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

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- 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

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<u>Wheat flour T 55</u>

Ash	0.497	%
Protein d.b.	13.3	%
Wet gluten	34.3	%
Falling no.	314	s
Water abs.	58.8	%
Gluten index	89	

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 %

Enzymes

No Baking without Enzymes!

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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

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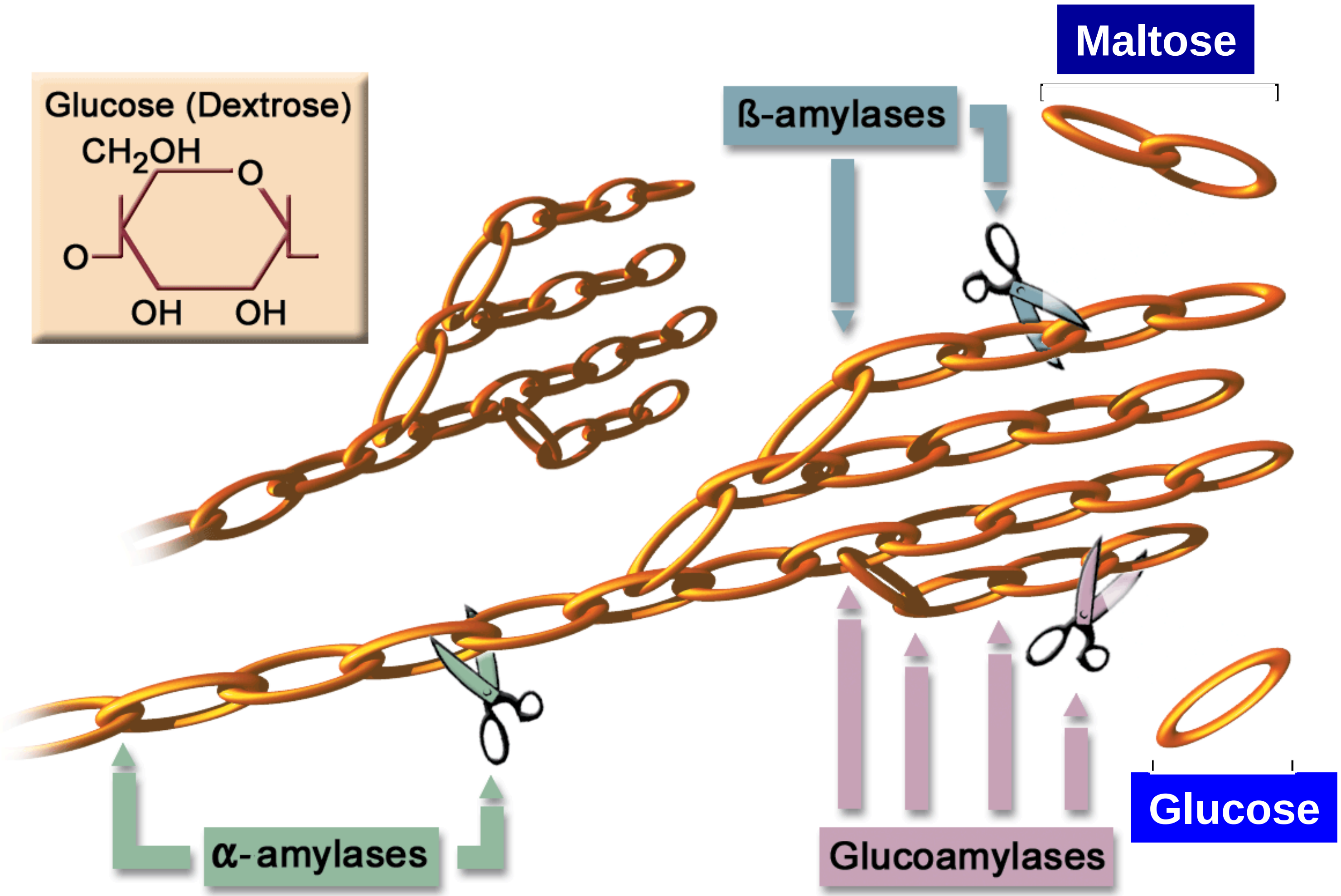
Enzyme	Claimed Effect
α-Amylase	Energy supply for yeast, dough viscosity, shelf life
Amyloglucosidase (glucoamylase)	Energy supply, colour, flavour
Ascorbate & amino acid oxidase	Gluten strengthening
Branching enzyme (glucotransferase)	Water binding
Cellulase	Water binding
Furanosidase, arabinofuranosidase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

Amylolytic Enzymes

Amylolytic Enzymes used in Baking



Effect of α-Amylase on Baking Properties

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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

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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

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- 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

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

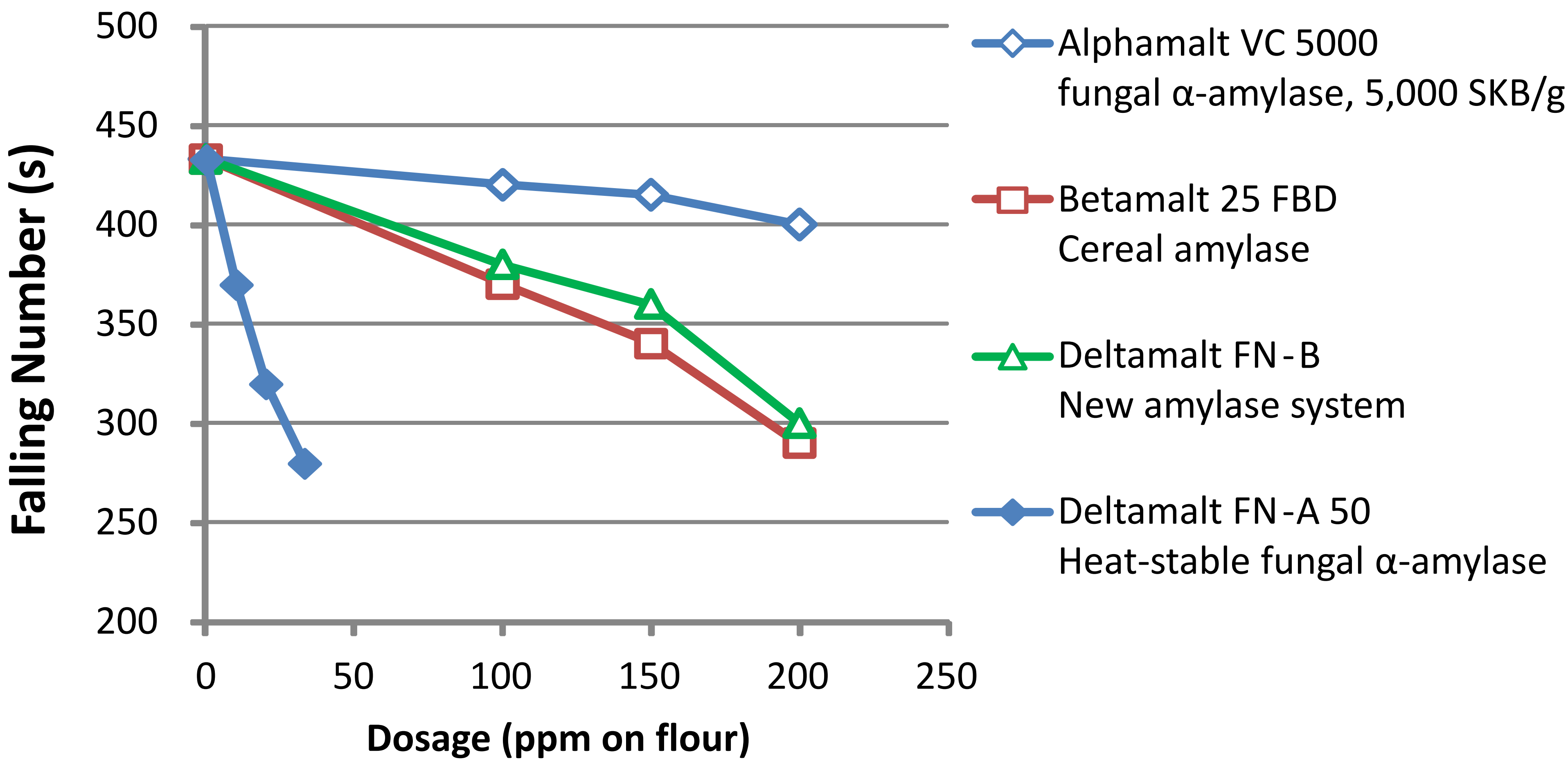
Falling number	Type 405 / 550, 70-75 % extraction	Type 812 / 1050, 80-85 % extraction
220 – 240	20	0
240 – 260	25	0
260 – 280	40	20
280 – 300	45	40
300 – 320	55	45
320 – 350	65	> 55
350 – 380	80	-
>380	> 100	-

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



Wheat flour T 550

Baking Trials with Falling Number-Reducing Amylolytic Enzymes

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Deltamalt FN-B 200 ppm 1780 mL	Standard 1500 mL	Deltam. FN-A50 33 ppm 1820 mL	Betam. 25 FBD 200 ppm 1540 mL	Alpham. VC 5000 200 ppm 1650 mL	Standard 1480 mL

MC Products for Reduction of the Falling Number

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

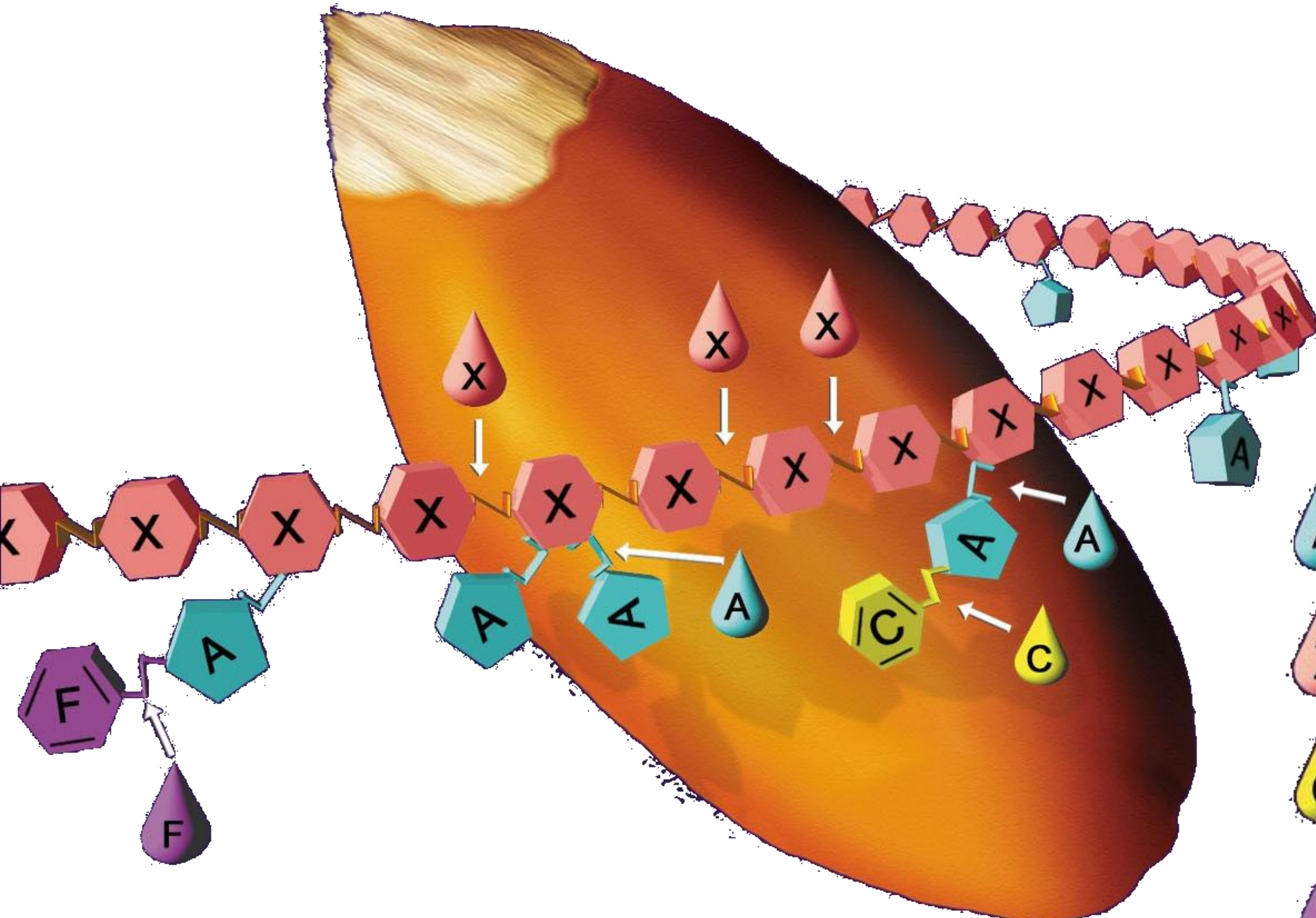
Hemicellulases

Pentosanases, Xylanases and Co.

The Family of Hemicellulases

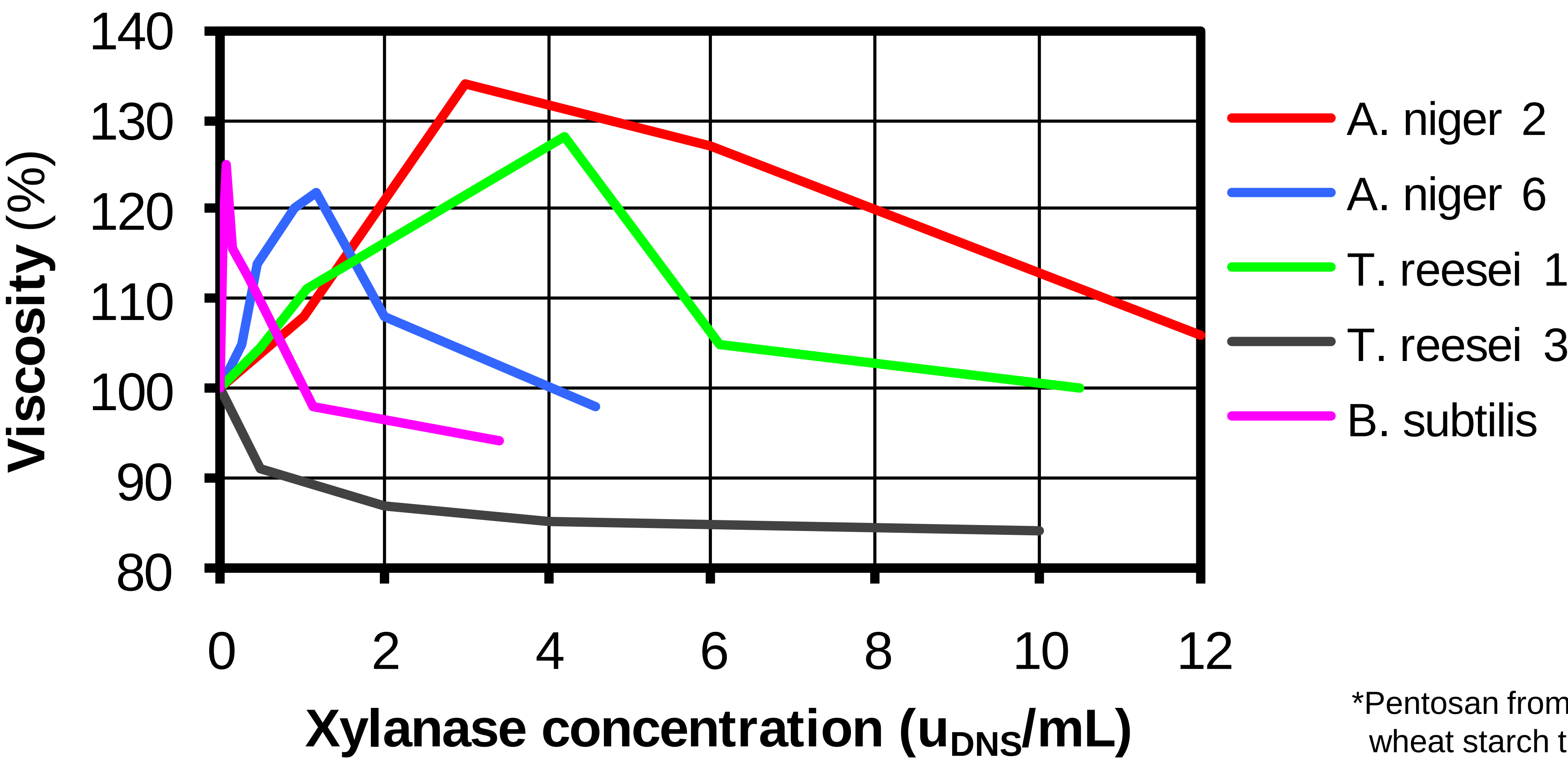
- **Hemicellulase**
  - **Pentosanase**
    - **Xylanase**
      - Endo-1,3-ß-Xylanase
      - Endo-1,4-ß-Xylanase
      - Exo-1,3-ß-Xylosidase
      - Exo-1,4-ß-Xylosidase
      - Arabino-Furanosidase
      - Ferulic Acid Esterase
      - Cumaric Acid Esterase
    - **Arabinanase**
  - **(Hexosanase)**
    - **ß-Glucanase**
    - **Galactanase**
    - **Mannanase**

Enzymatic Hydrolysis Sites in Wheat Xylan



- Arabinose
- Xylose
- Coumaric acid
- Ferulic acid
- α-L-Arabinofuranosidase
- Endo-1,4-ß-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 → dough drying
- release of water → 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

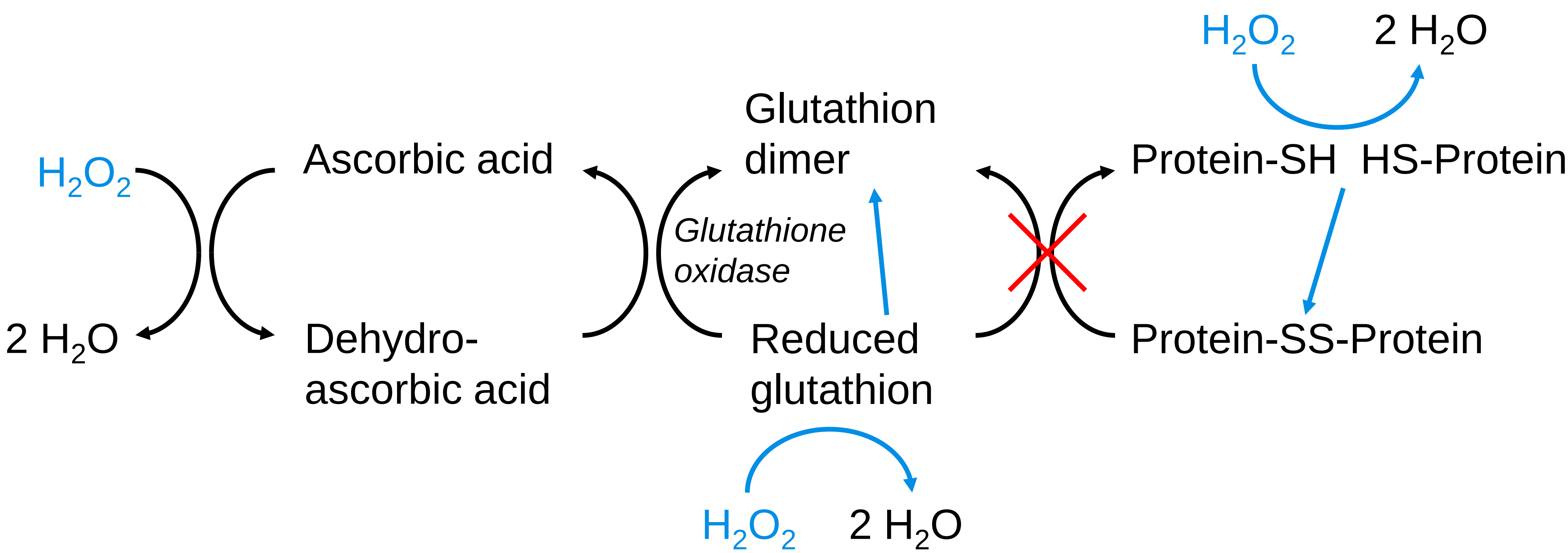
Oxidases

Some Oxidizing Enzymes

- Glucose oxidase
- Galactose oxidase
- Hexose oxidase
- Sulfhydryl oxidase
- Phenoloxidase (laccase)
- Peroxidase
- Katalase

Effects of Glucose Oxidase in Dough

$$\text{Glucose} + O_2 + H_2O \xrightarrow{\text{GOD}} \text{Gluconic acid} + H_2O_2$$



$$\text{Pentosan} + H_2O_2 \xrightarrow{\text{(Peroxidase)}} \text{Oxidative gelation}$$

Effect of Glucose-Oxidase on Dough Development

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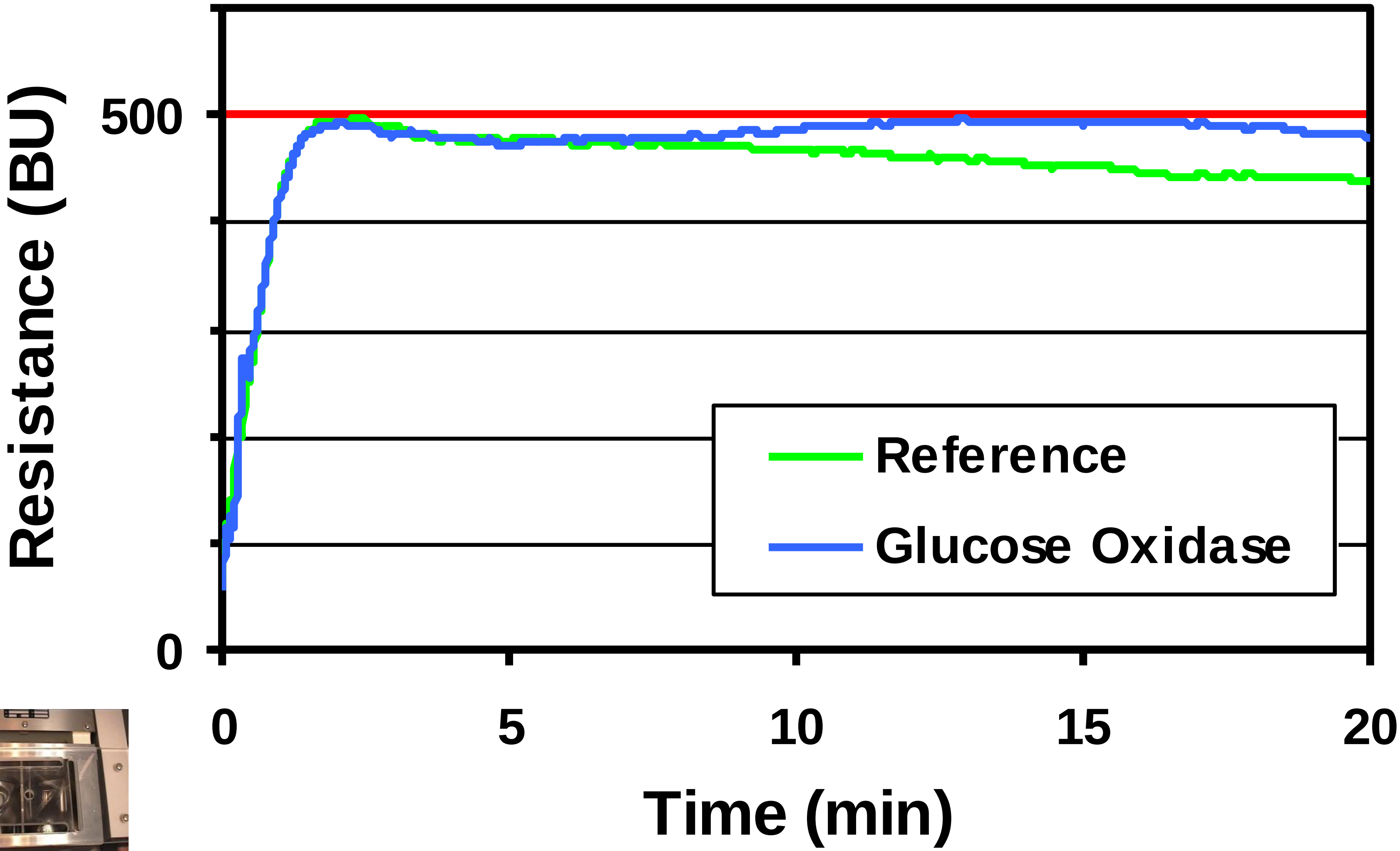


Glucose Oxidase in German Breakfast Rolls

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

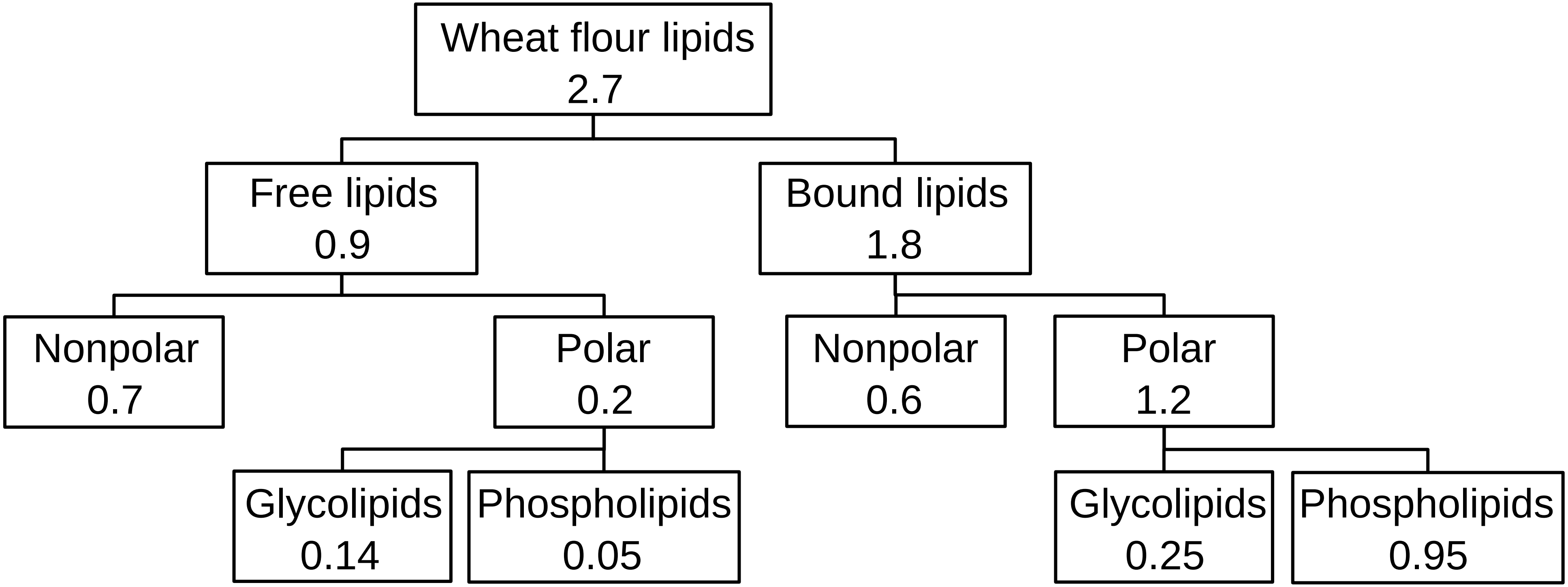
Improve dough stability

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.)



Modif. from Pomeranz & Chung, 1978, using data from Chung & Ohm, 2009

Action of Lipolytic Enzymes

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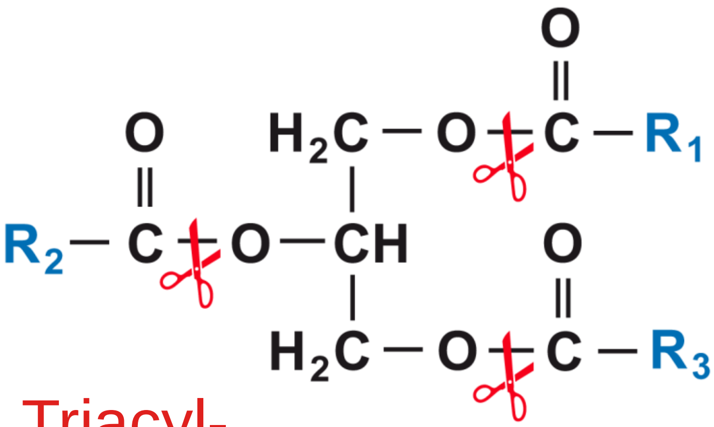
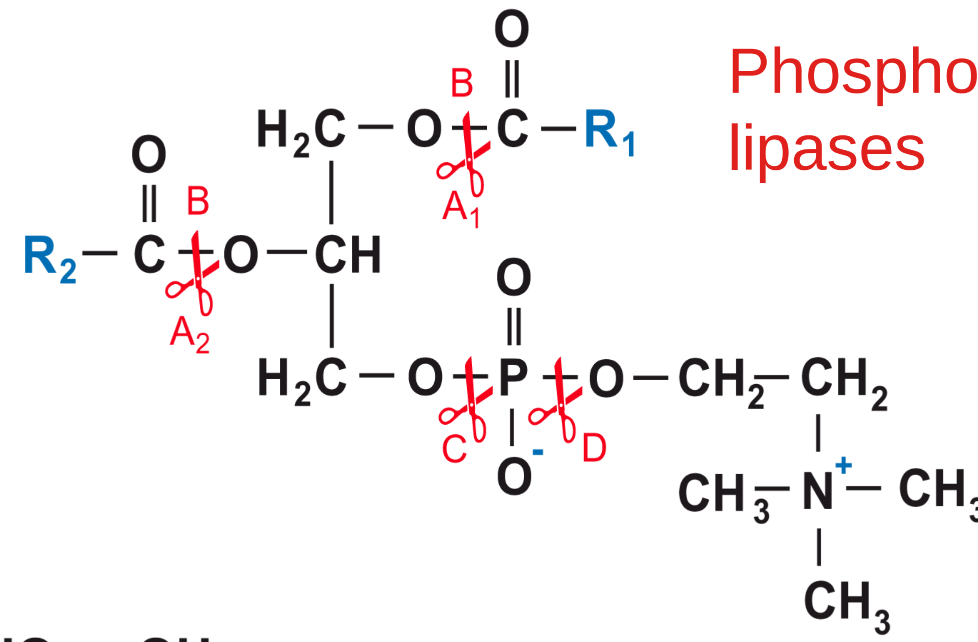
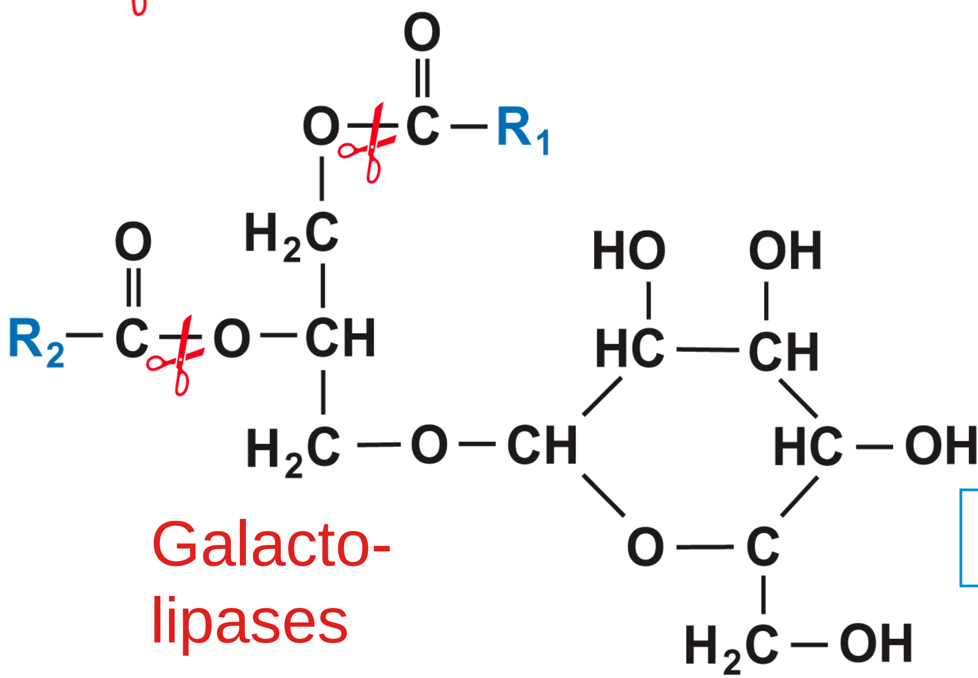


Triacyl-
lipases



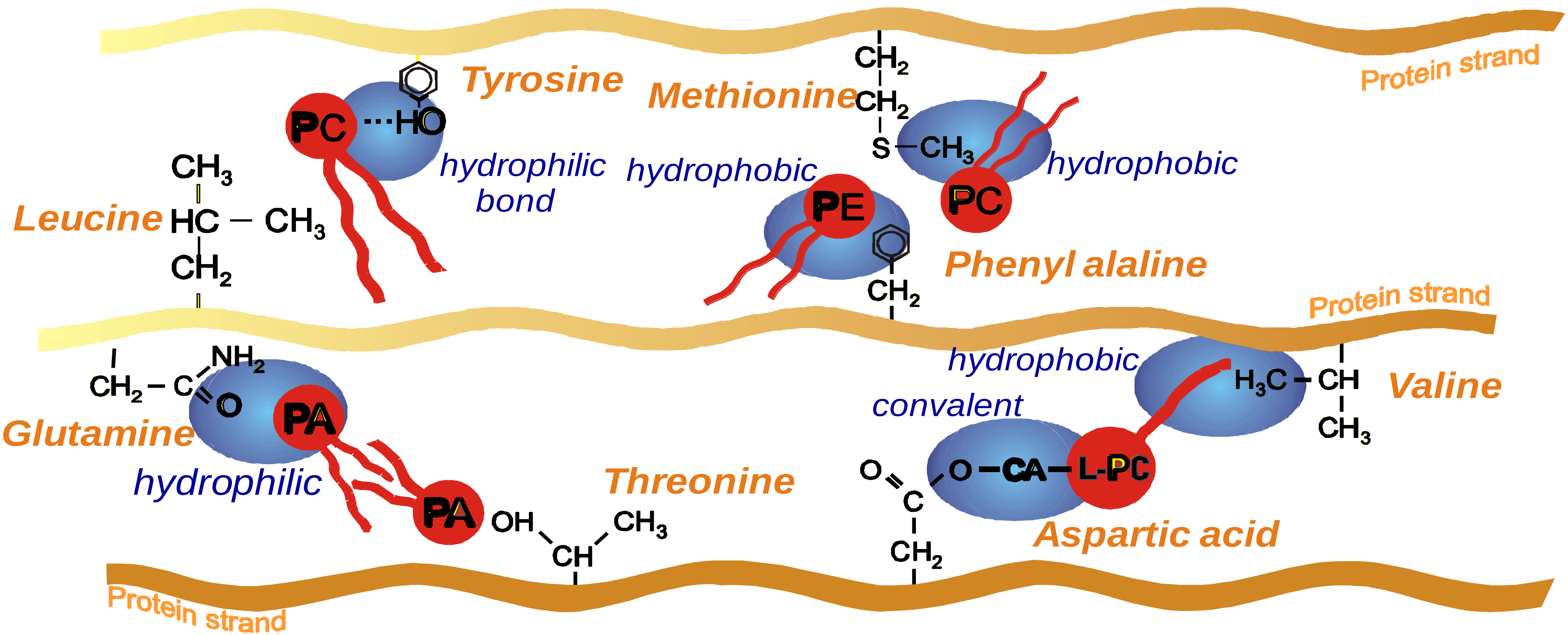
Phospho-
lipases



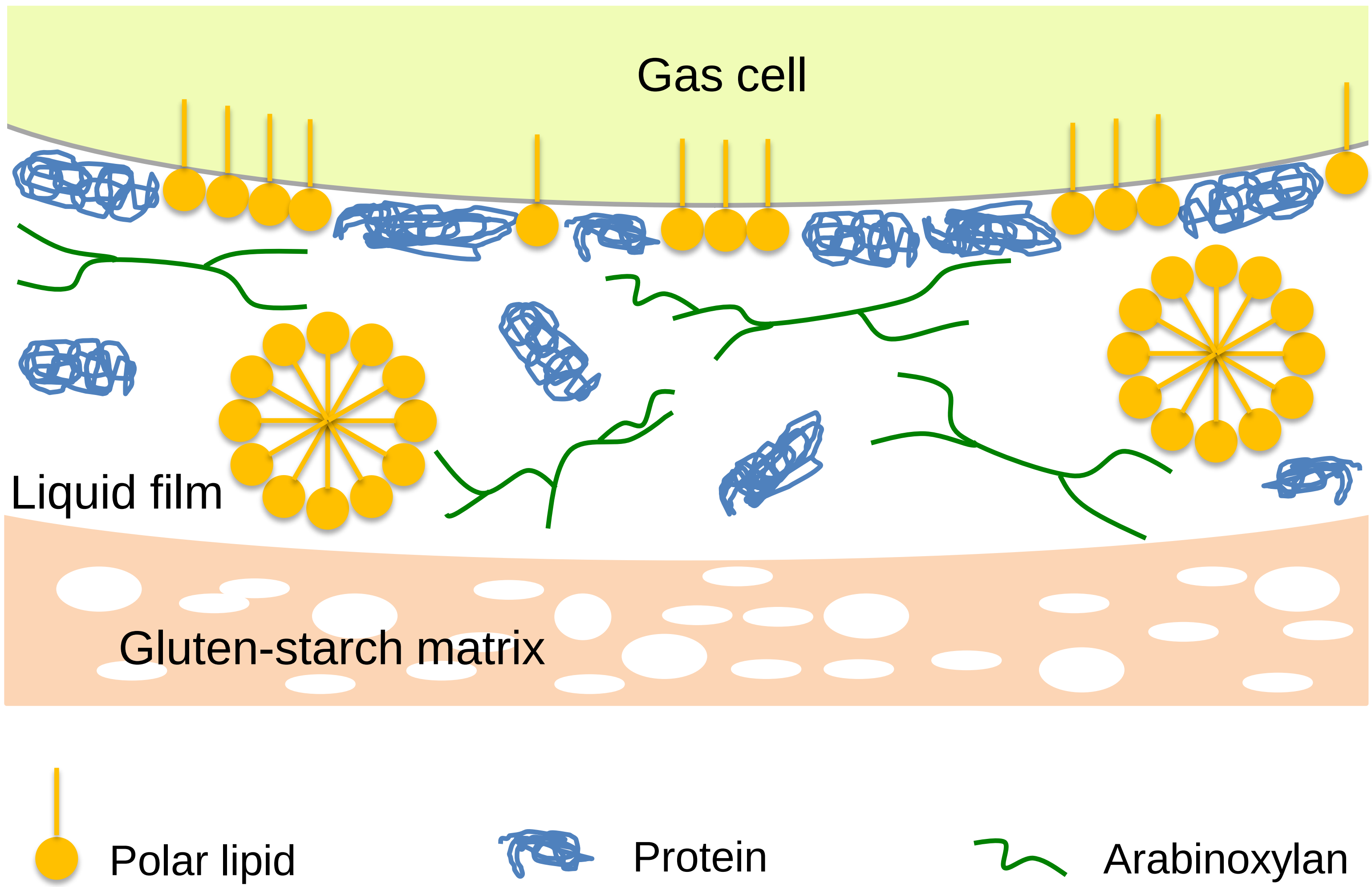
Galacto-
lipases

R_1, R_2, R_3 = fatty acid residues

Formation of Lipoprotein Complexes by Phospholipids

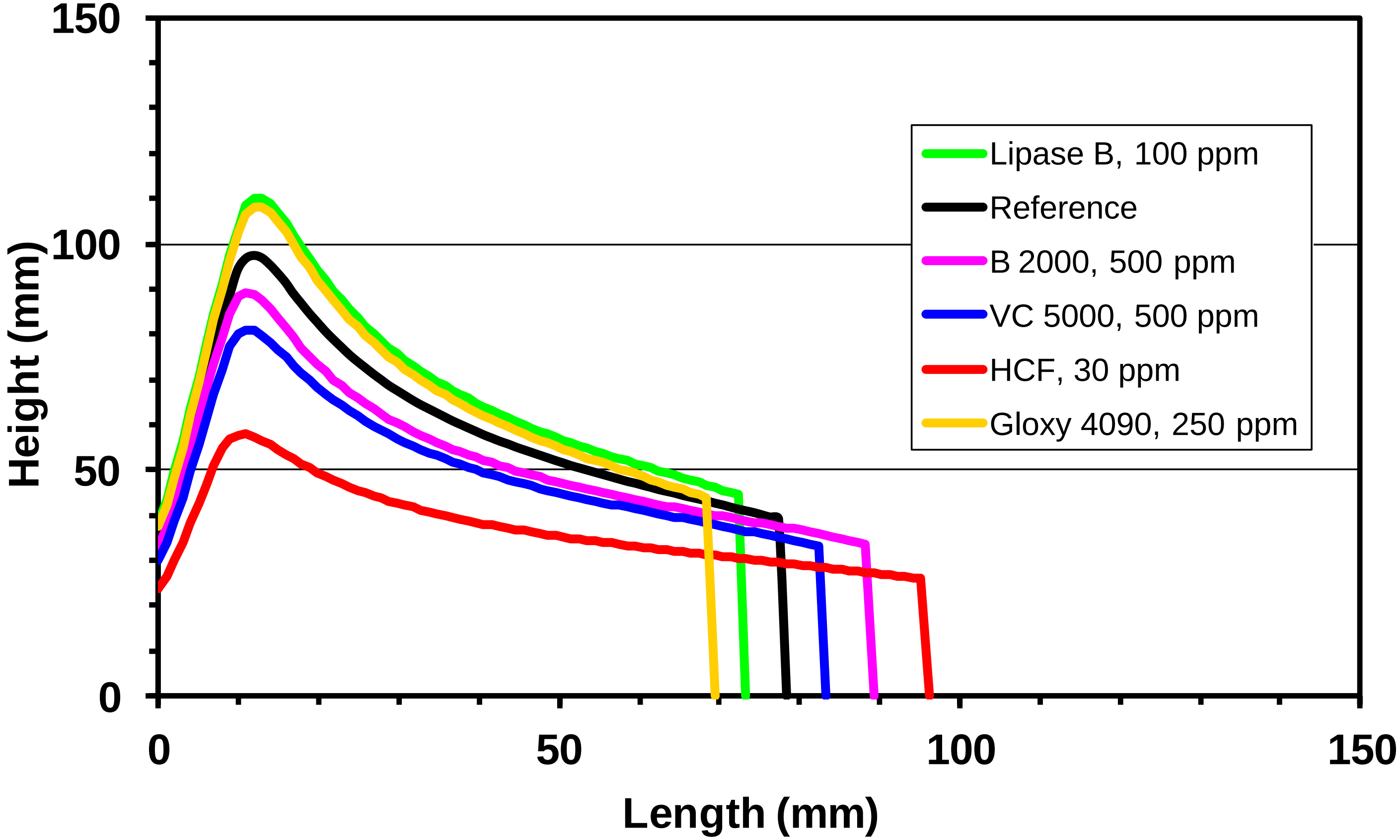


Gas Cell Stabilization by Proteins, Lipids and Arabinoxylans



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*

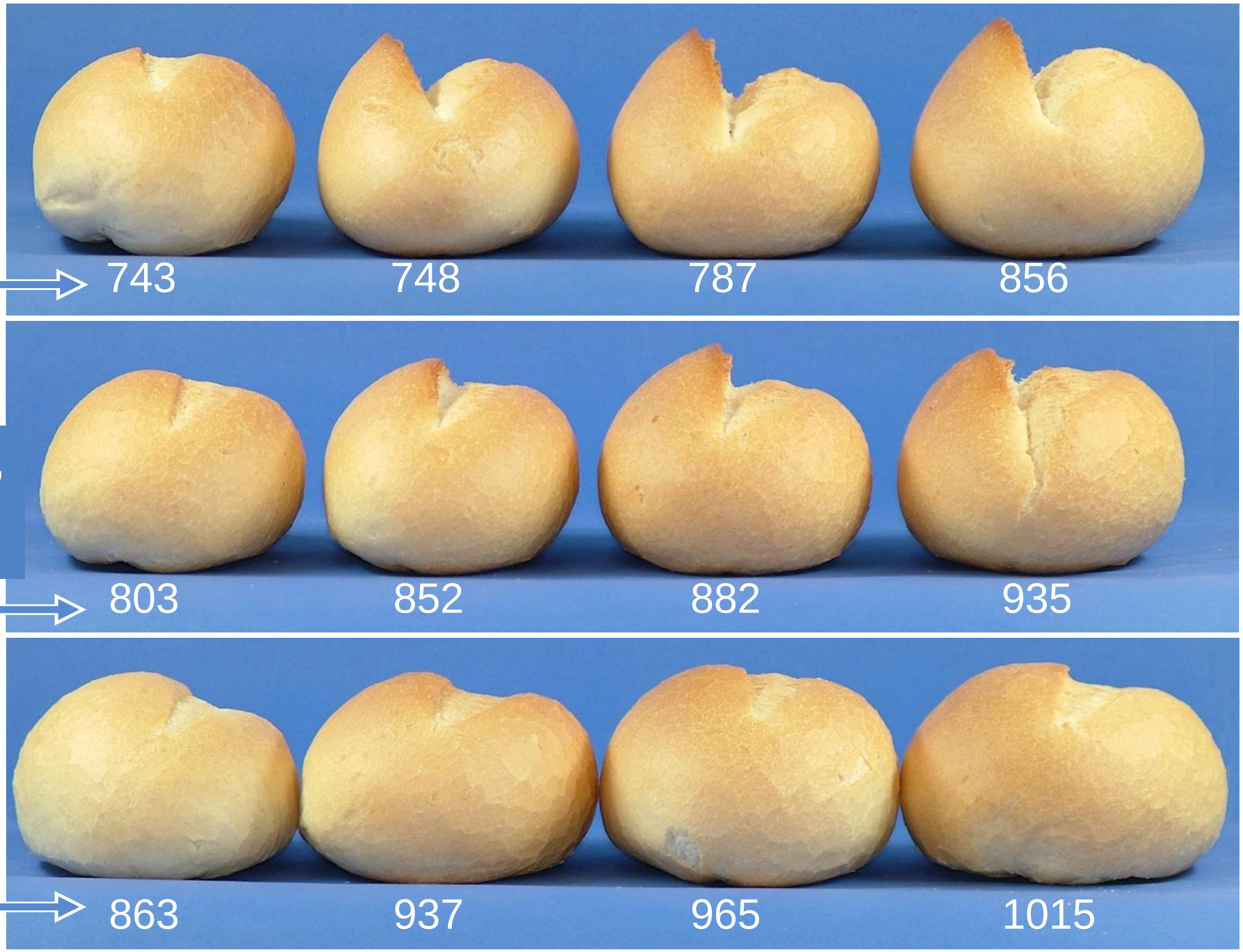
Gloxy 4090 = glucose oxidase from *Aspergillus niger*, 1,500 u/g

Effect of Dosage and Proof Time on Baguette Rolls with *Alphamalt EFX Super*

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

Volume yield, mL/100 g flour

0 ppm 10 ppm 25 ppm 50 ppm



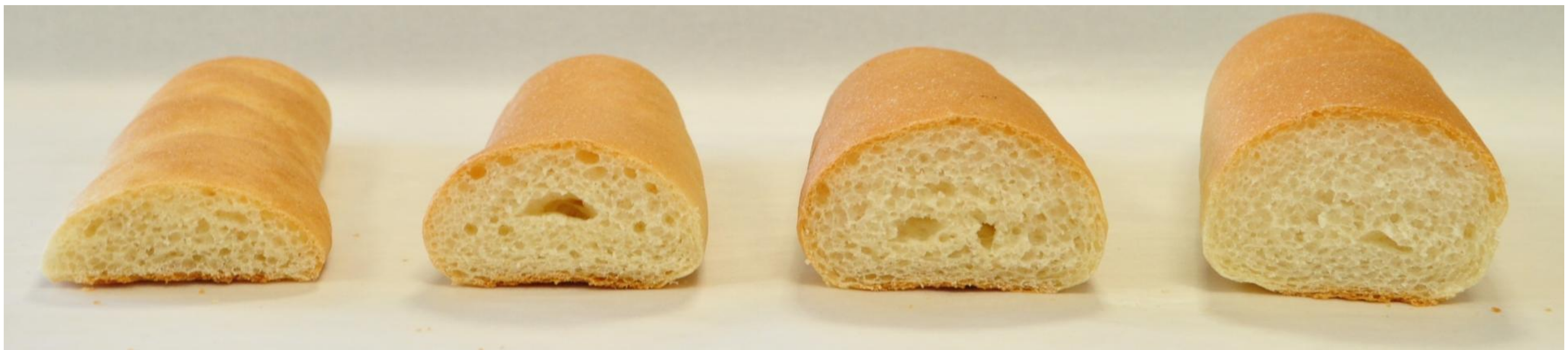
1.5 h, normal proof

2 h, over-proof 1

2.5 h, over-proof 2

Carboxyl Esterase Boosts the Baking Results

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



Reference	ELCO, 50 ppm A 15140, 10 ppm	ELCO, 50 ppm A 15140, 10 ppm HC 13045, 30 ppm	ELCO, 40 ppm A 15140, 10 ppm HC 13045, 30 ppm Gloxy 14080, 20 ppm EFX Mega, 10 ppm

Summary of the Properties of Carboxyl Esterases

- Produce emulsifier-like substances from lipids
- Enhance dough stability
- Increase volume yield
- Result in fine porer 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

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Résumé

Improvement of Baking Properties and Baked Product Quality by Enzymes

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Baking	Problem	Enzymatic solution
Dough	Short dough	Amylase, xylanase, protease
	Slack dough	Glucose oxidase, xylanase
	Low rising power	Amylase, glucoamylase
	Sticky dough	Glucose oxidase, xylanase
Baked good appearance	Volume yield	Amylase, xylanase, carboxyl esterase
	Shape	Amylase, xylanase, glucose oxidase
	Cut & shred	Glucose oxidase
	Coloration	Amylase, glucoamylase
	Crust flaking	Glucoamylase, amylase
	Blisters (frozen dough)	Carboxyl esterase
Crumb	Crust separation (f.d.)	Carboxyl esterase, amylase
	Pore structure	Carboxyl esterase, xylanase
	Crumb color	Lipoxygenase, lipase, xylanase
	Softness	Amylase, xylanase, carboxyl esterase
	Shelf-life of softness	Amylase

Typical Effects of Enzymes on Bread Quality
used at common dosages

Enzyme	WA(1)	Volume(2)	Stability(3)	Cut(4)	Colour(5)	Crumb(6)	Shelf-life(7)
α-Amylase, fungal	o	++	-	+	+	-	+
α-Amylase, cereal	-	+	--	-	++	--	+
α-Amylase, bacterial	-	(+)	(-)	o	o	-	+
α-Amylase, maltogenic	o	o	o	o	o	o	++
$Xylanase_{WUX}$	+	++	+	+	o	+	(+)
$Xylanase_{WEX}$	-	+	-	-	o	-	o
Protease	o	(+)	(+)/-	+	o	(-)	o
Oxidase	++	+	++	++	o	+	(+)
Carboxylesterases	+	++	+	+	o	++	+
Transglutaminase	o	o	+	+	o	o	o

(1) Water absorption (2) Baking volume yield (3) Shape stabilty (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

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HRW in grist	(%)	30	20	10	0
French wheat	($/MT flour)	224.28	256.32	288.36	320.40
HRW	($/MT flour)	118.62	79.08	39.54	0.00
EMCEgluten^{Plus} Baguette*	(ppm)	0	250	450	650
	($/MT flour)	0.00	4.43	7.98	11.52
Ascorbic acid	(ppm)	0	0	0	30
	($/MT flour)	0.00	0.00	0.00	0.53
Total cost	($/MT flour)	342.90	339.83	335.87	332.45
Savings	($/MT flour)	0.00	3.07	7.02	10.44

* Improver premix incl. hydrocolloids and enzymes