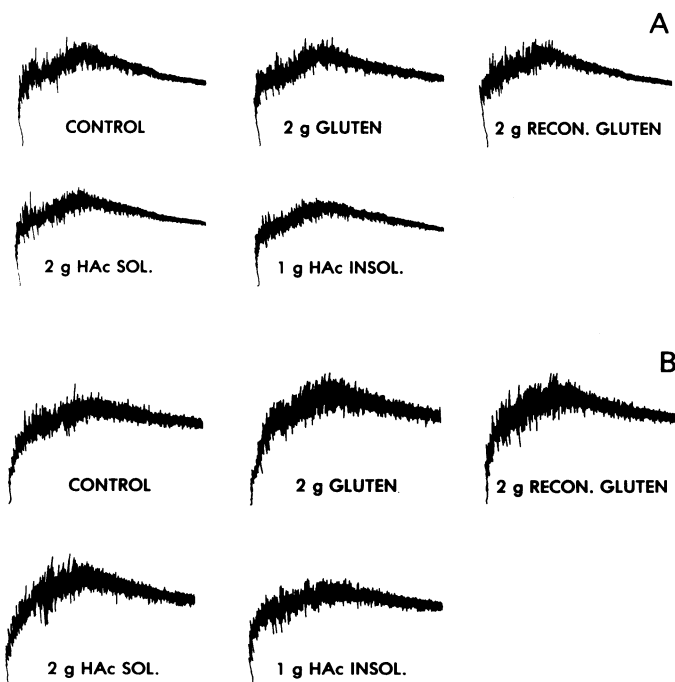


Fig. 1. Effects of 2% gluten, reconstituted gluten, acid-soluble gluten, and 1% acid-insoluble gluten upon the mixograph properties of Brazilian flour (A) and No. 1 CWRS-11.5 flour (B).
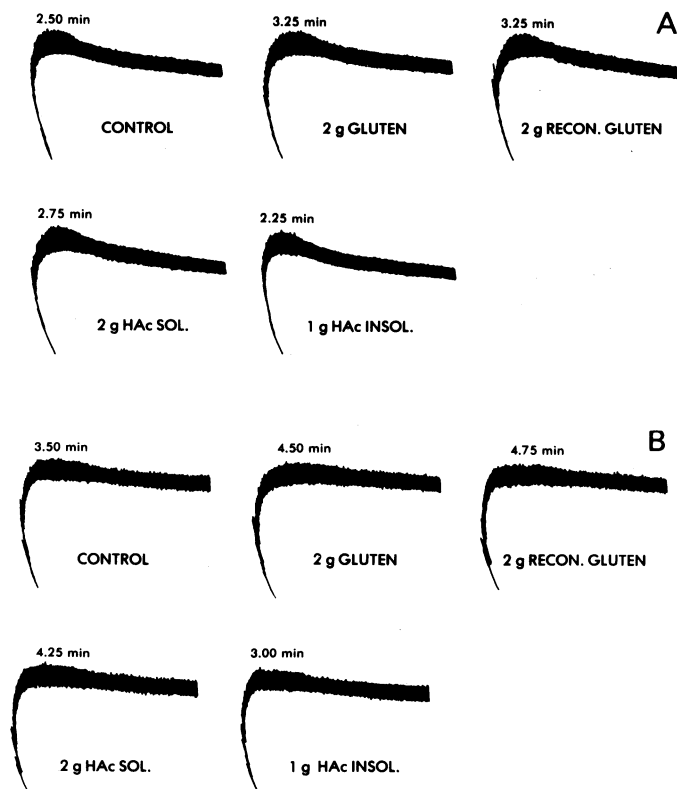


Fig. 2. Effects of 2% gluten, reconstituted gluten, acid-soluble gluten, and 1% acid-insoluble gluten upon the farinograph properties of Brazilian flour (A) and No. 1 CWRS-11.5 flour (B). Dough development times shown above peaks.

and a small area; the No. 1 CWRS flour gave a more "balanced" extensigraph curve. Addition of increasing levels of unfractionated gluten gave stronger curves, as indicated by a marked increase in area. This increase in area was attributable to increases in both resistance to extension and extensibility (length), resulting in curves that were similar in general shape to the curves for the corresponding control flours.

Addition of reconstituted gluten caused similar increases in extensigram area. However, these increases in area were largely attributable to increases in resistance. Brazilian flour showed a marked decrease in extensibility and the No. 1 CWRS flour a small decrease compared to those of the control flours.

The effects of the acid-soluble gluten fraction on extensigraph properties were intermediate between the effects of unfractionated and reconstituted gluten. With both flours, increases in areas with the addition of acid-soluble gluten were similar to those obtained with unfractionated gluten. These increases were mainly attributable to increases in resistance, although values were considerably lower than resistances obtained with the reconstituted gluten. Although extensibility varied somewhat, values were generally close to those for the corresponding base flours.

Addition of acid-insoluble gluten caused a marked reduction in extensibility and an increase in resistance. The net effect was a slight decrease in extensigram area for both flours.

### Effects of Gluten Fractions on Baking Performance

Table III shows the effects of the addition of 2% gluten, reconstituted gluten, and a commercial gluten (Supergluten 80, Industrial Grain Products, Montreal) on loaf volume of the base flours, utilizing the GRL-Chorleywood and remix baking procedures. Addition of the glutens to both the base flours gave significant increases in loaf volume in both baking procedures. The results also showed that the reconstituted gluten was as effective as the unfractionated gluten for loaf volume. Commercial wheat gluten, added as a control, gave lower loaf volume responses than did either the reconstituted or unfractionated gluten. This may be partially due to commerical drying procedures using higher temperatures, which may partially denature the proteins.

*Chorleywood Procedure.* The effects of the addition of increasing levels of gluten, acid-soluble gluten, and acid-insoluble gluten on loaf volume of the base flours using the GRL-Chorleywood baking procedure are shown in Figs. 4A–C. Increasing levels of both gluten (Fig. 4A) and acid-soluble gluten (Fig. 4B) gave significant increases in loaf volume when added to either of the flours, the increases from unfractionated gluten being slightly greater. Loaf volume responses were somewhat greater with the weaker Brazilian flour than with the No. 1 CWRS flour.
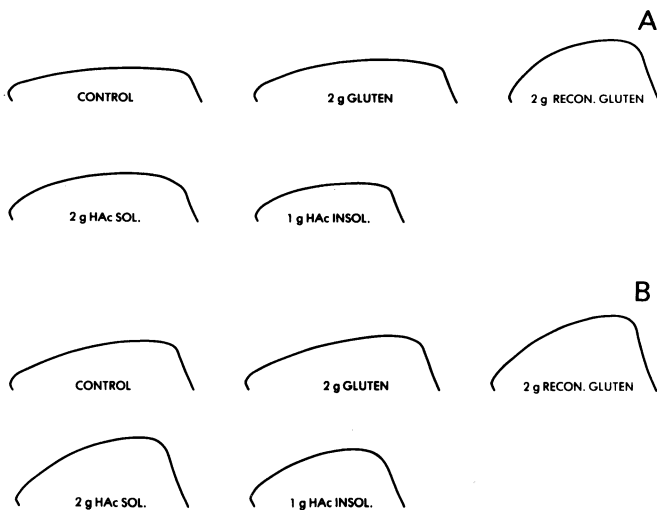
**Fig. 4.** Effects of increasing concentrations of gluten (**A**), acid-soluble gluten proteins (**B**), and acid-insoluble gluten proteins (**C**) upon the Grain Research Laboratory's Chorleywood loaf volume with Brazilian (--o--) and No. 1 CWRS-11.5 (--•--) flours.

**Fig. 3.** Effects of 2% gluten, reconstituted gluten, acid-soluble gluten, and 1% acid-insoluble gluten upon the extensigraph properties of Brazilian flour (**A**) and No. 1 CWRS-11.5 flour (**B**). Curves obtained after 135 min.
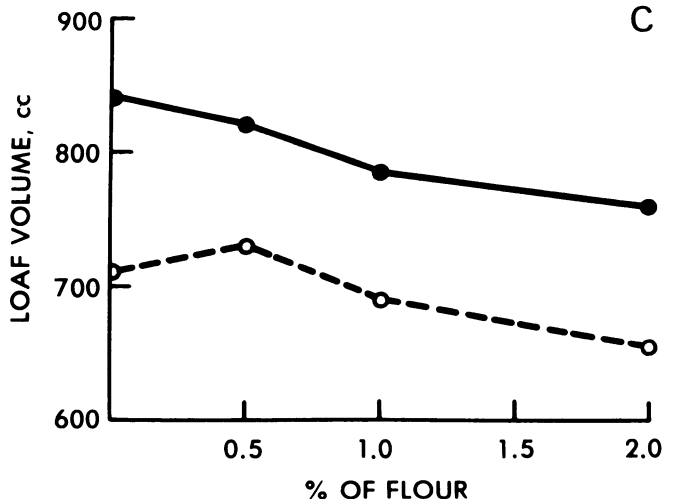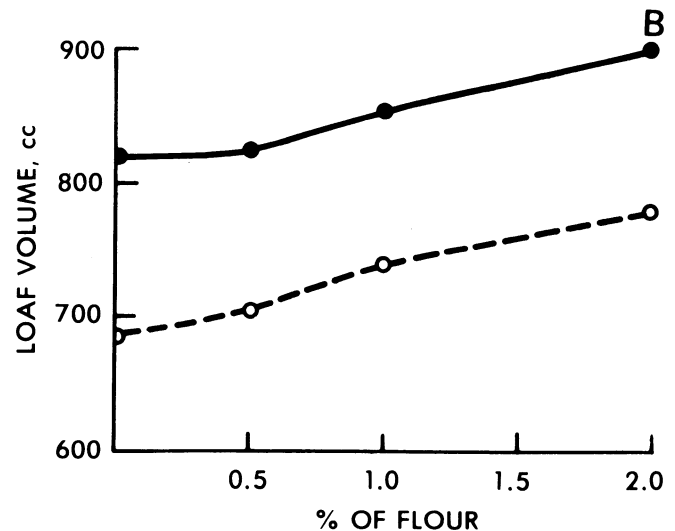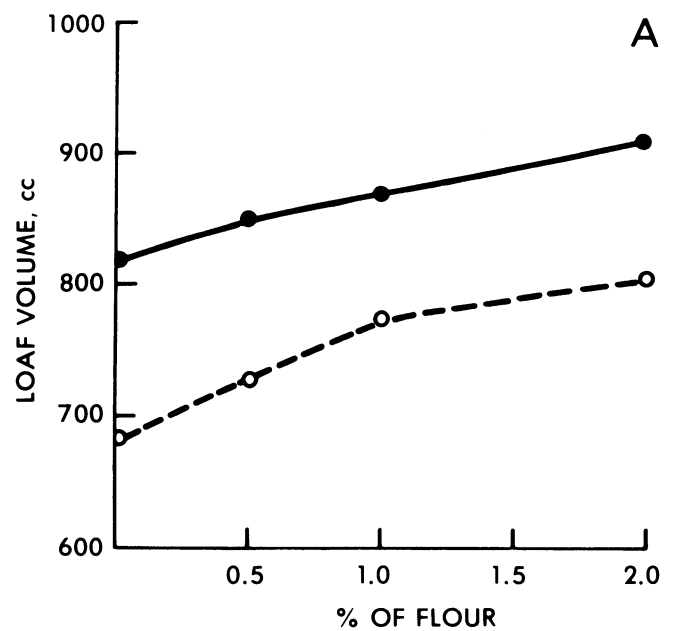
Addition of increasing levels of acid-insoluble gluten to the No. 1 CWRS flour gave significant reductions in loaf volume as shown in Fig. 4C. With the Brazilian flour, addition of 0.5% acid-insoluble gluten gave a 20-cc increase in loaf volume compared to that of the control. However, higher levels of this fraction (1.0 and 2.0%) significantly decreased loaf volume.

*Remix Procedure.* Figures 5A–C show the effects of increasing levels of unfractionated gluten, acid-soluble gluten, and acid-insoluble gluten on loaf volumes for the Brazilian and No. 1 CWRS flours with the remix baking procedure. Loaf volumes of both flours increased with increasing levels of unfractionated gluten (Fig. 5A) and acid-soluble gluten (Fig. 5B). The increase in loaf volume for the Brazilian flour was greater with gluten than with acid-soluble gluten, whereas loaf volume response was similar for both additives with the No. 1 CWRS flour. Loaf volume response was, overall, less for the remix method than for the Chorleywood procedure.

Addition of increasing levels of acid-insoluble gluten caused significant reductions in loaf volume (Fig. 5C). This was particularly evident with the No. 1 CWRS flour, which decreased in loaf volume by 180 cc with 2% acid-insoluble gluten. Comparison of the results from the two baking procedures showed that this fraction depressed loaf volume more in the remix procedure than in the GRL-Chorleywood procedure, particularly with the stronger No. 1 CWRS flour.

## DISCUSSION

Previous studies have shown that the levels of acid-insoluble proteins in bread wheat flours show wide variations that can be related to flour strength and baking quality (Axford et al 1978, Orth and Bushuk 1972). However, during dough mixing a large portion of the acid-insoluble flour proteins become soluble, suggesting the occurrence of a disaggregation process (Mecham et al 1962, Meredith 1961, Tsen 1967). A similar process also appears to occur during the preparation of gluten, as indicated by the decreased levels of acid-insoluble proteins found by Shogren et al (1969) and in the present study. However, in all of the above studies a significant proportion of the acid-insoluble flour proteins appeared to be highly resistant to this disaggregation process. Thus, flour appears to contain two rather distinct classes of acid-insoluble proteins, which differ in their resistance to "mechanical" (dough mixing) disaggregation. In the present study the mechanically disaggregated acid-insoluble flour proteins are present in the acid-soluble gluten fraction, and the acid-insoluble gluten protein fraction contains the proteins most resistant to mechanical disaggregation.

### Effects on Rheological Properties

Addition of unfractionated gluten to both base flours resulted in increased dough strengths, as evidenced by increases in dough
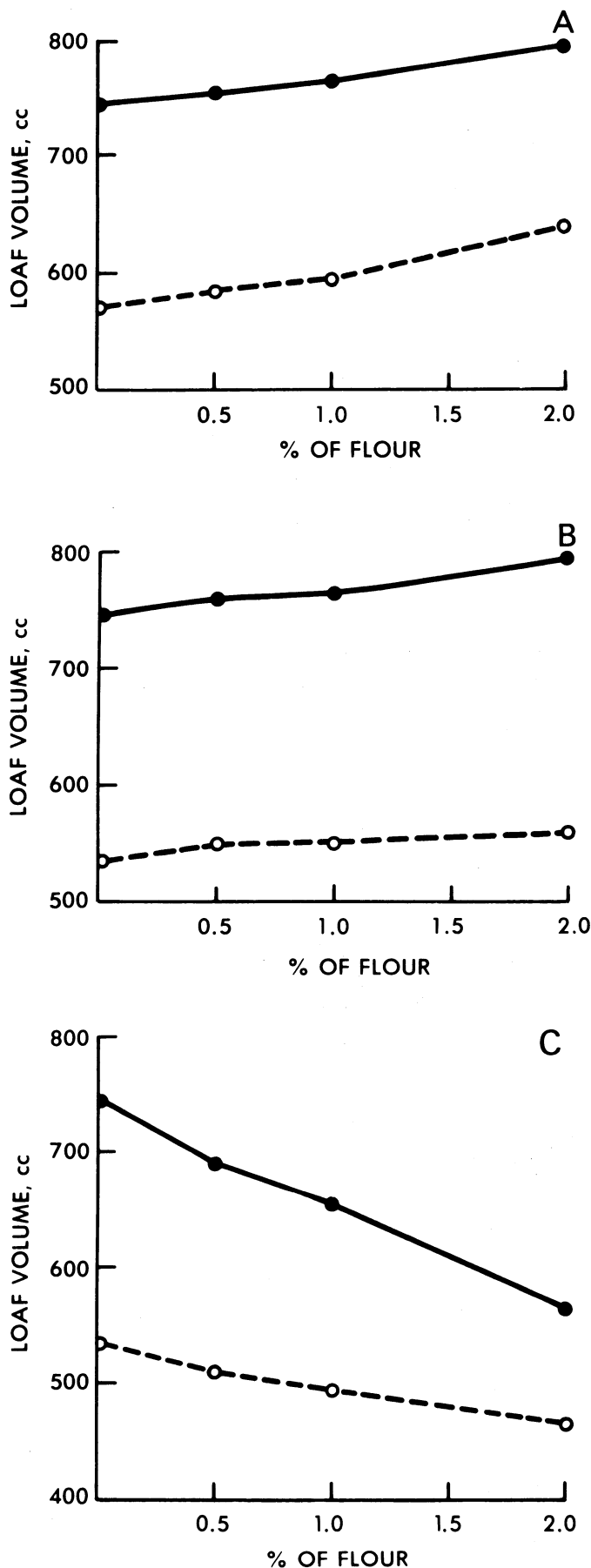
**Fig. 5.** Effects of increasing concentrations of gluten (A), acid-soluble gluten proteins (B), and acid-insoluble gluten proteins (C) upon the Grain Research Laboratory's remix loaf volume with Brazilian (--o--) and No. 1 CWRS-11.5 (--●--) flours.

**TABLE III**
**Effects of Gluten, Reconstituted Gluten,[a] and Commercial Vital Gluten on Loaf Volume**

| Flour | Loaf Volume, cc[b] | |
|---|---|---|
| | Chorleywood[c] | Remix[c] |
| Brazilian | | |
| Control | 710 | 535 |
| With addition of 2% | | |
| Gluten | 790 | 590 |
| Reconstituted gluten | 780 | 560 |
| Commercial gluten | 755 | 560 |
| 1 CW 11.5 | | |
| Control | 820 | 745 |
| With addition of 2% | | |
| Gluten | 905 | 795 |
| Reconstituted gluten | 910 | 795 |
| Commercial gluten | 890 | 795 |

[a] Reconstituted gluten consisted of 1.8 g of acid-soluble (pH 7.0 insoluble) plus 0.2 g of acid-insoluble fractions.
[b] Loaf volume based on 100 g of flour or flour plus additive on 14% mb.
[c] Grain Research Laboratory procedures.

development times and dough stability in both mixograph and farinograph tests. Previous studies by Aitken and Geddes (1938, 1939), involving the effects upon mixing properties of adding increasing levels of gluten to flours of varying quality, have shown similar effects upon dough strength. The similar effects of reconstituted and unfractionated gluten upon the mixograph and farinograph properties suggested that the inherent mixing properties of the protein fractions are not significantly altered by the fractionation procedures. Previous studies have shown that under appropriate fractionation conditions with organic acids, fractionation and reconstitution of gluten proteins did not significantly alter mixing or baking properties from those of unfractionated gluten (Goforth et al 1977, Shogren et al 1969).

Previous studies by Lee and MacRitchie (1971), MacRitchie (1972), Orth and Bushuk (1972), and Huebner and Wall (1976) have shown that in flour, the insoluble (high molecular weight) glutenins are responsible for mixing strength. However, in these studies no differentiation was made between the insoluble glutenins that disaggregated (become acid-soluble) during mixing (or gluten preparation) and the insoluble glutenins that resisted disaggregation during mixing and remained acid-insoluble. The present study indicated that the acid-insoluble gluten proteins had little effect upon mixograph properties and had a slight dough weakening effect upon farinograph properties. By contrast, the acid-soluble gluten proteins were responsible for increased dough strength properties. Comparison of these results with those of the previous studies cited above suggested that the dough-strengthening effects of the acid-soluble gluten proteins were probably associated with the acid-insoluble, high molecular weight glutenin proteins in flour that were disaggregated during gluten preparation. Presumably this disaggregation process would increase the effective surface area of these high molecular weight proteins and thus increase interprotein interactions, leading to increases in dough mixing strength.

The inability of the insoluble gluten proteins resistant to disaggregation to significantly alter mixing properties when added alone to the base flours is probably associated with their very high apparent molecular weights. This probably reduces their total effective surface areas (per unit weight) and thus restricts their ability to interact with other flour components. However, comparison of the effects of the acid-soluble gluten fraction and the reconstituted gluten showed that the acid-soluble gluten proteins were less effective, depending on the base flour, in increasing dough strength than was the reconstituted gluten. Thus although the insoluble gluten proteins are relatively inert with respect to mixing properties when added in excess, they appear to be capable of interacting with other gluten protein components, resulting in increased dough strength. One possibility is that these very high molecular weight proteins may provide stable interaction sites that are resistant to mechanical disruption and thus stabilize dough structure during mixing.

The increases in extensigraph resistance and extensibility when unfractionated gluten was added to the base flours were consistent with previous studies by MacRitchie (1973). Although increases in extensigraph area were similar for reconstituted gluten, resistances were significantly higher and extensibilities lower than for the unfractionated gluten. These differences may be attributable to a number of factors. Previous studies have suggested that the amount of water-soluble flour protein can alter dough properties (Smith and Mullen 1965). Thus the omission of the pH 7.0 soluble gluten proteins in the reconstituted gluten may be partially responsible for these differences. Studies by Webb et al (1971) have also shown that repeated lyophilization/rehydration cycles can significantly alter the relaxation times of gluten. Thus the gluten fractionation procedure may have altered the relaxation properties of the reconstituted gluten fractions. A third possibility is that rearrangement of lipid binding during the fractionation procedure may alter extensigraph properties.

The acid-soluble gluten proteins also increased extensigraph resistance over that of the control but had little effect on extensibility. The increase in resistance was probably related to the presence of the mechanically disaggregated glutenins (acid-

insoluble flour proteins) in the acid-soluble gluten fraction. During relaxation, these proteins would be expected to reaggregate, leading to increases in their effective molecular weight and a corresponding increase in dough viscosity. This explanation is consistent with MacRitchie's studies (1972, 1973), which showed that extensigraph properties are sensitive to the molecular weight distribution of the proteins.

In contrast to the relatively small effects of the acid-insoluble gluten proteins upon mixograph and farinograph properties, marked effects upon extensigraph properties (increase resistance and decreased extensibility) were observed. At present the reasons for these differences are not known. They would appear, however, to be related to the interactions of these proteins with other gluten proteins under high stress and minimal stress relaxation, such as occurs in mixing, compared to those under extensigraph conditions, which permit stress relaxation. The former conditions would tend to minimize interactions, whereas the latter conditions would maximize them.

**Effects on Baking Properties**

The baking methods used in the present study were chosen because previous experience in our laboratory had shown that they accentuate differences in loaf volume response and bread characteristics of bread wheat flours of varying quality. These differences in response can be attributed mainly to differences in dough strength characteristics.

Although the loaf volume responses showed that fractionation procedures do not alter inherent baking properties, the differences in extensigraph properties of the glutens make this lack of alteration surprising. Extensigraph properties may not, at least under the conditions of the present studies, be as good an indicator of the effects of fermentation upon dough properties as has been previously suggested (Bloksma 1971). This, in part, may be caused by the relatively short rest periods used in extensigraph studies compared to the longer fermentation and/or proof periods used in most baking procedures. Studies by Prihoda et al (1971) with the Hoeppler consistometer have shown significant changes in both dough viscosity and elasticity during 3 hr of fermentation.

Baking results showed that the acid-soluble gluten fraction was only slightly less effective than the unfractionated or reconstituted glutens in increasing loaf volumes. These results suggest that the protein components primarily responsible for baking quality are in the acid-soluble gluten fraction. Previous reconstitution studies (Harris and Frokjer 1952, Shogren et al 1969) have shown similar results.

In contrast to the effects of gluten and acid-soluble gluten, the acid-insoluble gluten fraction, with one exception, had a detrimental effect upon the baking quality (loaf volumes) of the base flours. This detrimental effect occurred only when this fraction was added in excess, however, and resulted in increases in the relative concentration of acid-insoluble gluten proteins compared to other gluten (or flour) proteins. In fact the slightly larger loaf volumes with the unfractionated and reconstituted glutens compared to those of the acid-soluble gluten fraction suggest that low levels of acid-insoluble gluten proteins may be beneficial with respect to loaf volume potential.

Previous studies by Orth and Bushuk (1972) and by Axford et al (1978), with the remix and Chorleywood baking procedures, respectively, have shown significant positive correlations between the levels of acid-insoluble (glutenin) proteins in flours and loaf volumes. Furthermore, MacRitchie's recent studies (1978) using reconstitution techniques suggested that differences in baking response are mainly caused by the more insoluble glutenin proteins. The results of the present study suggest that the acid-insoluble (glutenin) flour proteins that disaggregate during mixing (or gluten preparation), rather than the more insoluble gluten proteins resistant to mechanical disaggregation, are of major importance in determining bread-making quality.

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