18.10 Dough Rheology as a Function of Flour Treatment

Determination of the rheological properties of a dough is part of the quality assessment of flour. The rheological properties depend to a large extent on wheat variety, crop properties and the milling process. Provided that a sufficient supply of wheat with different rheological behaviour exists, the miller will be able to adjust the desired properties by blending different lots. Nevertheless, fine tuning will require using additives such as enzymes or oxidizing agents. If raw material of adequate quality is unavailable or in short supply, more extensive flour treatment will be required. Although the author supports the idea of adjusting the rheological properties, he also insists that we should not believe in numbers only; ultimately, the properties have to suit the flour user's requirements in a chosen application.

18.10.1 Viscosity

High Falling Numbers can be reduced by adding α-amylase. Since the conventional method of determining the Falling Number includes heating almost to boiling point, a conventional heat-labile **fungal amylase** will be destroyed too early to have any serious effects at reasonable dosage.

Cereal amylase is slightly more heat resistant, so it will have a noticeable effect on the Falling Number. In fact this is well known, since flour from sprouted wheat (high endogenous amylase) has low Falling Numbers. Cereal amylase can also be added in the form of malt flour or malt flour extracts from (sprouted and then malted) wheat, barley or rye.

Many **bacterial α-amylases** are fairly heat-stable and will therefore be active until the

end of the Falling Number assay, lowering the viscosity of the slurry. But they would also survive baking and result in severe damage to the crumb structure.

Fig. 135 shows a comparison of the effects of malt flour, malt extract and a fungal amylase with slightly increased heat stability on the Falling Number. The amylase from *A. niger* used in this test has slightly better heat stability than a common amylase from *A. oryzae*.

As far as the improvement of baking performance is concerned, fungal amylase has a better effect than is indicated by its influence on the Falling Number. In the cold dough there is hydrated damaged starch on which the enzyme can act, creating yeast food and releasing water; this lowers the viscosity of the dough and improves hydration of the gluten. All this will result in improved baking results. Due to the sophisticated standardization process in the production of microbial amylase, the results will be more predictable than with cereal amylase from malt flour.

Low Falling Numbers can be raised by inhibiting the cereal amylase by means of a reduction or increase in the pH, using acidic or alkaline buffering agents. Fig. 136 also shows a good example of the fact that although the rheological property "Falling Number" can be increased by adding more improver, the baking properties will not improve correspondingly. Although more specific inhibitors of cereal amylase exist, they have not yet been developed into commercial products. One reason is that they also inhibit human digestive amylase.

18.10.2 Mixing Resistance

119 Four main wishes have been identified concerning the modification of the Farinogram curve: increased or reduced water absorption and increased or reduced stability.

Enhancing the water uptake of a dough means reducing its stickiness and increasing the potential for adding more water, e.g. to achieve a longer shelf-life of the finished product.
Besides adding hydrocolloids or vital wheat gluten, more elegant means exist – for instance xylanase, that only acts on water-insoluble xylan. The resulting solubilized xylan absorbs more water (Fig. 137). Xylanase preparations for improved volume yield do not only enable

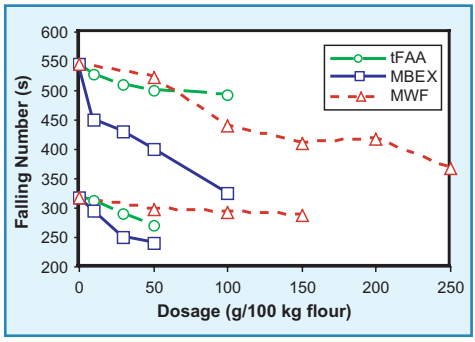

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Fig. 135: Effect of fungal α-amylase from A. niger (1,000 SKB/g; tFAA), dried extract from malted barley (1,100 SKB/g; MBEX) and malted wheat flour (100 SKB; MWF) on the Falling Number of German soft wheat and U.S. hard wheat

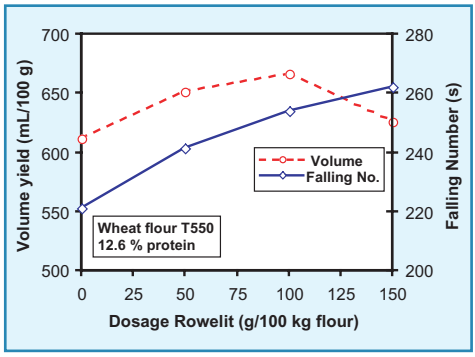

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Fig. 136: Volume yield (breakfast rolls) and Falling Number as affected by the addition of an alkaline buffering agent (Rowelit) to flour from sprout-damaged German soft wheat

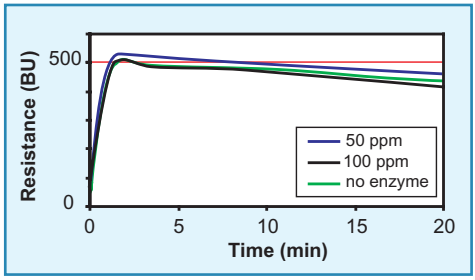

Fig. 137: Effect of the hemicellulase Alphamalt TTC on water absorption, as shown by the Farinogram

this activity; they also contain xylanases which degrade the pentosan fragments further, releasing water again. Although this improves the volume yield, the water uptake is reduced. Enzymes creating hydrocolloids *in situ* also improve water absorption; they include alternan sucrase (Popper, 2002) and dextran sucrase.

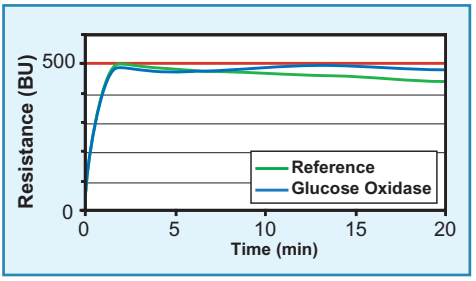

Fig. 138: Effect of glucose oxidase on the Farinogram

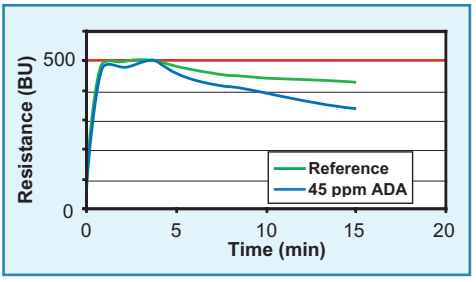

Fig. 139: Effect of azodicarbonamide (ADA) on the Farinogram

Farinogram stability can be improved with oxidases (Fig. 138). Oxygen is a limiting factor within a dough system. In doughs larger than those used in the Farinogram the effect will be much weaker, as the surface-to-volume ratio becomes smaller with increasing dough weight. Although one would expect oxidizing agents to result in better stability, this cannot be shown in the Farinogram. Even the opposite can happen with strong and fast oxidizing agents such as azodicarbonamide: an almost normal resistance is built up at the beginning of the mixing process, but the hard and resilient dough absorbs a lot of energy which causes its rapid breakdown (Fig. 139). Whereas the Farinograph does not take the energy input into account but keeps mixing at a constant speed, a baker would decide to stop mixing earlier, to mix at a lower speed, or to make the dough softer with additional water, etc.

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Unfortunately, the very useful Farinograph sometimes creates misleading data. Another example: the instrument measures the torque caused by the resistance of the dough to kneading. The greater the torque, the greater is the assumed water absorption. The instrument does not reflect the interaction of the dough with the bowl surface, for instance a sticky dough with little water absorption adhering to the instrument and thus increasing the torque.

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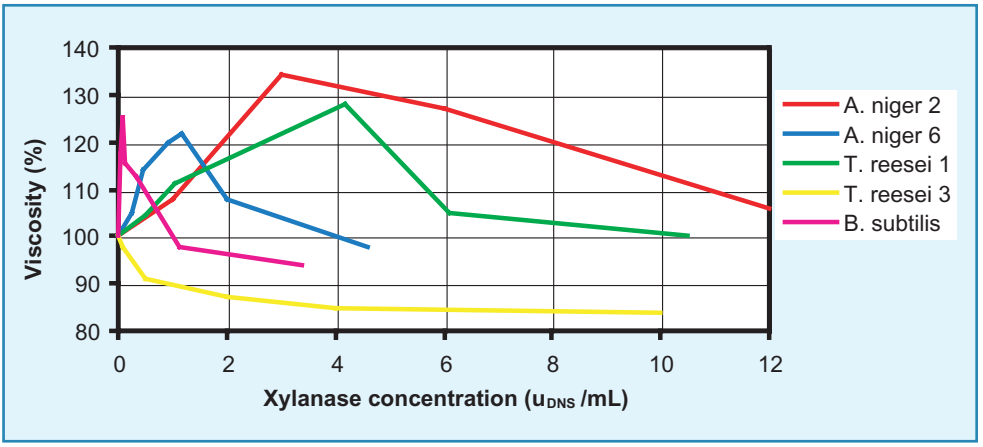


Fig. 140: Effect of commercial xylanase on the viscosity of a pentosan suspension, determined by capillary viscometry

120 Reduced water absorption can be achieved with enzymes too. Xylanases acting on the water-soluble moiety of the pentosans reduce water absorption by these polymers. This is shown by Fig. 140 using pentosans extracted from wheat. Only *Trichoderma* xylanase 3 reduced the viscosity of a pentosan slurry, whereas all the other xylanases tested resulted in an initial increase (caused by degradation of the insoluble pentosans into soluble pentosans absorbing more water). A low viscosity is equivalent to a low water absorption.

As we have already said, many commercial xylanase preparations contain various xylanases of different specificity. So in most cases it will only be possible to select a xylanase in which the above effect prevails. With most commercial xylanases it is also possible to increase the dosage in order to achieve a viscosity reduction in a given time (Fig. 140). Unfortunately, the Farinograph using a very viscous dough made from flour is a rather slowly reacting system compared with a viscometer using extracted pentosans.

18.10.3 Extensibility and Resistance

The Extensograph and the Alveograph have many properties in common. Nevertheless it is interesting to note that most inquiries on optimization concern the Alveogram. In particular, wishes for modification include the extensibility and resistance of the Extensogram, the L-value and the P-value of the Alveogram, and also the P/L ratio of the Alveogram. Sometimes the areas beneath the curves (equivalent to the energy input) need to be modified.

Increasing the resistance of the Extensogram or the P-value of the Alveogram does not seem to be difficult, since hardly any inquiries ask for it. And in fact applying oxidizing agents effectively increases both. Fig. 141 depicts the effect of ascorbic acid and potassium bromate respectively on the resistance of the Extensogram. As potassium bromate is a rather slowly-reacting oxidizing agent, its effect can hardly be observed after only a short incubation time (Fig. 141, curve PBr 45').
Consequently, its impact on the Alveogram will

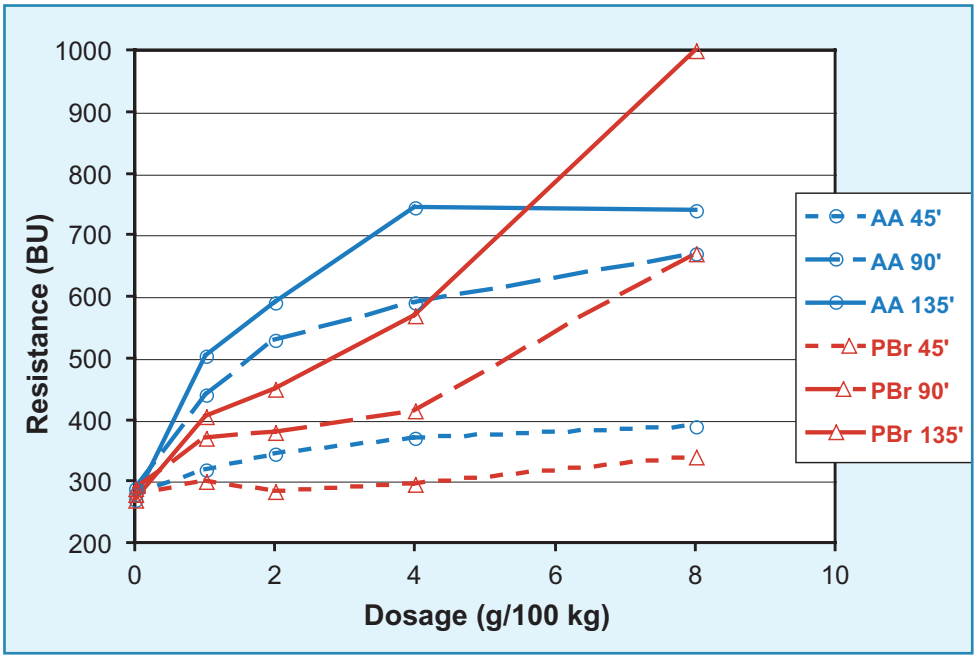


Fig. 141: Effect of ascorbic acid (AA) and potassium bromate (PBr) on the resistance of the Extensogram

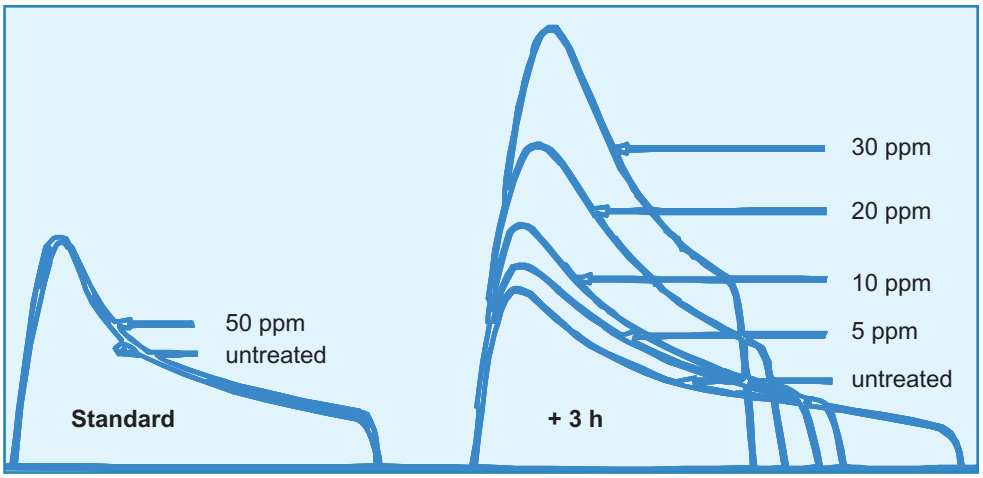


Fig. 142: Effect of prolonged dough resting time on the Alveograms, using potassium bromate (Faridi & Rasper, 1987)

not be very strong within the standard dough processing time of 28 min. Prolongation to 2 or 3 h will make it more obvious (Fig. 142). Of course the effect of enzymes will also be more pronounced after a longer resting period of the dough (Tab. 93).

Transglutaminase is a cross-linking enzyme that connects protein chains by forming lysine-glutamine bridges (Fig. 143). The cross-linking results in an increase in the stability of the protein. Using the Extensograph, an increase in the resistance and a reduction of the extensibility can be measured (Fig. 144). Since transglutaminase is still a rather expensive enzyme, its use is recommended chiefly in prolonged fermentation processes where a small quantity has sufficient time to achieve the desired effect.

Tab. 93: Effect of resting time on Alveograms with enzymes

Enzyme	Dosage ppm	Rest min	P mm	L mm	P/L	W $J \cdot 10^{-4}$
Untreated		20	66	110	0.60	196
Hemicellulase, *A. niger*	40	20	63	106	0.59	183
		45	58	127	0.46	190
		90	55	128	0.43	190
Hemicellulase, *B. subtilis*	40	20	63	115	0.55	196
		45	60	106	0.57	170
		90	52	122	0.43	170
Amylase, *A. oryzae*	2	20	56	121	0.46	183
		45	51	120	0.43	170
		90	48	124	0.39	177
Protease, *A. oryzae*	10	20	65	108	0.60	190
		45	63	106	0.59	183
		90	59	106	0.56	170

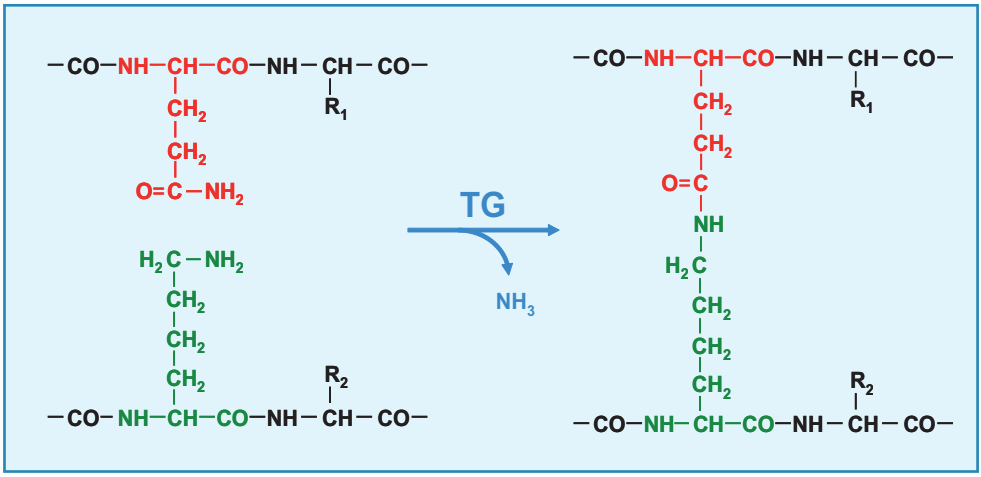


Fig. 143: Crosslinking of protein by transglutaminase

Increasing the extensibility is a more delicate task. For this purpose it is necessary to soften the dough, but too much softening will result in early rupture of the dough strand (Extensogram) or bubble (Alveogram); this is reflected in an even shorter curve.

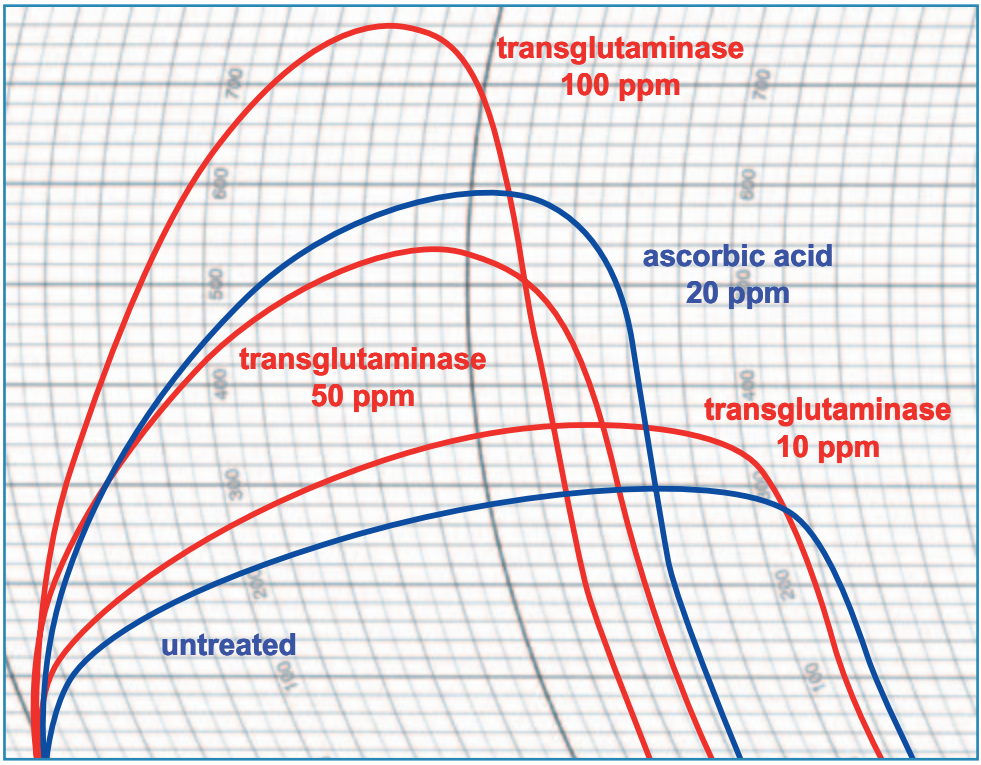
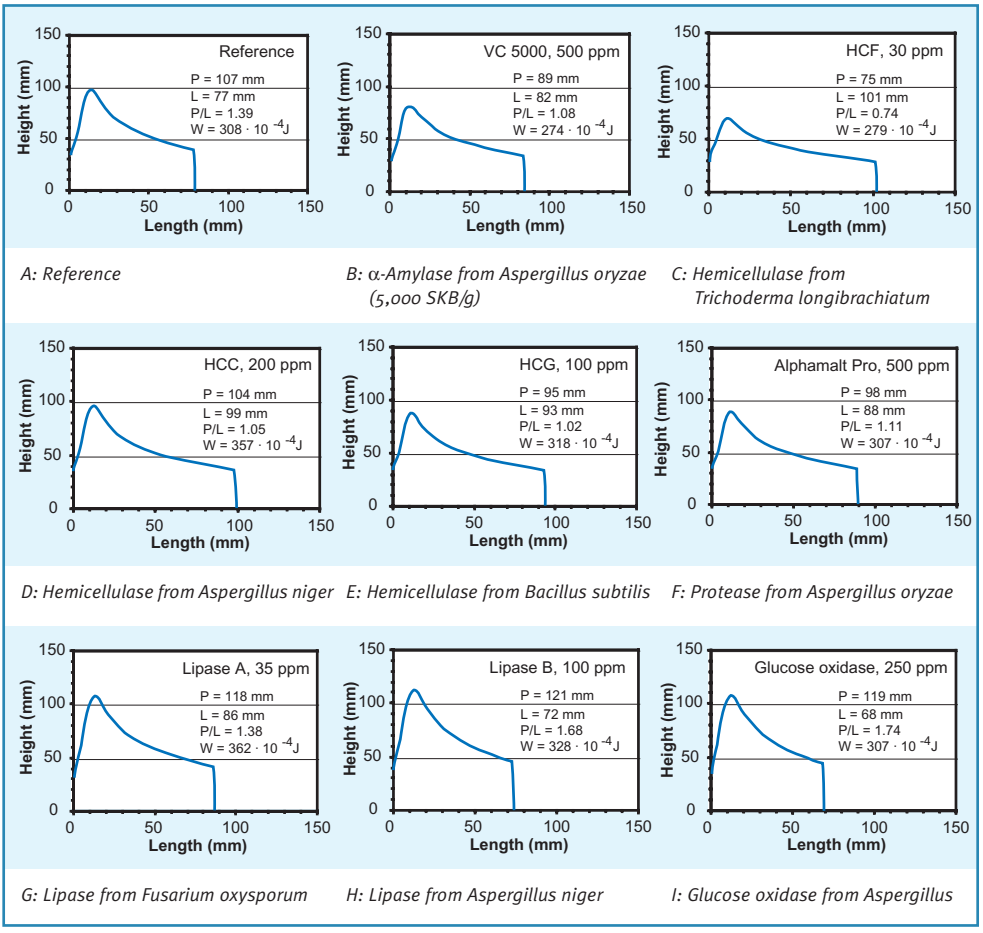


Fig. 144: Transglutaminase increases the strength of wheat flour dough; here: comparison with ascorbic acid

Dough is a complex system composed mainly of starch, water, protein and pentosans. The gluten formed by protein and water certainly plays a predominant role in dough rheology, but the other components have significant effects too. The starch competes for the water present in the dough, and so do the pentosans. In addition, the pentosans probably form complexes with each other and with gluten (Neukom and Markwalder, 1978; Hoseney and Faubion, 1981). So releasing water from starch or the pentosans would improve the hydration of the gluten. Destroying the network of protein and pentosans would also increase the softness of the dough.

A good approach would therefore be to keep the protein as intact as possible, maybe counteracting an excess of stability with some cysteine or specific proteases, but to focus on the starch – particularly the damaged moiety – and the pentosans. Both can be effectively degraded by enzymes.

Fig. 145 proves that with the aid of amylolytic and hemicellulolytic enzymes (A - E) an increase in extensibility is feasible, accompanied by a decrease in resistance; but it can also be achieved with specific proteases (F). A lipase from *Fusarium oxysporum* (G) increased both extensibility and resistance, whereas a lipase



A: Reference

B: α-Amylase from Aspergillus oryzae (5,000 SKB/g)

C: Hemicellulase from Trichoderma longibrachiatum

D: Hemicellulase from Aspergillus niger

E: Hemicellulase from Bacillus subtilis

F: Protease from Aspergillus oryzae

G: Lipase from Fusarium oxysporum

H: Lipase from Aspergillus niger

I: Glucose oxidase from Aspergillus

Fig. 145: Effect of various commercial enzymes on the Alveogram

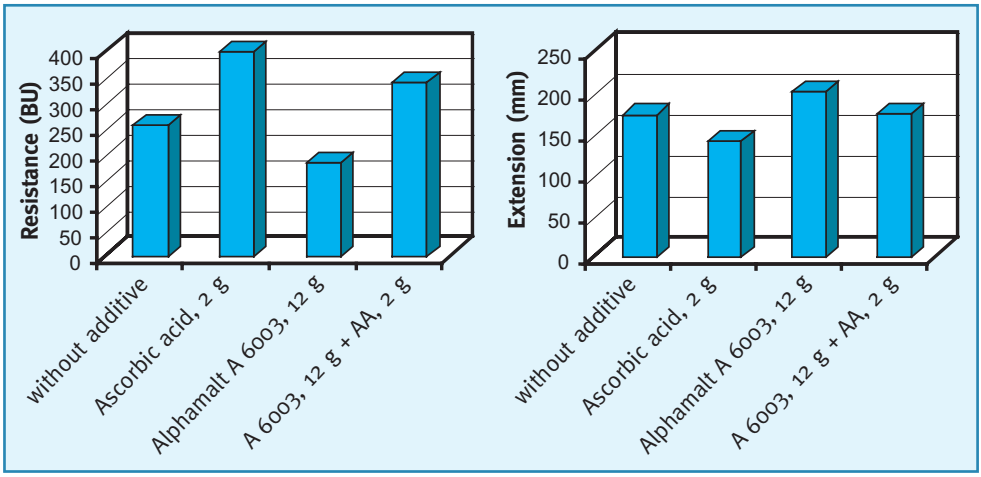


Fig. 146: Resistance (left) and extensibility (right) from Extensograms with a combination of amylase and xylanase (Alphamalt A 6003) and ascorbic acid (AA)

from *Aspergillus niger* (H) only increased resistance and reduced extensibility. Furthermore, the Alveograms with glucose oxidase (I) showed a reduction of extensibility and an increase in resistance.

Using combinations of amylases and hemicellulases it is possible to keep extensibility constant while resistance is increased (Fig. 146). The resulting increase in the area under the curve (energy) is an indication that a better volume yield in baking is likely.

Kieffer (2003) has recently published results from comparative investigations into dough rheology and volume yield. He concludes that only resistance is positively related to baked volume. This is quite surprising because all reports from bakers indicate that extensibility goes along with volume provided that sufficient resistance of the dough can be achieved, e.g. with oxidizing agents. In chapter 14 of this book, Kieffer adds further arguments to his view.

Tab. 94 provides a summary of the effects of various flour improvers on the Alveogram. It should be mentioned again that at much lower or higher dosages, rather different tendencies may be revealed.

Tab. 94: Effect of various flour additives on Alveograms

Treatment	P	L	P/L	W
Untreated	83	97	0.86	209
Ascorbic acid	+	-	+	++
Potassium bromate	++	-	+	++
Cysteine	-	+	-	-
Sodium metabisulphite	-	-	-	-
α-Amylase, fungal	--	++	--	-
Hemicellulase, AN[a]	-	o	-	-
Hemicellulase, TR[b]	--	+	-	-
Hemicellulase, BS[c]	-	-	+	-
Protease, fungal	-	+	-	-
Glucose oxidase	+	-	+	o
Alphamalt A 6003[d]	-	+	-	-
Alphamalt LQ 4020[e]	--	+	--	--
Alphamalt BX[f]	++	--	++	+
Vital wheat gluten	+	-/o	+	++

[a] *Aspergillus niger*
[b] *Trichoderma reesei (longibrachiatum)*
[c] *Bacillus subtilis*
[d] *Standard baking enzyme compound based on α-amylases and xylanases*
[e] *Proteolytic enzymes for wafer batters*
[f] *Flour improver compound based on enzymes and oxidizing agents for replacing potassium bromate*

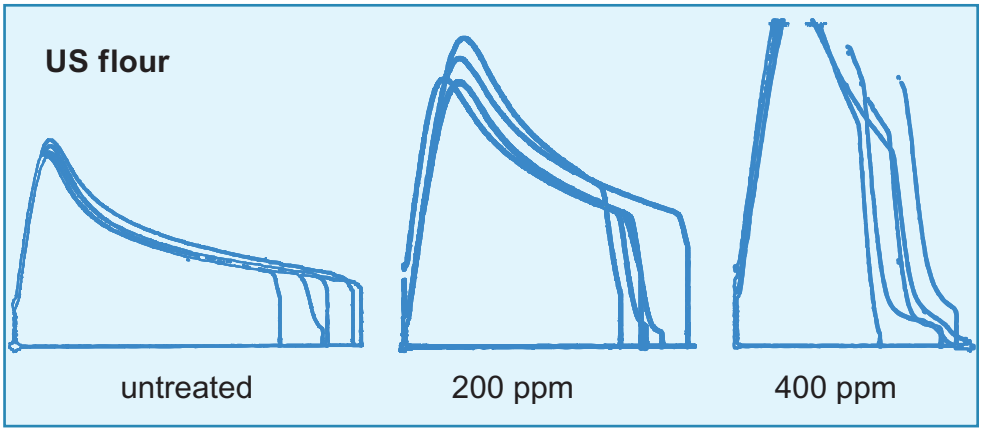


Fig. 147: Alveograms without Alphamalt BX (potassium bromate replacing compound) (left), with 200 ppm and with 400 ppm. (Flour from DNS and CWRS wheat)

18.10.4 Don't Believe in Numbers only – Bake!

Rheological methods are effective means of checking flour quality when milling wheat of rather homogeneous composition. Large fluctuations in wheat properties should lead to re-adjustment of the specifications, because certain parameters may fluctuate without the baking performance being impaired.
If treated flour is to be evaluated by rheological methods, the specifications usually have to be quite different from those for untreated flour. Fig. 147 shows the Alveogram for what is probably the most successful bromate replacing compound worldwide. Nobody used to Alveograms would even dare to treat flour with this improver. Nevertheless, under the typical conditions for which this product was designed, it achieves superior baking volumes (Fig. 148).

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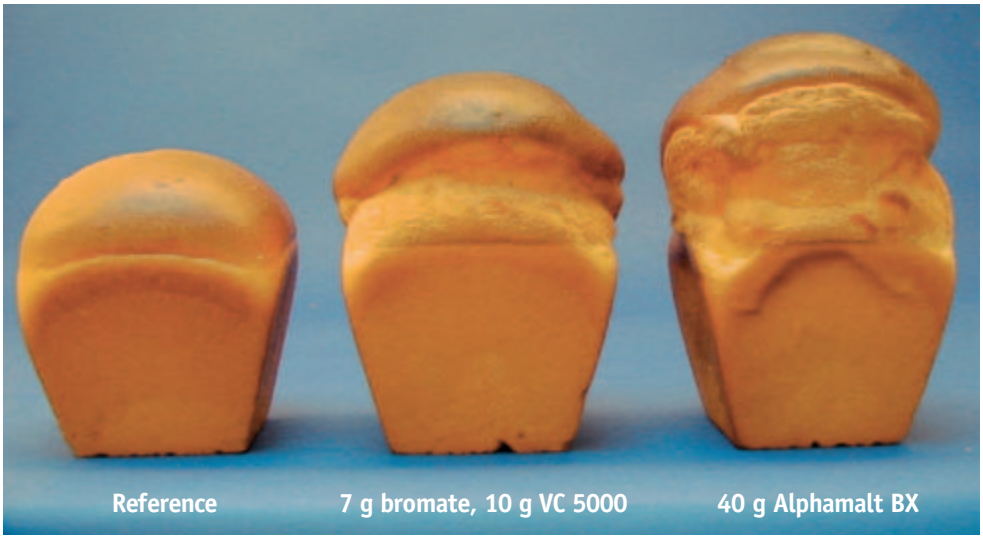

Fig. 148: Baking results with potassium bromate combined with α-amylase (VC 5000 contains 5,000 SKB/g) and Alphamalt BX. (Flour from DNS and CWRS wheat)