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# Preliminary Investigation into the Effect of Some Bakery Improvers in the Rheology of Bread Wheat Dough †

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**Abstract:** Wheat flour quality varies largely, affecting the quality of the final baked products. In order to fulfil the consumer's demand for bakery products with high quality and extended shelf-life different types of improvers have been used in the bakery industry. This study aimed to investigate the effect of different bread improvers on rheological parameters of dough made from all-purpose wheat flour comparing that with strong, soft, extra-soft and pastry wheat flour.

**Keywords:** wheat flour; improvers; alveograph; dough rheology; extensograph; farinograph

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## 1. Introduction

Wheat flour quality varies largely affecting the quality of final baked products. In order to meet the consumer's demand for bakery products with high quality and extended shelf-life different types of improvers have been used from the bakery industry[1]. Thus, improvers are used to standardize the wheat flour in terms of technological quality (i.e., gluten strength, color, fermentability etc.). Improvers are added to improve dough handling properties and bread quality. Gluten is essential for the formation of a three dimensional network during dough formation and responsible for dough elasticity, stability and resistance.

Among the improver's oxidants are generally recognized to strengthen gluten network by formation of disulfide bonds[2]. Ascorbic acid (AA) has gained an important role as improver not only due to its strong oxidizing effect on dough and improver of bread crumb structure that increases its volume but also because it is recognized as being a vitamin by the consumers[3–5]. Discrepancies exists among the authors about the levels used in order to improve final bread quality [3,6]. Besides the level, other factors such as the initial quality of flour and the breadmaking procedure affect the final bread quality [7].

Citric acid (CA) another bread improver was reported to be used alone or in combination with other dough improvers in bread-making when one has to deal with extremely low-quality wheat flour because it increases gluten strength [4,8]. According to Galal, et al. [9] and Damodaran and Kinsella [10] the strengthening of gluten from addition of CA was associated with dough acidification during which hydrogen anions derived from acid create bonds with negatively charged parts of amino acids altering the overall protein charge.

L-cysteine that exists naturally in wheat flour, is used as food additive and considered a reducing agent with GRAS status. According to Lagrain, et al. [11]low concentrations of reducing agent facilitates gliadin–glutenin cross-linking during heating. In their review article Abedi and Pourmohammadi [12] suggested that improvement of extensibility, machinability, and adhesiveness and the reduced elastic (G′) and viscous (G″) moduli, tolerance to mixing, and mixing time observed from other authors [1,13,14] upon addition of cysteine are due to (i) breaking of cross-links and depolymerization, (ii) increased sulphydryl (SH)–disulfide (SS) interchange reactions, (iii) progressive water hydration capacity as a result of conformational changes, and (iv) reduced surface hydrophobicity.

The demand for a wide range of bread types increases the need of baking industry to alter the structure as well the viscoelastic properties of doughs. The dough properties are generally studied as predictors of its functional behavior in bread-making using equipment such as alveograph, farinograph and extensograph.

The present work aimed to investigate the effect of different bread improvers on rheological parameters of dough made from one commercial all-purpose wheat flour and compare those with that of strong, soft, extra-soft and pastry wheat flour.

## 2. Materials and Methods

### *2.1. Materials*

Four conventional flours were used for the research and one all-purpose wheat flour (Papafilis, Corinth, Greece) was used as control (humidity 13%, wet gluten 29.2%, protein dry matter 11.64% an ash 0.554%). The four commercial flours used are: strong wheat flour (STWF) (Papafilis, Corinth, Greece) with humidity of 13.9%, soft wheat flour (SOWF) (Papafilis, Corinth, Greece) with humidity of 14.1%, extra soft wheat flour (ESWF) (Papafilis, Corinth, Greece) with humidity of 14% and pastry flour (PWF) (Papafilis, Corinth, Greece) with humidity of 13.5%. Ascorbic acid (AA) was obtained from Kalas Papadopoulos, Athens, Greece, citric acid from Kalas Papadopoulos, Athens, Greece and L-cysteine (CYS) from Kalas Papadopoulos, Athens, Greece. NaCl was obtained from Kalas Papadopoulos, Athens, Greece. For the preparation of the doughs distilled water was added. Commercial samples have improvement agents from the beginning. Improvement agents are purchased from Frantzeskakis company, Greece.

### *2.2. Alveograph Tests*

Alveograph measurements were performed according to the method AACC International Method 54-30.02 (2010). For the alveograph, the improvers used are ascorbic acid (AA) at levels 30 and 60 ppm, citric acid (CA) at levels 10 and 20 ppm and L-cysteine (CYS) at levels 20 and 40 ppm. Firstly, 250 g of wheat flour were weighed and placed into the mixing bowl, adding 13.00 mL of water with the help of the pipette and the alveogram begins. After 8 min the alveograph beats and the process begins to cut five equal dough pieces. At the end of 28 min the machine makes the process of puffing the doughs with air pressure, in this way the set of curves that have been created is given and thus the graph is produced. The following parameters were obtained: P (dough tenacity or maximum overpressure), L (dough biaxial extensibility or abscissa at rupture), W (deformation energy), P/L (configuration ratio). Measurements were performed in duplicate.

### *2.3. Farinograph Tests*

Doughs fortified with ascorbic acid (AA) at levels 30 and 60 ppm, citric acid (CA) at levels 10 and 20 ppm and L-cysteine (CYS) at levels 20 and 40 ppm, calculated on a flour dry weight basis, were tested according to the ICC-standard method 115/1 (1992). Each improver in a dry powder form was first mixed well with the wheat flour into the mixing bowl (300 g) of the farinograph (Brabender, Duisburg, Germany) that was connected with a circulating water pump and a thermostat which operated at 30 ± 0.2 °C. The following parameters were obtained from farinograph: farinograph water absorption (WA), dough development time (DT), and dough stability (DS). Measurements were performed in duplicate.

*2.4. Extensograph Tests*

The control and the doughs enriched with improvers were prepared in the 300 g mixing bowl of the Farinograph (Brabender, Duisburg, Germany). The wheat flour was first mixed well with the improvers at different concentration levels as reported for farinograph measurements, before salt (1%) and water addition, to produce the dough samples. For extensograph measurements, the water added was that needed to produce dough with a consistency of 500 BU (Brabender Units), after 5 min of mixing. Dough (150 g) was first rounded into a ball and then shaped into a cylinder before clamped into the holder and remained to mature for 45, 90 and 135 min in total. Each dough piece was stretched in the Brabender Extensograph by a hook until rupture according to ICC-Standard 114/1 method (1992) after 45, 90 and 135 min resting times in the Extensograph cabinet at 30–32 °C. The following parameters were obtained from the graph: resistance to constant deformation after stretching (R), extensibility(E) and Energy (A). Measurements were performed in duplicate.

*2.5. Statistical Analysis*

Characteristics of the various dough preparations were compared with analysis of variance (ANOVA) followed by Tukey's HSD *post hoc* comparisons at a 0.05 significant level by using SPSS v20 (IBM Corp., Armonk, NY, USA).

## 3. Results and Discussion

Alveograph and farinograph results are shown in Figure 1 and Figure 2 respectively. As depicted, dough tenacity of the control (94.9 ± 1.5 mm) differs statistically (ANOVA F = 415.7, $p < 0.05$) from the 30 and 60 ppm ascorbic acid doughs (120 ± 1.2 mm and 110 ± 1.9 mm) as well as from 20 and 40 pm L-cysteine dough preparations (74.9 ± 2.5 mm and 62 ± 2.8 mm). Significant differences were also observed in doughs with commercial flours, since their values of tenacity ranged from 42 ± 1.6 mm for PWF to 80 ± 2.1 mm for STWF. In general, and at the levels used**,** AA increased the dough tenacity and decreased the dough biaxial extensibility (ANOVA F = 616.4, $p < 0.05$) whereas the opposite was observed for CYS as indicated on the respective graph with *post hoc* multiple comparisons (Tukey's HSD). On the other hand, CA addition did not significantly affect the dough tenacity (92 ± 1.3 mm and 95 ± 2.8 mm for 10 and 20 ppm citric acid preparations) but decreased biaxial extensibility (control: 77.4 ± 0.6 mm, CA 10 ppm: 75 ± 2 mm, CA 20 ppm: 70.9 ± 2.1 mm). Extensograph measurements showed that the resistance to deformation was increased compared to control (215 ± 5.1 EU after 90 min resting) when AA (365 ± 5.2 EU for AA30 and 460 ± 9.2 EU for AA60) and CA (230 ± 5.7 EU for CA10 and 250 ± 1.1 for CA20) were added but decreased with the addition of CYS (170± 3.9 EU for CYS20 and 130± 4.7 EU for CYS40) (Table 1). Although the water absorption level was not affected by the addition of improvers (ANOVA F = 1.8, $p > 0.05$) the dough development time was decreased (ANOVA F = 6.43, $p < 0.05$). AA increased (but not significantly) the stability whereas CA and CYS decreased it (ANOVA F = 45.76, $p < 0.05$). Variations were observed due to the addition of improvers. They altered the rheology of the control dough but were not able to resemble all the rheological characteristics of the commercial special flours used for comparative reasons in this study.

All these occurred, because AA does not act directly on the protein but it may seem like a protective factor against loss of protein stability in the presence of glutathione, a reducing (softening) agent, which occurs normally in the flour. This is only possible if the (E300) is oxidized in the beginning in dehydroascorbic acid (DHAA). In this process, the glutathione is oxidized to glutathione disulfide, eliminating thus the softening effect of glutathione. Furthermore, CA is a pH regulator for this and the dough tightens, but the dough length decreases. This is the reason why the addition of these improvers makes the dough stronger, but the extensibility is lower.

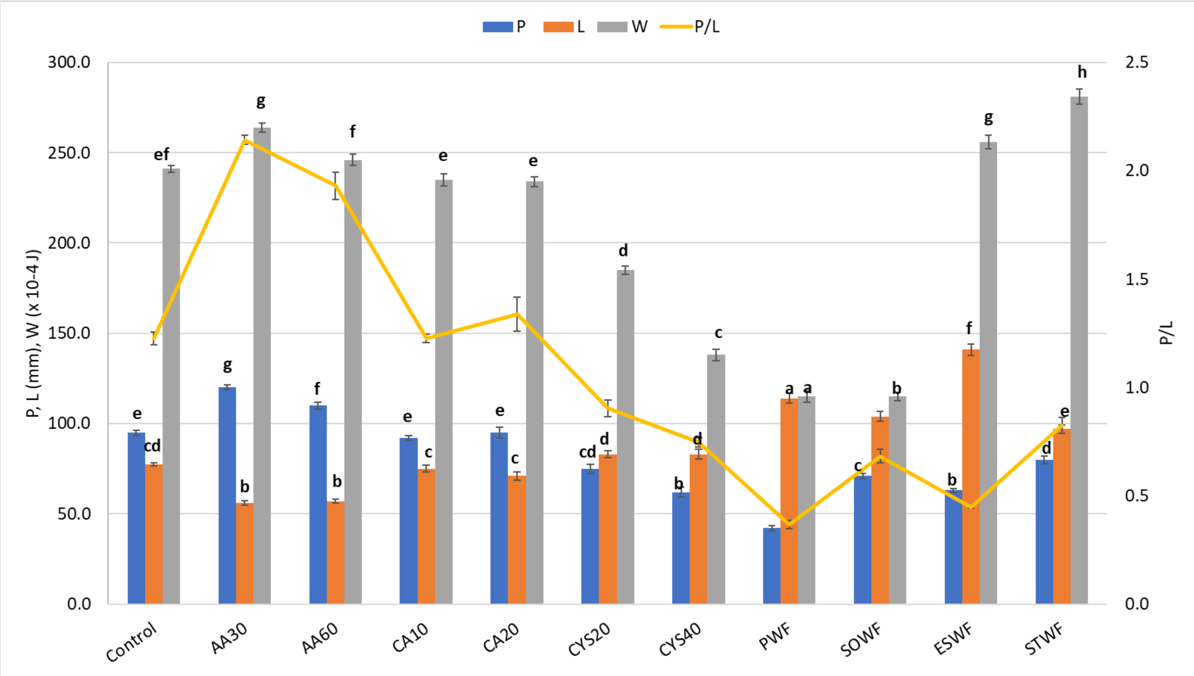


**Figure 1.** Variation of dough tenacity or maximum overpressure (P), average abscissa to rupture dough or biaxial extensibility (L), deformation energy (W) and the configuration ratio (P/L) of flours and control flour with added improvers (Ascorbic acid: AA30, AA60, Citric acid: CA10, CA20, L-Cysteine CYS20, CYS40). Similar letters over graph bars indicate no statistical difference for each particular characteristic of the various dough preparations (ANOVA with Tukey's HSD multiple comparisons, $p < 0.05$).

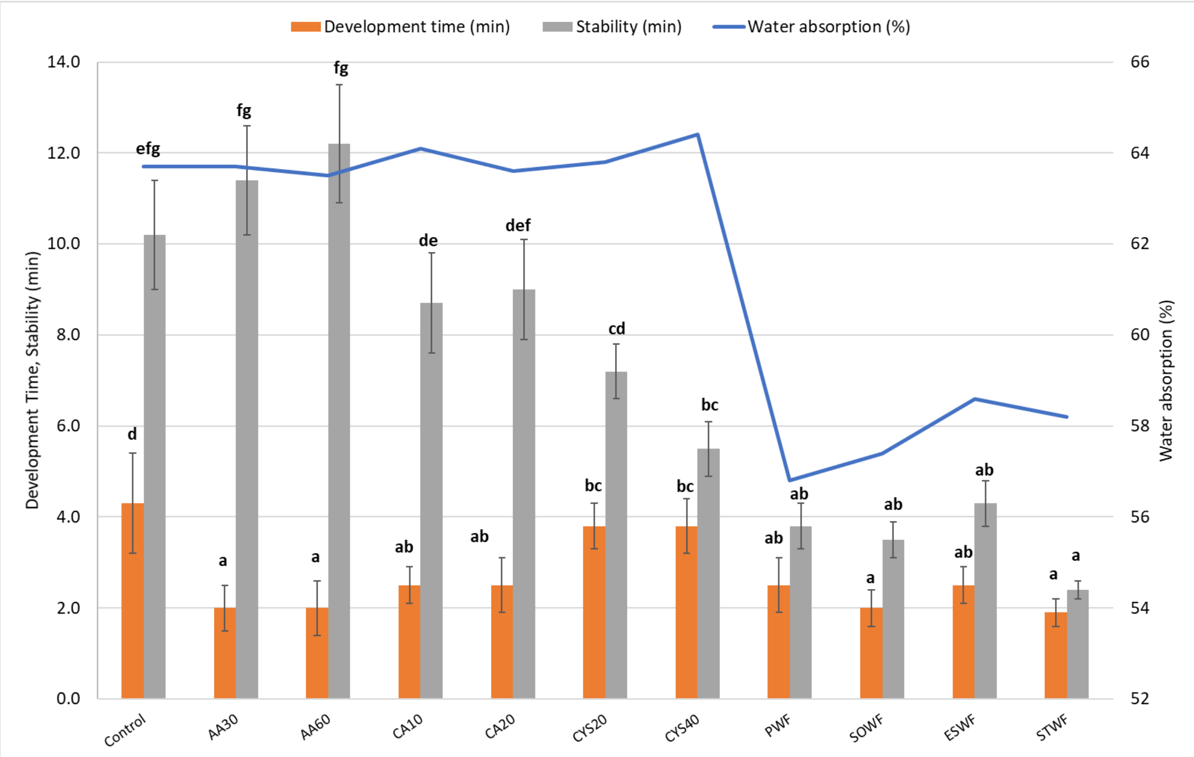


**Figure 2.** Variation of dough development time, stability and water absorption of flours and control flour with added improvers (Ascorbic acid: AA30, AA60, Citric acid: CA10, CA20, L-Cysteine CYS20, CYS40). Similar letters indicate no statistical difference for each particular characteristic of the various dough samples (ANOVA with Tukey's HSD multiple comparisons, $p < 0.05$).

Finally, CYS, that is the Cysteine amino acid dimmers, where two Cysteine molecules are connected by a disulfide bridge. This sulfur bridge gives to molecule a certain oxidizing effect. But in low doses it is possible for gluten to soften as the reducing Cysteine is released when Cysteine reacts with the thiol groups of protein Lagrain, et al. [11]. Even though L-cysteine naturally exists in wheat flour, it can be commonly and extensively employed as food additive with GRAS status [15] as a reducing agent. That's why the extensibility is bigger and the dough is softer.

**Table 1.** Extensograph parameters of flours and control flour with added improvers.

| | Energy (cm$^2$) | | | Extensibility (mm) | | | Resistance (EU) | | |
|---|---|---|---|---|---|---|---|---|---|
| **Sample** | **45 min** | **90 min** | **135 min** | **45 min** | **90 min** | **135 min** | **45 min** | **90 min** | **135 min** |
| Control | 80 ± 1.2 $^{de}$ | 63.7 ± 7.7 $^{dc}$ | 60.7 ± 3.1 $^{c}$ | 163 ± 1.3 $^{dcd}$ | 152 ± 3 $^{d}$ | 152 ± 9 $^{d}$ | 210 ± 9.1 $^{c}$ | 215 ± 5.1 $^{de}$ | 210 ± 7.6 $^{d}$ |
| AA30 | 86 ± 1.8 $^{de}$ | 80 ± 3.6 $^{cd}$ | 78 ± 3.4 $^{e}$ | 153 ± 2.6 $^{adc}$ | 127 ± 1.9 $^{a}$ | 123 ± 8.6 $^{a}$ | 300 ± 7.8 $^{ef}$ | 365 ± 5.2 $^{g}$ | 360 ± 7.6 $^{f}$ |
| AA60 | 89 ± 5.3 $^{e}$ | 95.1 ± 7.2 $^{d}$ | 93 ± 6.5 $^{f}$ | 142 ± 3.7 $^{a}$ | 126 ± 1.2 $^{a}$ | 121 ± 2.5 $^{a}$ | 310 ± 4.3 $^{f}$ | 460 ± 9.9 $^{h}$ | 450 ± 4.8 $^{h}$ |
| CA10 | 61 ± 0.1 $^{dc}$ | 52 ± 3.5 $^{ad}$ | 59.5 ± 0.7 $^{c}$ | 167 ± 4.8 $^{cd}$ | 157 ± 8.1 $^{d}$ | 145 ± 8.9 $^{d}$ | 220 ± 9.5 $^{c}$ | 230 ± 5.7 $^{e}$ | 210 ± 4.8 $^{d}$ |
| CA20 | 71 ± 3.1 $^{cd}$ | 68.5 ± 8.1 $^{dc}$ | 64.1 ± 0.3 $^{cd}$ | 151 ± 5.5 $^{ad}$ | 153 ± 0.7 $^{d}$ | 148 ± 3.5 $^{d}$ | 260 ± 1.2 $^{d}$ | 250 ± 1.1 $^{f}$ | 250 ± 4.4 $^{e}$ |
| CYS20 | 44 ± 9.4 $^{ad}$ | 41.5 ± 6.1 $^{a}$ | 43.4 ± 7.3 $^{d}$ | 150 ± 4 $^{a}$ | 152 ± 0.6 $^{d}$ | 150 ± 6 $^{d}$ | 180 ± 3 $^{d}$ | 170 ± 3.9 $^{c}$ | 170 ± 9.3 $^{c}$ |
| CYS40 | 35.5 ± 7.7 $^{a}$ | 35.5 ± 5.8 $^{a}$ | 29.5 ± 6.3 $^{a}$ | 162 ± 8.8 $^{d}$ | 161 ± 6.7 $^{d}$ | 158 ± 6.3 $^{dc}$ | 130 ± 7 $^{a}$ | 130 ± 4.7 $^{d}$ | 125 ± 5.9 $^{d}$ |
| PWF | 47 ± 6.4 $^{ad}$ | 41.5 ± 4.8 $^{a}$ | 43 ± 3.4 $^{d}$ | 204 ± 2.9 $^{f}$ | 191 ± 3.7 $^{cd}$ | 201 ± 7.2 $^{d}$ | 130 ± 3.7 $^{a}$ | 110 ± 2.3 $^{a}$ | 100 ± 7.1 $^{a}$ |
| SOWF | 79 ± 8.2 $^{de}$ | 79 ± 1.6 $^{cd}$ | 75 ± 1.2 $^{de}$ | 182 ± 4.1 $^{e}$ | 184 ± 8.2 $^{c}$ | 174 ± 8.4 $^{c}$ | 210 ± 7.4 $^{c}$ | 210 ± 2.7 $^{d}$ | 210 ± 8.7 $^{d}$ |
| ESWF | 79 ± 7.7 $^{de}$ | 74 ± 5.5 $^{c}$ | 70 ± 2.5 $^{cde}$ | 206 ± 1.6 $^{f}$ | 202 ± 1.4 $^{d}$ | 202 ± 4.6 $^{d}$ | 185 ± 2.8 $^{d}$ | 180 ± 7.1 $^{c}$ | 180 ± 1.7 $^{c}$ |
| STWF | 114 ± 3.2 $^{f}$ | 120 ± 8.9 $^{e}$ | 128 ± 5.7 $^{g}$ | 172 ± 0.4 $^{de}$ | 157 ± 6.7 $^{d}$ | 163 ± 1.9 $^{dc}$ | 290 ± 4.9 $^{e}$ | 350 ± 9.2 $^{g}$ | 420 ± 3.8 $^{g}$ |

Similar superscript letters in columns indicate no statistically significant differences (ANOVA with Tukey's HSD *post hoc* comparison) among the various dough samples for the same maturing time (45, 90 and 135 min).

## 4. Conclusions

In conclusion, the results from the alveograph showed that AA and CYS have a more pronounced impact on the measured parameters compared to CA. In addition, although the improvers did not affect the water absorption capacity of the control flour, they decreased the dough development time. Furthermore, CYS was more effective in decreasing the energy required to expand the dough decreasing the flour strength compared to CA, whereas the addition of AA increased the dough baking strength. Results presented in this work suggest that each improver added affected the dough rheology in a different way. Future work involves comparison of the combined effect of different improvers.

**Institutional Review Board Statement:**

**Informed Consent Statement:**

**Data Availability Statement:**

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