Methods and Benefits of Flour Improvement

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Reasons for Application of Flour Improvers

Equilibrate fluctuations of flour properties due to

- grain from new harvest or
- different varieties or
- different lots
- grain damage

Reduce grist costs

Improve baking performance

Diversify applicability

Suit customers specifications
Flour Improvement Procedure

Complete analysis of flour, particularly
- Protein & wet gluten content & properties
- Falling Number
- Farinograph
- Extensograph or Alveograph

Baking trials with estimated treatment

Adjust & optimize treatment

Rheological analysis to establish specifications

Production control by rheological analyses
Additives Used in Flour Improvers

Enzymes
Oxidizing agents
Reducing agents
Emulsifiers
Acidity regulators

Malt flour
Vital wheat gluten
Hydrocolloids
Pulse flour
Preservatives
Maturing Agents for Flour

- Chlorine & chlorine dioxide
- Hypochlorite
- Benzoyl peroxide
- Ascorbic acid, resp.
- Dehydroascorbic acid
- Sodium hypophosphite
- Cystine
- Hydrogen peroxide
- Oxygen

- Potassium bromate
- Potassium iodate
- Calcium bromate
- Calcium iodate
- Azodicarbonamide
- Calcium peroxide
- Ammonium persulfate
- Potassium persulfate
- Acetone peroxide
Effects of Ascorbic Acid in Baking

- Compensates lack of flour maturation
- Improves dough stability
- Improves fermentation tolerance
- Reduces dough extensibility
- Reduces dough stickiness
- Improves dough handling properties and machinability
- Results in finer crumb structure (smaller pores)
- Increases volume yield
**Effect of Ascorbic Acid on Baking Results**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat flour T 55</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>0.497 %</td>
</tr>
<tr>
<td>Protein d.b.</td>
<td>13.3 %</td>
</tr>
<tr>
<td>Wet gluten</td>
<td>34.3 %</td>
</tr>
<tr>
<td>Falling no.</td>
<td>314 s</td>
</tr>
<tr>
<td>Water abs.</td>
<td>58.8 %</td>
</tr>
<tr>
<td>Gluten index</td>
<td>89</td>
</tr>
</tbody>
</table>

Without treatment:

- ELCO C-100
- 3.5 g/100 kg
General Directions for Use of ELCO C-100 in Flour Improvement

**Typical dosage:** 2 – 6 g per 100 kg flour = 20 – 60 g per ton = 20 – 60 ppm

- High and soft protein: 6 – 10 g
- High and short protein: 2 – 4 g
- Low and soft protein: max. 6 g
- Low and short protein: 2 g

Low Falling Numbers (below 220 s):
  Increase above dosages by 50 %
No Baking without Enzymes!

In all baking processes, enzymes are involved, because
- flour contains cereal enzymes
- yeast has enzymes to convert flour components into fermentable substances

Flour & bread improvers contribute additional enzymes to the baking process.
- for standardization of optimization of the flour’s baking performance and for improvement of the end product quality

If all enzyme activities shall be avoided, the flour has to be treated by chemicals (f.i. chlorine) or heat in order to inactivate the enzymes.
- An accordingly treated flour could only be used to produce flat bread, chemically leavened bread, soft biscuits or the like
- Some extruded snack products can be made from enzyme-inactive flour.
## Enzymes Suggested for Bread and Flour Improvers

<table>
<thead>
<tr>
<th>Enzyme</th>
<th>Claimed Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>α-Amylase</td>
<td>Energy supply for yeast, dough viscosity, shelf life</td>
</tr>
<tr>
<td>Amyloglucosidase (glucoamylase)</td>
<td>Energy supply, colour, flavour</td>
</tr>
<tr>
<td>Ascorbate &amp; amino acid oxidase</td>
<td>Gluten strengthening</td>
</tr>
<tr>
<td>Branching enzyme (glucotransferase)</td>
<td>Water binding</td>
</tr>
<tr>
<td>Cellulase</td>
<td>Water binding</td>
</tr>
<tr>
<td>Furanosidase, arabinofuranosidase</td>
<td>Dough structure, water binding</td>
</tr>
<tr>
<td>Ferulic &amp; cumaric acid esterase</td>
<td>Dough structure, water binding</td>
</tr>
<tr>
<td>Glutathion oxidase</td>
<td>Gluten strengthening</td>
</tr>
<tr>
<td>Glycolipase, galactolipase</td>
<td>Dough stability &amp; volume yield</td>
</tr>
<tr>
<td>β-Glucanase</td>
<td>Structure, liquefaction</td>
</tr>
<tr>
<td>Glucose / galactose / hexose oxidase</td>
<td>Gluten strengthening</td>
</tr>
<tr>
<td>Hemicellulase, xylanase, pentosanase</td>
<td>Dough structure, water binding, volume yield</td>
</tr>
<tr>
<td>Laccase, monophenol oxidase</td>
<td>Dough strengthening</td>
</tr>
<tr>
<td>Lipase (triacyl lipase)</td>
<td>Flavour, emulsification, dough stability &amp; vol. yield</td>
</tr>
<tr>
<td>Lipoxygenase, lipoxidase</td>
<td>Dough structure, decolorization</td>
</tr>
<tr>
<td>exo-Peptidase</td>
<td>Colour, flavour</td>
</tr>
<tr>
<td>Peroxidase</td>
<td>Gluten strengthening</td>
</tr>
<tr>
<td>Phospholipase</td>
<td>Pore structure &amp; volume yield</td>
</tr>
<tr>
<td>Polyphenol oxidase</td>
<td>Gluten strengthening</td>
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<tr>
<td>Protease, proteinase, peptidase</td>
<td>Protein relaxation, liquefaction</td>
</tr>
<tr>
<td>Pullulanase</td>
<td>Structure, water binding</td>
</tr>
<tr>
<td>Sulphydryl oxidase &amp; transferase</td>
<td>Gluten strengthening</td>
</tr>
<tr>
<td>Transglutaminase</td>
<td>Protein cross-linking, gluten stabilization</td>
</tr>
</tbody>
</table>
Amylolytic Enzymes
Amylolytic Enzymes used in Baking

Glucose (Dextrose)
\[ \text{CH}_2\text{OH} \]
\[ \text{OH} \]

\[ \text{OH} \]

α-amyloses

β-amyloses

Maltose

Glucoamylases

Glucose
Effect of α-Amylase on Baking Properties

Break-down of hydrated starch (only mechanically or thermally damaged starch)

Release of water
- Reduction of dough viscosity/consistency
- Improved extensibility
- May cause stickiness if used in excess

Produces “limit dextrins” (branched fragments) and short linear dextrins and finally maltose from linear sections of the starch molecule
- Improved browning
- Improved shelf life
- Better fermentation

Enhanced volume yield and bread aspect
Falling Number – Viscometric Determination of Amylase Activity in Flour
Interpretation of the Falling Number

61 - 150 : extreme sprout damage & amylase activity, can only be used in flour mixes or with strong sour dough

150 - 200 s: sprout damage, very high amylase activity, excessive browning, sticky dough, weak crumb

200 - 250 s: some sprout damage, high amylase, soft crumb, good browning

250 - 300 s: normal amylase activity, normal baking behaviour

300 - 450 s: low amylase, reduced oven rise & browning

> 450 s very low amylase, poor oven rise & browning; heat damage?
Factors Affecting the Falling Number Precision

- Sampling (field, truck, railcar, or bin sample)
- Flour or meal moisture content
- Elevation and barometric pressure
- Stirrer geometry and condition
- Temperature of the meal/flour and water mixture at the start of the test
- Consistency in dimensions of precision test tubes
- Purity and pH of water used in the tube
- Mass of flour or meal and volume of water
- Test tube preparation (mixing, timing)
- Fineness of meal
- Cleanliness of the stirrer and tube
- Instrument hardware
- Air entrainment during agitation

Modif from Delwiche et al., 2015 [4705]
Dosage Recommendation for Fungal α-Amylase

Minimum dosage (ppm) of Alphamalt VC 5000 (5,000 SKB/g) estimated from Falling Number and extraction rate

<table>
<thead>
<tr>
<th>Falling number</th>
<th>Type 405 / 550, 70-75 % extraction</th>
<th>Type 812 / 1050, 80-85 % extraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>220 – 240</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>240 – 260</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>260 – 280</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>280 – 300</td>
<td>45</td>
<td>40</td>
</tr>
<tr>
<td>300 – 320</td>
<td>55</td>
<td>45</td>
</tr>
<tr>
<td>320 – 350</td>
<td>65</td>
<td>&gt; 55</td>
</tr>
<tr>
<td>350 – 380</td>
<td>80</td>
<td>-</td>
</tr>
<tr>
<td>&gt;380</td>
<td>&gt; 100</td>
<td>-</td>
</tr>
</tbody>
</table>

Strong gluten allows for higher dosages
New Enzymes for the Adjustment of the Falling Number

Deltamalt FN-A and Deltamalt FN-B – Intermediate Heat-stable Amylases
Comparison of the Effect of Alphamalt, Betamalt and Deltamalt on the Falling Number

- **Alphamalt VC 5000**
  - Fungal α-amylase, 5,000 SKB/g

- **Betamalt 25 FBD**
  - Cereal amylase

- **Deltamalt FN-B**
  - New amylase system

- **Deltamalt FN-A 50**
  - Heat-stable fungal α-amylase

**Wheat flour T 550**
Baking Trials with Falling Number-Reducing Amylolytic Enzymes

<table>
<thead>
<tr>
<th></th>
<th>Deltamalt FN-B</th>
<th>Standard</th>
<th>Deltam. FN-A50</th>
<th>Betam. 25 FBD</th>
<th>Alpham. VC 5000</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>ppm/ mL</td>
<td>200 ppm 1780 mL</td>
<td>1500 mL</td>
<td>33 ppm 1820 mL</td>
<td>200 ppm 1540 mL</td>
<td>200 ppm 1650 mL</td>
<td>1480 mL</td>
</tr>
</tbody>
</table>

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### MC Products for Reduction of the Falling Number

<table>
<thead>
<tr>
<th>Product</th>
<th>Composition</th>
<th>Dosage ppm</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMCEmalt</td>
<td>Malted wheat flour</td>
<td>500-2,000</td>
<td>reduces FN, little effect on vol., sticky dough possible</td>
</tr>
<tr>
<td>Alphamalt VC 5000</td>
<td>Fungal amylase</td>
<td>50-500</td>
<td>little effect on FN</td>
</tr>
<tr>
<td>Betamalt 25 FBD</td>
<td>Barley &amp; wheat amylases</td>
<td>50-250</td>
<td>good effect on FN</td>
</tr>
<tr>
<td>Deltamalt FN-B</td>
<td>Barley &amp; fungal amylases</td>
<td>50-250</td>
<td>good effect on FN &amp; volume</td>
</tr>
<tr>
<td>Deltamalt FN-A 5000</td>
<td>Fungal amylase, heat stable</td>
<td>20-250</td>
<td>good effect on FN &amp; volume</td>
</tr>
<tr>
<td>Deltamalt FN-A 85</td>
<td>Fungal amylase, heat stable</td>
<td>2-20</td>
<td>good effect on FN &amp; volume, low dosage</td>
</tr>
</tbody>
</table>
Hemicellululases

Pentosanases, Xylanases and Co.
The Family of Hemicellulases

Hemicellulase

- Pentosanase
  - Xylanase
  - Arabinanase
  - Endo-1,3-β-Xylanase
  - Endo-1,4-β-Xylanase
  - Exo-1,3-β-Xylosidase
  - Exo-1,4-β-Xylosidase
- (Hexosanase)
  - β-Glucanase
  - Galactanase
  - Mannanase
  - Arabino-Furanosidase
  - Ferulic Acid Esterase
  - Cumaric Acid Esterase
Enzymatic Hydrolysis Sites in Wheat Xylan

- Arabinose
- Xylose
- Coumaric acid
- Ferulic acid
- $\alpha$-L-Arabinofuranosidase
- Endo-1,4-\(\beta\)-xylanase
- Coumaric acid esterase
- Ferulic acid esterase
Effect of Various Xylanases on Pentosan* Viscosity

*Pentosan from wheat starch tailings
Summary of the Effects of Xylanases

Break down xylan backbone

Soften gluten-xylan network

Hydrolyse soluble and insoluble pentosans
  - initial increase of water absorption $\rightarrow$ dough drying
  - release of water $\rightarrow$ softening of gluten

Improve extensibility

Dough softening

Volume increase of baked goods

Can be used to achieve finer or coarser crumb

May cause stickiness if not suitable or overdosed
Oxidases
Some Oxidizing Enzymes

- Glucose oxidase
- Galactose oxidase
- Hexose oxidase
- Sulfhydryl oxidase
- Phenoloxidase (laccase)
- Peroxidase
- Katalase
Effects of Glucose Oxidase in Dough

Glucose + O₂ + H₂O $\xrightarrow{\text{GOD}}$ Gluconic acid + H₂O₂

H₂O₂ $\xrightarrow{\text{Ascorbic acid}}$ Dehydro-ascorbic acid

H₂O₂ $\xrightarrow{\text{Glutathione oxidase}}$ Reduced glutathion
dimer

H₂O₂ $\xrightarrow{\text{Protein-SH}}$ HS-Protein

H₂O₂ $\xrightarrow{\text{Glutathione oxidase}}$ Reduced glutathion

H₂O₂ $\xrightarrow{\text{Dehydro-ascorbic acid}}$ Ascorbic acid

H₂O₂ $\xrightarrow{\text{Protein-SS-Protein}}$ Protein-SH

H₂O₂ $\xrightarrow{\text{Peroxidase}}$ Oxidative gelation

Pentosan + H₂O₂ $\xrightarrow{(\text{Peroxidase})}$ Oxidative gelation
Effect of Glucose-Oxidase on Dough Development

![Graph showing the effect of glucose-oxidase on dough development. The graph plots resistance (BU) against time (min). There are two lines: one for reference and another for glucose oxidase. The reference line remains constant at 500 BU, while the glucose oxidase line shows a temporary increase before stabilizing at a lower resistance.]
Glucose Oxidase in German Breakfast Rolls

Stress test by over-proof of dough pieces

Wheat flour: German soft wheat; rolls
Summary of the Effects of Oxidases

Create hydrogen peroxide

Cause cross-linking of proteins and pentosans

“Inactivate” softening (reducing) substances such as cysteine or glutathione

Increase water absorption

Result in dryer dough surfaces and hence better handling properties

Improve the opening of the cut, f.i. of baguette

Improve dough stability

Help to preserve the dough shape in long fermentations
Carboxyl Esterase

Lipase, Phospholipase, Galactolipase & Co.
Simplified Classification and Distribution of the Main Lipids in Wheat Flour (averages; % d.s.)

- **Wheat flour lipids**: 2.7%
  - **Free lipids**: 0.9%
    - **Nonpolar**: 0.7%
      - **Glycolipids**: 0.14%
      - **Phospholipids**: 0.05%
    - **Polar**: 0.2%
  - **Bound lipids**: 1.8%
    - **Nonpolar**: 0.6%
      - **Glycolipids**: 0.25%
      - **Phospholipids**: 0.95%
    - **Polar**: 1.2%

Modif. from Pomeranz & Chung, 1978, using data from Chung & Ohm, 2009
Action of Lipolytic Enzymes

Triacyl-lipases

Galacto-lipases

Phospho-lipases

$R_1, R_2, R_3 =$ fatty acid residues
Formation of Lipoprotein Complexes by Phospholipids

- Leucine
- Glutamine
- Tyrosine
- Methionine
- Phenyl alanine
- Threonine
- Aspartic acid
- Valine

[Diagram showing hydrophilic and hydrophobic bonds and protein strands with various amino acids and phospholipids.]
Gas Cell Stabilization by Proteins, Lipids and Arabinoxylans

Modif. from Sroan and MacRitchie, 2009
Effect of Lipase and Various other Enzymes on the Alveogram

VC 5000 = alpha-amylase from *Aspergillus oryzae*, 5,000 u/g (SKB)
HCF = hemicellulase from *Trichoderma reesei*
B 2000 (Alphamalt Pro) = protease from *Aspergillus oryzae*
Gloxy 4090 = glucose oxidase from *Aspergillus niger*, 1,500 u/g
Effect of Dosage and Proof Time on Baguette Rolls with Alphamalt EFX Super

Basic treatment:
FAA, 1 SKB/g
ADA, 40 ppm
Asc., 160 ppm
SSL, 0.3 %

Volume yield, mL/100 g flour

<table>
<thead>
<tr>
<th>Dosage (ppm)</th>
<th>1.5 h, normal proof</th>
<th>2 h, over-proof 1</th>
<th>2.5 h, over-proof 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>743</td>
<td>803</td>
<td>863</td>
</tr>
<tr>
<td>10</td>
<td>748</td>
<td>852</td>
<td>937</td>
</tr>
<tr>
<td>25</td>
<td>787</td>
<td>882</td>
<td>965</td>
</tr>
<tr>
<td>50</td>
<td>856</td>
<td>935</td>
<td>1015</td>
</tr>
</tbody>
</table>
Carboxyl Esterase Boosts the Baking Results

- **ELCO C 100K:**
- **Alphamalt A 15140:**
- **Alphamalt HC 13045:**
- **Alphamalt Gloxy 14080:**
- **Alphamalt EFX Mega:**
  - Ascorbic acid, 100 %
  - Amylase, 140,000 SKB/g
  - Hemicellulase
  - Glucose oxidase
  - Carboxyl esterase

Reference | ELCO, 50 ppm A 15140, 10 ppm | ELCO, 50 ppm A 15140, 10 ppm | ELCO, 40 ppm A 15140, 10 ppm | ELCO, 50 ppm HC 13045, 30 ppm
<table>
<thead>
<tr>
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</thead>
<tbody>
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</tr>
</tbody>
</table>
Summary of the Properties of Carboxyl Esterases

- Produce emulsifier-like substances from lipids
- Enhance dough stability
- Increase volume yield
- Result in fine porous structure
- Enhance crumb whiteness be physical (shallower shadows) and chemical (indirect bleaching) effects
- Improvement of initial crumb structure & bread volume
- Improved crumb softness after storage
- May cause off-flavour if not compatible with involved lipids
Résumé
# Improvement of Baking Properties and Baked Product Quality by Enzymes

<table>
<thead>
<tr>
<th>Baking</th>
<th>Problem</th>
<th>Enzymatic solution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dough</strong></td>
<td>Short dough</td>
<td>Amylase, xylanase, protease</td>
</tr>
<tr>
<td></td>
<td>Slack dough</td>
<td>Glucose oxidase, xylanase</td>
</tr>
<tr>
<td></td>
<td>Low rising power</td>
<td>Amylase, glucoamylase</td>
</tr>
<tr>
<td></td>
<td>Sticky dough</td>
<td>Glucose oxidase, xylanase</td>
</tr>
<tr>
<td><strong>Baked good appearance</strong></td>
<td>Volume yield</td>
<td>Amylase, xylanase, carboxyl esterase</td>
</tr>
<tr>
<td></td>
<td>Shape</td>
<td>Amylase, xylanase, glucose oxidase</td>
</tr>
<tr>
<td></td>
<td>Cut &amp; shred</td>
<td>Glucose oxidase</td>
</tr>
<tr>
<td></td>
<td>Coloration</td>
<td>Amylase, glucoamylase</td>
</tr>
<tr>
<td></td>
<td>Crust flaking</td>
<td>Glucoamylase, amylase</td>
</tr>
<tr>
<td></td>
<td>Blisters (frozen dough)</td>
<td>Carboxyl esterase</td>
</tr>
<tr>
<td><strong>Crumb</strong></td>
<td>Crust separation (f.d.)</td>
<td>Carboxyl esterase, amylase</td>
</tr>
<tr>
<td></td>
<td>Pore structure</td>
<td>Carboxyl esterase, xylanase</td>
</tr>
<tr>
<td></td>
<td>Crumb color</td>
<td>Lipoxygenase, lipase, xylanase</td>
</tr>
<tr>
<td></td>
<td>Softness</td>
<td>Amylase, xylanase, carboxyl esterase</td>
</tr>
<tr>
<td></td>
<td>Shelf-life of softness</td>
<td>Amylase</td>
</tr>
</tbody>
</table>
Typical Effects of Enzymes on Bread Quality used at common dosages

<table>
<thead>
<tr>
<th>Enzyme</th>
<th>WA&lt;sup&gt;(1)&lt;/sup&gt;</th>
<th>Volume&lt;sup&gt;(2)&lt;/sup&gt;</th>
<th>Stability&lt;sup&gt;(3)&lt;/sup&gt;</th>
<th>Cut&lt;sup&gt;(4)&lt;/sup&gt;</th>
<th>Colour&lt;sup&gt;(5)&lt;/sup&gt;</th>
<th>Crumb&lt;sup&gt;(6)&lt;/sup&gt;</th>
<th>Shelf-life&lt;sup&gt;(7)&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>α-Amylase, fungal</td>
<td>o</td>
<td>++</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>α-Amylase, cereal</td>
<td>-</td>
<td>+</td>
<td>--</td>
<td>-</td>
<td>++</td>
<td>--</td>
<td>+</td>
</tr>
<tr>
<td>α-Amylase, bacterial</td>
<td>-</td>
<td>(+)</td>
<td>(-)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>α-Amylase, maltogenic</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>++</td>
</tr>
<tr>
<td>Xylanase&lt;sub&gt;WUX&lt;/sub&gt;</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td>(+)</td>
</tr>
<tr>
<td>Xylanase&lt;sub&gt;WEX&lt;/sub&gt;</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Protease</td>
<td>0</td>
<td>(+)</td>
<td>(+)/-</td>
<td>+</td>
<td>0</td>
<td>(-)</td>
<td>0</td>
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<tr>
<td>Oxidase</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>0</td>
<td>+</td>
<td>(+)</td>
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<tr>
<td>Carboxylesterases</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Transglutaminase</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

(1) Water absorption (2) Baking volume yield (3) Shape stability (4) Opening of the cut, shred (5) Crust colour (6) Crumb fineness (7) Non-microbial shelf-life
# Case Study: Cost Savings by Reduction of Strong Wheat

<table>
<thead>
<tr>
<th>HRW in grist</th>
<th>(%)</th>
<th>30</th>
<th>20</th>
<th>10</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>French wheat</td>
<td>($)</td>
<td>224.28</td>
<td>256.32</td>
<td>288.36</td>
<td>320.40</td>
</tr>
<tr>
<td>HRW</td>
<td>($)</td>
<td>118.62</td>
<td>79.08</td>
<td>39.54</td>
<td>0.00</td>
</tr>
<tr>
<td>EMCEgluten&lt;sup&gt;Plus&lt;/sup&gt; Baguette* (ppm)</td>
<td></td>
<td>0</td>
<td>250</td>
<td>450</td>
<td>650</td>
</tr>
<tr>
<td></td>
<td>($)</td>
<td>0.00</td>
<td>4.43</td>
<td>7.98</td>
<td>11.52</td>
</tr>
<tr>
<td>Ascorbic acid</td>
<td>(ppm)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>($)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.53</td>
</tr>
<tr>
<td>Total cost</td>
<td>($)</td>
<td>342.90</td>
<td>339.83</td>
<td>335.87</td>
<td>332.45</td>
</tr>
<tr>
<td>Savings</td>
<td>($)</td>
<td>0.00</td>
<td>3.07</td>
<td>7.02</td>
<td>10.44</td>
</tr>
</tbody>
</table>

* Improver premix incl. hydrocolloids and enzymes