# EFFECTS OF THIOLATED GELATINS AND GLUTATHIONE ON RHEOLOGICAL PROPERTIES OF WHEAT DOUGHS[1]

EVANGELINA VILLEGAS[2], Y. POMERANZ, AND J. A. SHELLENBERGER

**ABSTRACT**

Adding three thiolated gelatins varying in molecular weight and –SH content, and of glutathione, resulted in a slight decrease in farinograph absorption and in a pronounced reduction in dough development time and valorimeter value. Thiolated gelatin and glutathione increased the extensibility and decreased elasticity and extensigram areas of flours milled experimentally from four classes of wheat and of two commercially milled untreated flours. Glutathione consistently had the most detrimental effect; the low –SH-containing thiolated gelatin exerted the smallest effect. The modifications induced by the reducing agents could be reversed by adding an excess of oxidants or N-ethylmaleimide. The extent of reversibility depended on the extent of modification resulting from the action of the reducing agents. Excess of bromate or persulfate, but not of iodate or N-ethylmaleimide, was canceled on remixing. Glutathione and thiolated gelatin accelerated the rate of relaxation of strains introduced by mechanical treatment. Adding N-ethylmaleimide to doughs containing thiolated gelatin canceled the enhanced rate of relaxation; bromate reduced it less. Glutathione and high levels of thiolated gelatin of high thiol content decreased volume substantially and impaired loaf characteristics of bread baked from experimentally milled flour and a commercially milled flour.

The role and significance of reactive sulfhydryl groups in flour continue to intrigue cereal chemists in many research centers in the world (1,4,5,7,8,9). The study of the mechanism of action of reducing agents and oxidants on rheological properties has been concerned primarily with the action of the free thiol-containing cysteine or glutathione and the maturing agents bromate, persulfate, and iodate. A great amount of useful information has been obtained more recently by using specific sulfhydryl-blocking reagents, N-ethylmaleimide (NEMI) and *p*-chloromercuribenzoate (PCMB). The availability of thiol-containing compounds comparable in molecular weight to flour proteins such as thiolated gelatin prepared according to the procedure of Benesch and Benesch (2) or relatively simple techniques for the production of thiolated flour presents a new tool for study of the effect of –SH groups on dough properties (6). McDermott and Pace (7) found that adding thiolated gelatin modified load-extension curves of

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wheat flour doughs, whereas the effect of normal gelatin was insignificant. Bushuk and Hlynka (3), however, found that doughs containing as much as 2.5 $\mu$moles –SH per g. of flour in the form of thiolated gelatin felt no different from control doughs.

In the present study the effects of thiolated gelatins varying in molecular weight and –SH content on the rheological properties and bread-baking potentialities of wheat doughs have been investigated. Additionally, the effects of oxidants on reversibility of Thiogel-induced changes in flour doughs were studied.

## Materials and Methods

Two samples of untreated patent flour, commercially milled from hard red winter wheat, were used. The composition and characteristics of the flours are given in the table below: Additionally, four samples

| *Sample* | *Protein Content (N × 5.7)* | *Ash* | *Farinograph Absorption* |
|---|---|---|---|
| | % | % | % |
| A | 11.9 | 0.43 | 64.9 |
| B | 14.4 | 0.39 | 62.4 |

of wheat were milled on a Miag Multomat[3] mill; see table below for their characteristics. The thiolated gelatins were purchased from

| | *Extraction* | *Protein Content (N × 5.7)* | *Ash* | *Farinograph Absorption* |
|---|---|---|---|---|
| | % | % | % | % |
| Hard red winter | 73.2 | 10.7 | 0.43 | 66.4 |
| Soft red winter | 70.9 | 9.1 | 0.36 | 56.0 |
| Northern spring | 72.7 | 13.1 | 0.44 | 64.6 |
| Durum | 67.0 | 11.9 | 0.56 | 63.6 |

Schwarz BioResearch, Inc., Mount Vernon, N.Y. Their properties are listed below. The gelatin used in this study was purchased from

| | *Average Molecular Weight* | *–SH Equivalents in 100,000 g.* |
|---|---|---|
| Thiogel A | 10,000 | 14.2 |
| Thiogel B | 100,000 | 13.3 |
| Thiogel C | 100,000 | 3.2 |

Difco Lab., Inc., Detroit, Mich. The oxidizing, –SH-blocking, and reducing agents employed were of analytical reagent grade and were purchased from Nutritional Biochemical Corp., Cleveland, Ohio, or from Fisher Scientific Co., St. Louis, Mo.

Farinograms were made by mixing 50 g. of flour in a small stainless-steel farinograph bowl (56-r.p.m. drive) with sufficient distilled water

[3]Mention in this publication of a trade product, equipment, or a commercial company does not imply its endorsement by the U.S. Department of Agriculture over similar products or companies not named.

to give a maximum dough consistency centered around the 500-B.U. line. From the results obtained, the absorption, dough development time, and valorimeter value were computed. Extensigrams were obtained by mixing 300 g. flour, 6 g. salt, and distilled water equal to the farinograph absorption (corrected for the salt and use of the large bowl). Thiolated gelatin, if added, was dissolved in part of the water. Doughs were mixed for 1 min., rested 5 min., and remixed until centered around 500 B.U. All doughs were nonyeasted. After the dough was removed from the farinograph bowl, two 150-g. portions were scaled, each rounded 20 times, moulded into dough cylinders, and placed in the extensigraph cabinets at 30°C. Curves were drawn for duplicate doughs at 45, 90, and 135 min. To test the effects of oxidants or NEMI on doughs previously reacted with reducing agents, the doughs were remixed for 3 min. at low speed in the farinograph to incorporate the oxidant or NEMI, moulded, rested for 135 min. in the extensimeter cabinet, and stretched. For relaxation studies, two batches of dough, each from 300 g. of flour, were prepared. Six dough pieces for following the relaxation process were scaled and moulded. One piece was stretched after a 45-min. rest. The other dough pieces were remoulded and stretched immediately or after time intervals of 5, 15, 30, or 45 min. after moulding.

The baking experiments were on a laboratory scale employing the straight-dough procedure. The basic formula was:

| *Ingredients* | *Parts* |
|---|---|
| Flour | 100 |
| Water | variable |
| Yeast | 2 |
| Sucrose | 6 |
| Malted wheat flour | 0.5 |
| Shortening | 3 |
| Sodium chloride | 2 |
| Reducing agents | as indicated |

After they were mixed to optimum consistency, the doughs were fermented at 30°C. After 110 min. the doughs were punched, and 50 min. later punched again, divided, rested for 20 min. and moulded. The doughs were proofed at 30°C. for 45 min. and baked for 25 min. at 210°C. After baking, the loaf volume was measured, and after cooling, the loaves were scored for crust color, symmetry, break and shred, texture, grain, and crumb color.

## Results and Discussion

The effects of thiolated gelatin on farinograph characteristics of flours are shown in Table I. Comparison of the effects of the Thiogels

TABLE I

EFFECTS OF 0.5% THIOGEL ON FARINOGRAPH CHARACTERISTICS OF FLOURS

| REAGENT AND LEVEL | COMMERCIAL H.R.W. | | | EXPERIMENTAL H.R.W. | | | EXPERIMENTAL S.R.W. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Absorption | Dough Devel. Time | Valorimeter Value | Absorption | Dough Devel. Time | Valorimeter Value | Absorption | Dough Devel. Time | Valorimeter Value |
| *μmoles SH/g.* | % | *min.* | | % | *min.* | | % | *min.* | |
| ...... | 67.4 | 13.0 | 88 | 66.4 | 8.0 | 76 | 56.0 | 9.5 | 81 |
| Gelatin, 0 | 66.9 | 13.5 | 89 | 69.0 | 10.0 | 82 | 57.6 | 6.0 | 69 |
| Thiogel A, 0.71 | 66.0 | 7.5 | 75 | 65.0 | 5.0 | 66 | 55.8 | 5.5 | 68 |
| Thiogel B, 0.66 | 65.0 | 4.5 | 64 | 64.0 | 4.0 | 61 | 57.2 | 3.0 | 56 |
| Thiogel C, 0.16 | 65.0 | 10.0 | 82 | 66.0 | 6.0 | 69 | 57.2 | 5.5 | 71 |

| REAGENT AND LEVEL | EXPERIMENTAL H.R.S. | | | EXPERIMENTAL DURUM | | |
|---|---|---|---|---|---|---|
| | Absorption | Dough Devel. Time | Valorimeter Value | Absorption | Dough Devel. Time | Valorimeter Value |
| | % | *min.* | | % | *min.* | |
| ...... | 64.4 | 11.0 | 85 | 63.6 | 3.5 | 59 |
| Gelatin, 0 | 66.2 | 11.5 | 85 | 64.8 | 3.0 | 58 |
| Thiogel A, 0.71 | 64.4 | 7.0 | 73 | 62.4 | 3.0 | 55 |
| Thiogel B, 0.66 | 64.2 | 6.0 | 70 | 62.6 | 2.5 | 53 |
| Thiogel C, 0.16 | 65.0 | 9.5 | 81 | 63.0 | 3.0 | 56 |

with either the control or the gelatin-containing flours shows a small decrease in water absorption. No consistent effect on water absorption has been recorded, however, among the three tested Thiogels themselves. It is significant, however, that the Thiogels caused a decrease in the dough development time, as might be expected if these agents act as typical dough-reducing agents. Thiogel B had the greatest and Thiogel C the least effect on decrease of either dough development time or valorimeter value. The slightly more pronounced effects of Thiogel B than of Thiogel A might be due to the higher stability of the high-molecular Thiogel B during prolonged mixing.

The effects of thiolated gelatin on extensigraph characteristics of hard red spring wheat flour are summarized and compared with the action of reduced glutathione, in Table II. Similar results were obtained for the flours milled from the other three wheat samples. At the levels employed, the three Thiogels increased the extensibility of the tested doughs to an extent comparable with the action of glutathione. Glutathione had, however, a much more pronounced effect similar to that normally associated with reducing agents. Under the experimental conditions employed, there was no consistent difference between the actions of thiolated gelatins with molecular weights of 10,000 or 100,000 provided they did not differ in thiol content. Adding excess bromate to doughs previously treated with reducing agents showed that the extent of modification and potential reversal of this modifi-

TABLE II

EFFECTS OF 0.5% THIOLATED GELATINS AND OF GLUTATHIONE ON RHEOLOGICAL PROPERTIES OF HARD RED SPRING WHEAT FLOUR DOUGHS

| Reagent and Level | Extensigraph Data[a] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | After 45 min. | | After 90 min. | | After 135 min. | | 135 min. after Addition of $KBrO_3$[b] | |
| | A | B | A | B | A | B | A | B |
| *μmoles SH/g.* | | | | | | | | |
| ...... | 20 | 143 | 12 | 123 | 12 | 141 | 15 | 145 |
| Gelatin, 0 | 22 | 151 | 13 | 141 | 13 | 139 | 16 | 153 |
| Thiogel A, 0.71 | 23 | 73 | 23 | 77 | 26 | 120 | 26 | 192 |
| Thiogel B, 0.66 | 21 | 104 | 22 | 130 | 22 | 133 | 21 | 140 |
| Thiogel C, 0.16 | 25 | 226 | 22 | 254 | 18 | 217 | 16 | 177 |
| Glutathione, 0.66 | 25 | 31 | 26 | 41 | 25 | 87 | 24 | 38 |

[a] A = length, cm.; B = area, cm.$^2$
[b] $KBrO_3$ equivalent to 300% of added –SH groups.

cation by oxidants varied with the reducing agent used. Whereas adding glutathione resulted in a significant, irreversible change in rheological characteristics as assessed by the extensigraph, the changes introduced by the thiolated gelatins could be partially reversed. It is feasible that the difference in action between the thiolated gelatins and glutathione is a result of the association of the former with the wheat gluten, as observed by McDermott and Pace (7). Such an association would tend to confine the action of thiolated gelatins to a limited number of sites on the wheat protein molecule. The justification for employing an excess of oxidant is shown in the data summarized in Table III. Levels of bromate as high as equivalent to 100% of added –SH groups (in the form of thiolated gelatin) resulted in no

TABLE III

EFFECTS OF DIFFERENT LEVELS OF $KBrO_3$ ON UNTREATED COMMERCIALLY MILLED FLOUR (SAMPLE A) CONTAINING 0.5% THIOGEL B

| Reagent and Level | $KBrO_3$[b] | Extensigraph Data[a] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | After 45 min. | | After 90 min. | | After 135 min. | | 135 min. after Addition of $KBrO_3$ | |
| | | A | B | A | B | A | B | A | B |
| *μmoles SH/g.* | | | | | | | | | |
| ...... | .. | 20 | 160 | 13 | 140 | 11 | 120 | 15 | 137 |
| Gelatin, 0 | .. | 20 | 172 | 14 | 157 | 12 | 134 | 14 | 116 |
| Thiogel B, 0.66 | .. | 20 | 147 | 19 | 147 | 19 | 161 | 21 | 144 |
| Thiogel B, 0.66 | 25 | 20 | 122 | 19 | 133 | 21 | 140 | 21 | 144 |
| Thiogel B, 0.66 | 50 | 20 | 128 | 19 | 140 | 20 | 134 | 22 | 146 |
| Thiogel B, 0.66 | 100 | 19 | 124 | 19 | 133 | 21 | 133 | 21 | 143 |

[a] A = length, cm.; B = area, cm.$^2$
[b] Equivalent to % of the thiol groups added.

measurable reversal of the action of the reducing agent. A more detailed and extensive study of the effect of oxidants on Thiogel-treated doughs is given in Table IV. The reaction time of the reducing agents

TABLE IV

EFFECTS OF OXIDANTS AND NEMI ON RHEOLOGICAL PROPERTIES OF A COMMERCIALLY MILLED FLOUR (SAMPLE A), TREATED WITH REDUCING AGENTS

| Reagent | Level | Oxidant or NEMI | Oxidant Level | Farinograph Data: Absorption | Farinograph Data: Dough Devel. Time | Extensigraph Data[a]: A | Extensigraph Data[a]: B |
|---|---|---|---|---|---|---|---|
| | *µmoles SH/g.* | | *mg./g.* | *%* | *min.* | | |
| ...... | | .... | .... | 66.4 | 14.5 | 19 | 125 |
| 0.5% gelatin | | .... | .... | 66.0 | 11.5 | 21 | 145 |
| | | $KBrO_3$ | 0.333 | 66.4 | 15.5 | 18 | 121 |
| | | $(NH_4)_2S_2O_8$ | 0.455 | 66.4 | 13.0 | 15 | 119 |
| | | $KIO_3$ | 0.427 | 66.4 | 14.5 | 12 | 88 |
| | | NEMI | 0.250 | 66.4 | 14.5 | 12 | 74 |
| Thiogel B | 0.66 | .... | .... | 62.8 | 2.5 | 22 | 106 |
| | | $KBrO_3$ | 0.333 | 62.8 | | 22 | 155 |
| | | $(NH_4)_2S_2O_8$ | 0.455 | 62.8 | | 14 | 109 |
| | | $KIO_3$ | 0.427 | 62.8 | | 9 | 90 |
| | | NEMI | 0.250 | 62.8 | | 10 | 82 |
| Glutathione | 0.66 | .... | .... | 65.2 | 4.0 | 24 | 66 |
| | | $KBrO_3$ | 0.333 | 65.2 | | 24 | 78 |
| | | $(NH_4)_2S_2O_8$ | 0.455 | 65.2 | | 25 | 128 |
| | | $KIO_3$ | 0.427 | 65.2 | | 19 | 83 |
| | | NEMI | 0.250 | 65.2 | | 21 | 48 |

[a] A = length, cm.; B = area, $cm.^2$

with the flours was 45 min., and stretching with the extensigraph was carried out after an additional reaction time of 135 min. The large excess of either bromate or persulfate (in the absence of reducing agents) had no deleterious effect on the doughs, probably because of remixing after the first rest period. In the case of iodate and NEMI, the remix did not reverse the deleterious effect of excess oxidant or –SH-blocking reagent. Again, adding oxidants to Thiogel-treated flours reversed the effect of reducing agent on rheological properties of the dough. No measurable effect has been observed when any of the oxidants or NEMI was added to glutathione-treated flour.

The effects of adding oxidants and NEMI to a commercial flour are given in Table V. The flours were mixed in the farinograph bowl with the reducing agents, sodium chloride, and water required to center the consistency around the 500-B.U. line. After a reaction time of 45 min. in bulk in the extensigraph, the doughs were remixed for 3 min. at low speed with the oxidizing agents or NEMI. After scaling, the doughs were moulded and shaped, rested for 135 min., and stretched.

TABLE V

EFFECTS OF OXIDANTS AND NEMI ON RHEOLOGICAL PROPERTIES OF A COMMERCIALLY MILLED FLOUR (SAMPLE B), TREATED WITH REDUCING AGENTS

| Reagent and Level | Extensigraph Data[a] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Controls | | $KBrO_3$[b] | | $KIO_3$[b] | | NEMI[b] | |
| | A | B | A | B | A | B | A | B |
| *μmoles SH/g.* | | | | | | | | |
| ...... | 19 | 182 | 18 | 145 | 13 | 128 | 12 | 76 |
| Gelatin | 21 | 176 | 21 | 168 | 20 | 112 | 19 | 115 |
| Thiogel A, 0.71 | 27 | 132 | 28 | 218 | 12 | 99 | 15 | 107 |
| Thiogel B, 0.66 | 28 | 146 | 26 | 191 | 12 | 114 | 16 | 133 |
| Thiogel C, 0.16 | 19 | 161 | 16 | 127 | 11 | 97 | 11 | 84 |
| Glutathione, 0.66 | 23 | 39 | 25 | 75 | 21 | 102 | .. | .. |

[a] A = length, cm.; B = area, cm.$^2$
[b] Equivalent to 300% of –SH content of Thiogel B.

Doughs to which NEMI was added after previous reaction with glutathione were difficult to handle. Results of that series are, therefore, omitted. The over-all picture is similar to that recorded with the experimentally milled flours.

The rate of relaxation in doughs following the introduction of strains was studied in a flour treated with the three Thiogels and glutathione and compared with either the control or the gelatin-containing flours. Figure 1 shows that balling and shaping introduced

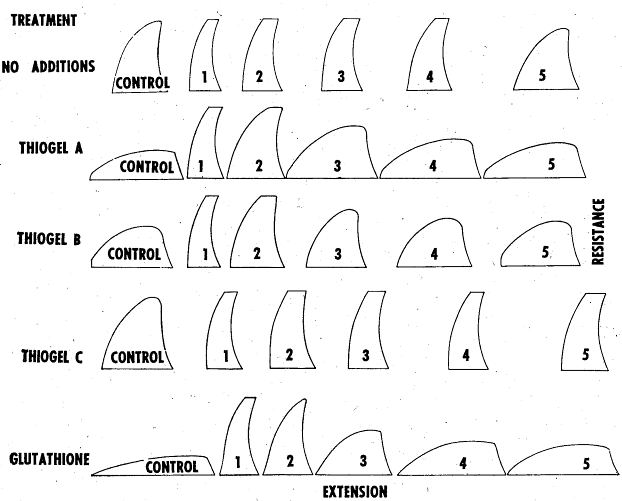


Fig. 1. Extensigrams of doughs tested at various time intervals after moulding. The reagents were added at levels of 0.71, 0.66, 0.16, and 0.66 μeq. –SH per g. of flour, for Thiogel A, B, C, and glutathione, respectively. Control was stretched 45 min. after moulding; doughs 1, 2, 3, 4, and 5 were stretched immediately, 5, 15, 30, and 45 min., respectively, after moulding at the end of the initial 45-min. rest period.

strains that resulted in a dough markedly toughened and shortened. These strains relaxed only slowly in the control doughs. Adding reducing agents did not prevent the buildup of strains in the dough after balling and shaping but allowed these strains to relax more and at a faster rate than in the control.

In Table VI are summarized the data of the effects of bromate and

TABLE VI

EFFECTS OF $KBrO_3$ AND NEMI ON RATE OF RELAXATION OF A COMMERCIALLY MILLED FLOUR (SAMPLE A), TREATED WITH 0.5% THIOGEL B (0.66 μMOLES –SH/G. FLOUR)

| Reagent | Level of Reagent[a] | | Control[b] | Doughs 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| $KBrO_3$ | 12.5 | A[c] | 18 | 8 | 10 | 10 | 11 | 15 |
| | | B | 173 | 94 | 119 | 116 | 134 | 175 |
| $KBrO_3$ | 100 | A | 18 | 8 | 9 | 12 | 12 | 13 |
| | | B | 189 | 90 | 109 | 142 | 142 | 165 |
| NEMI | 100 | A | 12 | 7 | 9 | 8 | 9 | 10 |
| | | B | 140 | 80 | 105 | 92 | 100 | 104 |

[a] Equivalent to % of the thiol groups added.
[b] Control was stretched 45 min. after moulding; doughs 1, 2, 3, 4, and 5 were stretched immediately, 5, 15, 30, and 45 min. rest after moulding at the end of the initial 45 min. rest period.
[c] A, length, cm.; B, area, cm.$^2$

TABLE VII

EFFECTS OF REDUCING AGENTS ON BAKING CHARACTERISTICS OF A COMMERCIALLY MILLED FLOUR (SAMPLE B)

| Reagent | Level | Loaf Volume | Total Score |
|---|---|---|---|
| *g./100 g. flour* | *μmoles SH/g.* | *ml.* | |
| ...... | .. | 945 | 89 |
| Gelatin | | | |
| 0.10 | 0 | 1005 | 91 |
| 0.25 | 0 | 1015 | 89 |
| 0.50 | 0 | 1005 | 89 |
| 1.00 | 0 | 965 | 89 |
| Thiogel A | | | |
| 0.10 | 0.14 | 975 | 88 |
| 0.25 | 0.36 | 915 | 86 |
| 0.50 | 0.71 | 810 | 82 |
| 1.00 | 1.42 | 710 | 68 |
| Thiogel B | | | |
| 0.10 | 0.13 | 915 | 84 |
| 0.25 | 0.33 | 970 | 86 |
| 0.50 | 0.66 | 875 | 85 |
| 1.00 | 1.32 | 800 | 84 |
| Thiogel C | | | |
| 0.10 | 0.03 | 995 | 88 |
| 0.25 | 0.08 | 970 | 87 |
| 0.50 | 0.16 | 1005 | 87 |
| 1.00 | 0.32 | 985 | 88 |
| Glutathione | | | |
| 0.004 | 0.13 | 910 | 86 |
| 0.010 | 0.33 | 785 | 81 |
| 0.020 | 0.66 | 650 | 69 |
| 0.040 | 1.32 | 560 | 53 |

NEMI on relaxation studies of doughs treated with Thiogel B. NEMI decreased the rate of relaxation to a larger extent than did bromate, a slow oxidizing agent. Frater *et al.* (4) suggested that the major effect of NEMI or of iodate was to stabilize the strained and/or oriented structure normally introduced into the dough during balling and shaping. The rapid action of NEMI in blocking –SH groups does not permit the dough to relax as does bromate that has a slow action.

The baking test was performed with a commercially milled flour (sample B) treated with gelatin, the three Thiogels, and glutathione at different levels. The results are presented in Table VII. Thiogel A and B at the 0.5% and 1% levels decreased the loaf volume and affected the other bread characteristics somewhat. Thiogel C seemed to have under certain conditions a slight improving effect. Glutathione added at a comparable sulfhydryl level had a detrimental effect throughout the whole course of the baking process; the loaf volume was considerably decreased and the bread characteristics were affected adversely.

Baking tests of the four experimentally milled flours containing the reducing agents are summarized in Table VIII. The effects of the

TABLE VIII

EFFECTS OF REDUCING AGENTS ON BAKING CHARACTERISTICS OF EXPERIMENTALLY MILLED FLOURS

| FLOUR | REAGENT | LOAF VOLUME | TOTAL SCORE |
|---|---|---|---|
| | *μmoles SH/g.* | *ml.* | |
| Hard red winter | ... | 780 | 81 |
| Gelatin, 0.25% | 0 | 850 | 83 |
| Thiogel A | 0.35 | 775 | 82 |
| Thiogel B | 0.33 | 790 | 83 |
| Thiogel C | 0.08 | 795 | 80 |
| Glutathione | 0.33 | 705 | 75 |
| Soft red winter | ... | 710 | 72 |
| Gelatin, 0.25% | 0 | 750 | 77 |
| Thiogel A | 0.35 | 700 | 72 |
| Thiogel B | 0.33 | 690 | 72 |
| Thiogel C | 0.08 | 725 | 76 |
| Glutathione | 0.33 | 695 | 75 |
| Northern spring | ... | 900 | 84 |
| Gelatin, 0.25% | 0 | 905 | 87 |
| Thiogel A | 0.35 | 875 | 88 |
| Thiogel B | 0.33 | 835 | 86 |
| Thiogel C | 0.06 | 965 | 92 |
| Glutathione | 0.33 | 810 | 86 |
| Durum | ... | 675 | 73 |
| Gelatin, 0.25% | 0 | 660 | 72 |
| Thiogel A | 0.35 | 650 | 68 |
| Thiogel B | 0.33 | 550 | 59 |
| Thiogel C | 0.06 | 665 | 69 |
| Glutathione | 0.33 | 550 | 54 |

reducing agents depended on the kind of flour used. Whereas glutathione had a consistently high detrimental effect, the thiolated gelatins varied in their effect on the different flours. High levels of Thiogel A or B decreased loaf volume and bread quality appreciably. Thiogel C, low in –SH content, had little or no effect on flours milled from hard red winter, soft red winter, or durum wheat. Both the commercially milled strong flour and the experimentally milled flour from northern spring wheat seem to be improved slightly by the addition of Thiogel C. This effect is comparable to that observed on addition of very low levels of proteases and seems to be a mellowing effect of the "bucky" high-protein flour.

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