Control of Wheat Flour Quality by Improvers

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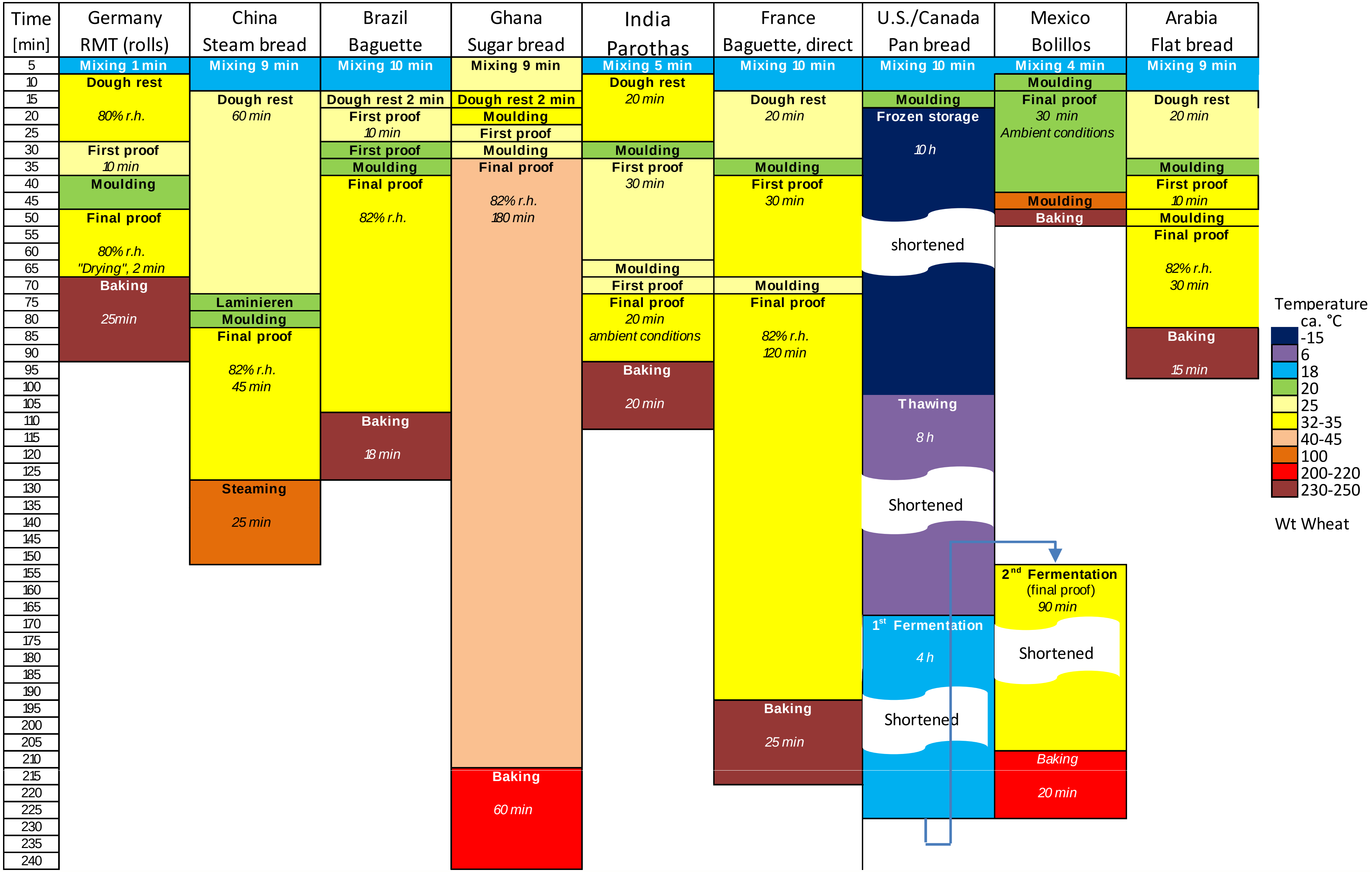
Diversity of Baking Procedures



Flour Improvers

Standardization and optimization of flour quality with micro-ingredients

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

Improve baking performance

Diversify applicability

Suit customers specifications

Additives Used in Flour Improvers

1 – 100 ppm on flour

- Enzymes
- Oxidizing agents
- Ascorbic acid
- Reducing agents

500 – 3,000 ppm on flour

- Emulsifiers
- Acidity regulators
- Malt flour
- Vital wheat gluten
- Hydrocolloids
- Soy flour
- Preservatives

Oxidizing Agents

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Reasons for the Use of Oxidation

- Modern milling technology (roller mills instead of stones) reduces thermal and oxidative stress
- Short storage of flour / just-in-time production reduces maturation period
- Air-tight packaging material or silo storage reduce access of oxygen
- Industrial bakers requiring very constant flour properties, and
- Higher dough tolerance
- Bleaching effects on flour and/or bread crumb
- Wheat varieties and high protein levels requiring / allowing for more oxidative maturation (?)

Oxidizing Agents as Flour Improvers

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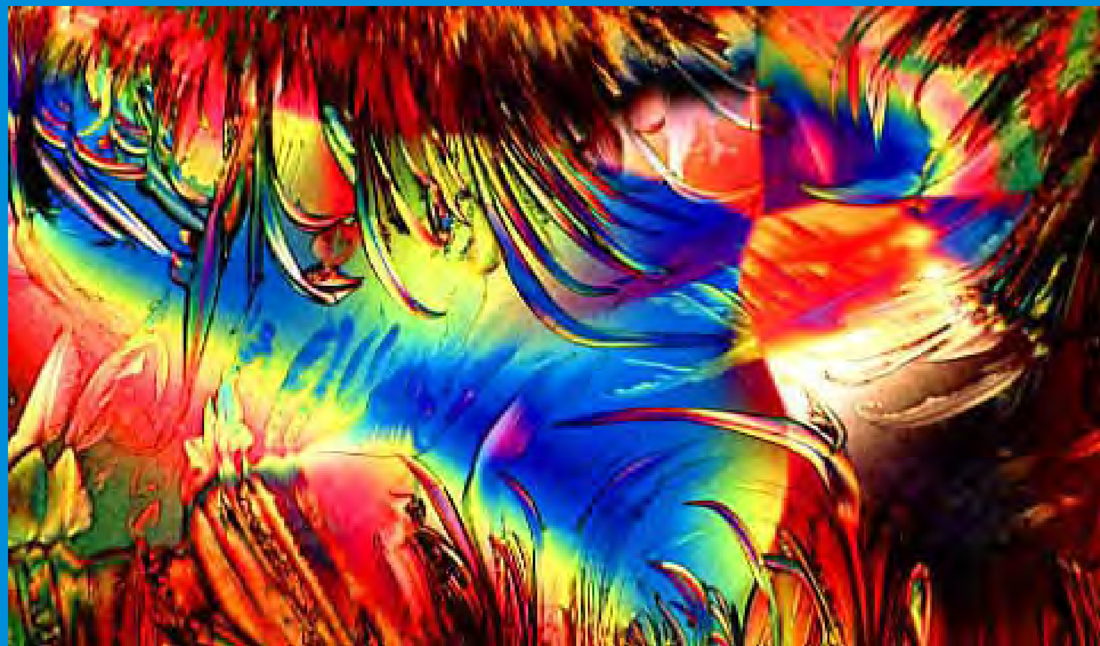
- Potassium bromate
- Potassium iodate
- Calcium bromate
- Calcium iodate
- Azodicarbonamide
- Calcium peroxide
- Ammonium persulfate
- Potassium persulfate
- Sodium perborate
- Sodium percarbonate
- Acetone peroxide
- Chlorine & chlorine dioxide
- Hypochlorite
- Benzoyl peroxide
- Ascorbic acid, resp.
- Dehydro-ascorbic acid
- Sodium hypophosphite
- Cystine
- Hydrogen peroxide
- Oxygen
- Ozone

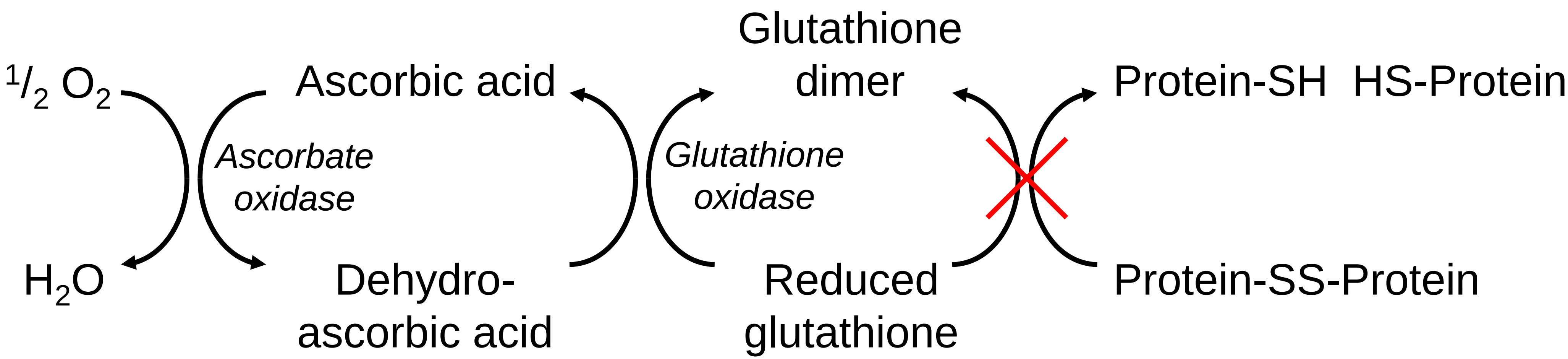
Ascorbic acid



Ascorbic acid under the microscope

Source: www.microscopy.fsu.edu/micro/gallery/vitamin/vitamin.html

Reactions of Ascorbic Acid in Dough



(modified from Grosch and Wieser, 1999)

General Directions for Use of Ascorbic Acid in Flour Improvement

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

High and soft protein: 60 – 100 ppm

High and short protein: 20 – 40 ppm

Low and soft protein: max. 60 ppm

Low and short protein: 20 ppm

Low Falling Numbers (below 220 s): Increase dosages by 50 %

Effects of Ascorbic Acid in Baking

- Compensates lack of flour maturation
- Improves dough stability
- Improves fermentation tolerance
- Increases dough elasticity
- 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

Wheat flour T 55

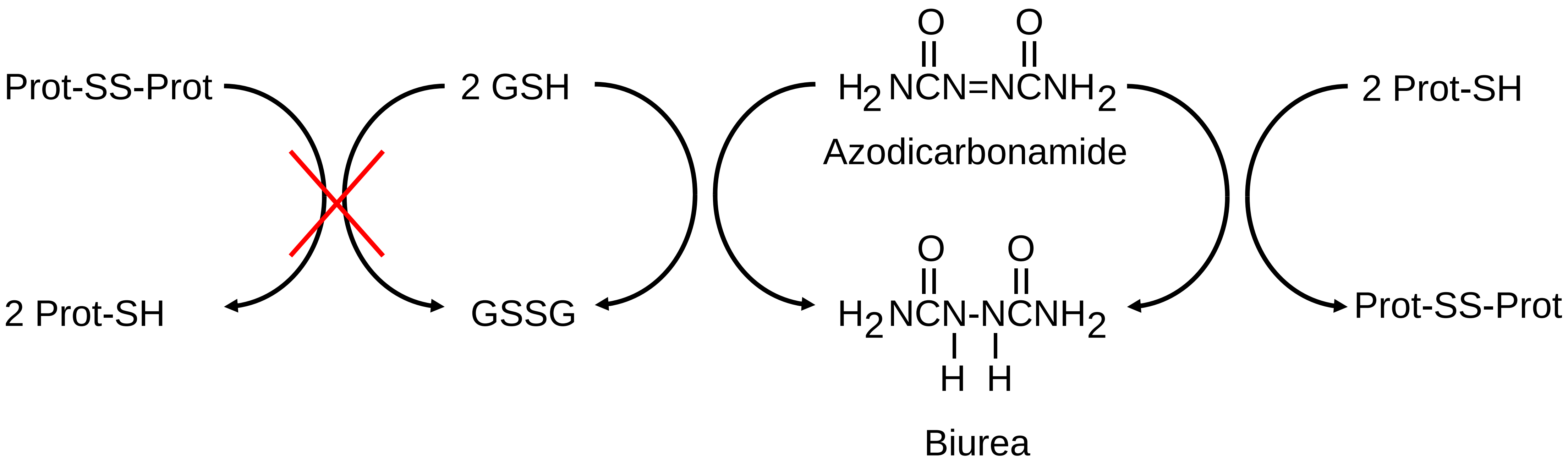
Ash	0.497 %
Protein d.b.	13.3 %
Wet gluten	34.3 %
Falling no.	314 s
Water abs.	58.8 %
Gluten index	89

without treatment

ELCO C-100
3.5 g/100 kg

Azodicarbonamide (ADA)

Possible Actions of Azodicarbonamide



GSH	=	reduced glutathione
GSSG	=	oxidized glutathione
Prot-SS-Prot	=	gluteline

Properties of Azodicarbonamide

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- Fast oxidizing effect
- Results in bucky doughs
- Improves dough stability
- Improves crumb structure, but
- Sometimes a few larger holes
- Bread surfaces rough when insufficient relaxing time
- Recommended max. level in bread flour 45 ppm

Enzymes

Nature’s all-purpose tools

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.

Sources for Industrial Food Enzymes

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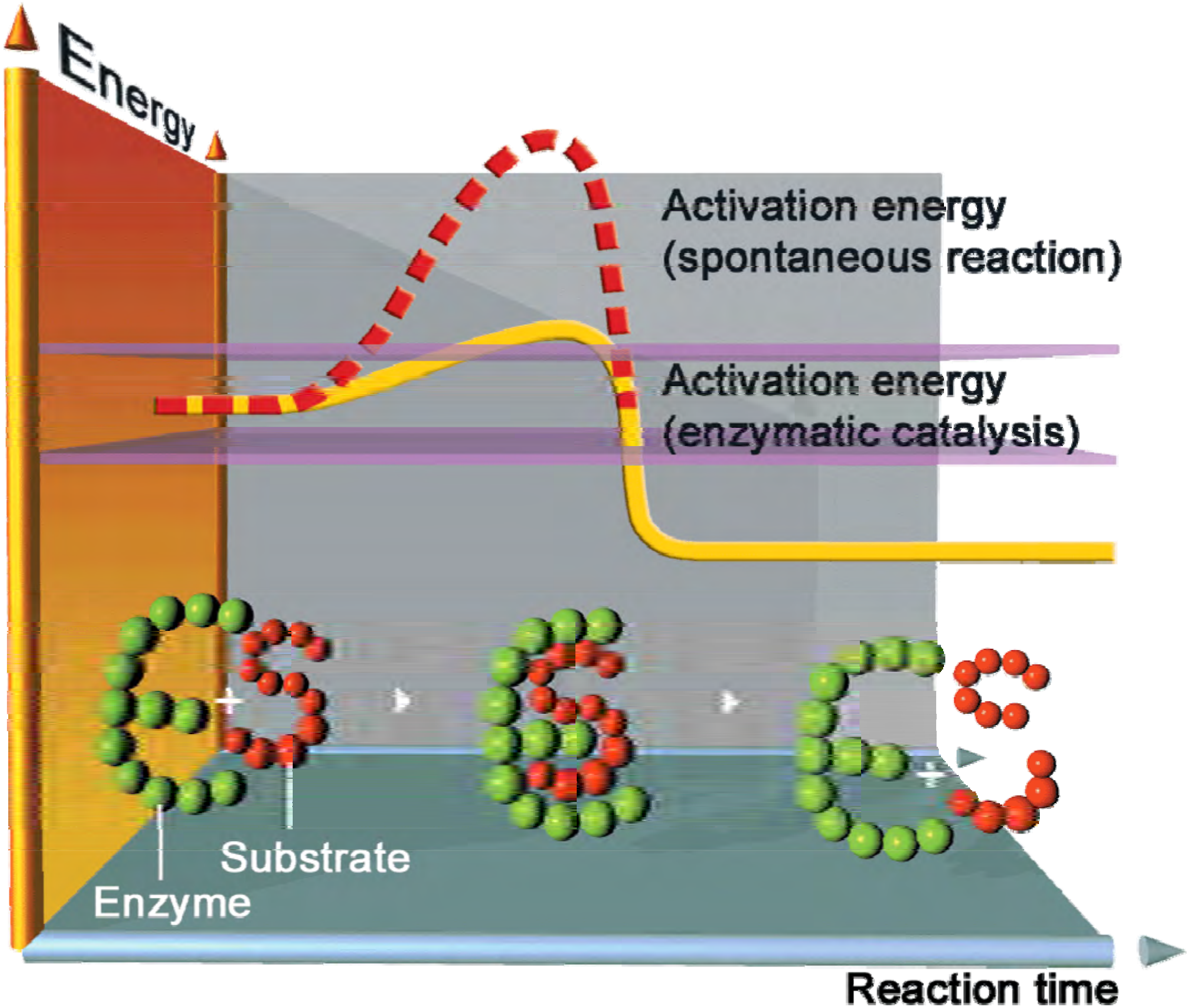
Plants	Figs	→	Ficin
	Pineapple	→	Bromelain
	Papaya	→	Papain
Animals	Pigs, calves	→	Pancreatin, Chymosin
	Hen eggs	→	Lysozyme
	Milk	→	Lactoperoxidase
Microbes	Yeast	→	Invertase, Lipase
	Moulds	→	Amylase, Xylanase,
	Bacteria	→	Protease, Oxidase

Energy of Activation & Enzyme Catalysis



Enzyme Activity Depends on Many Factors

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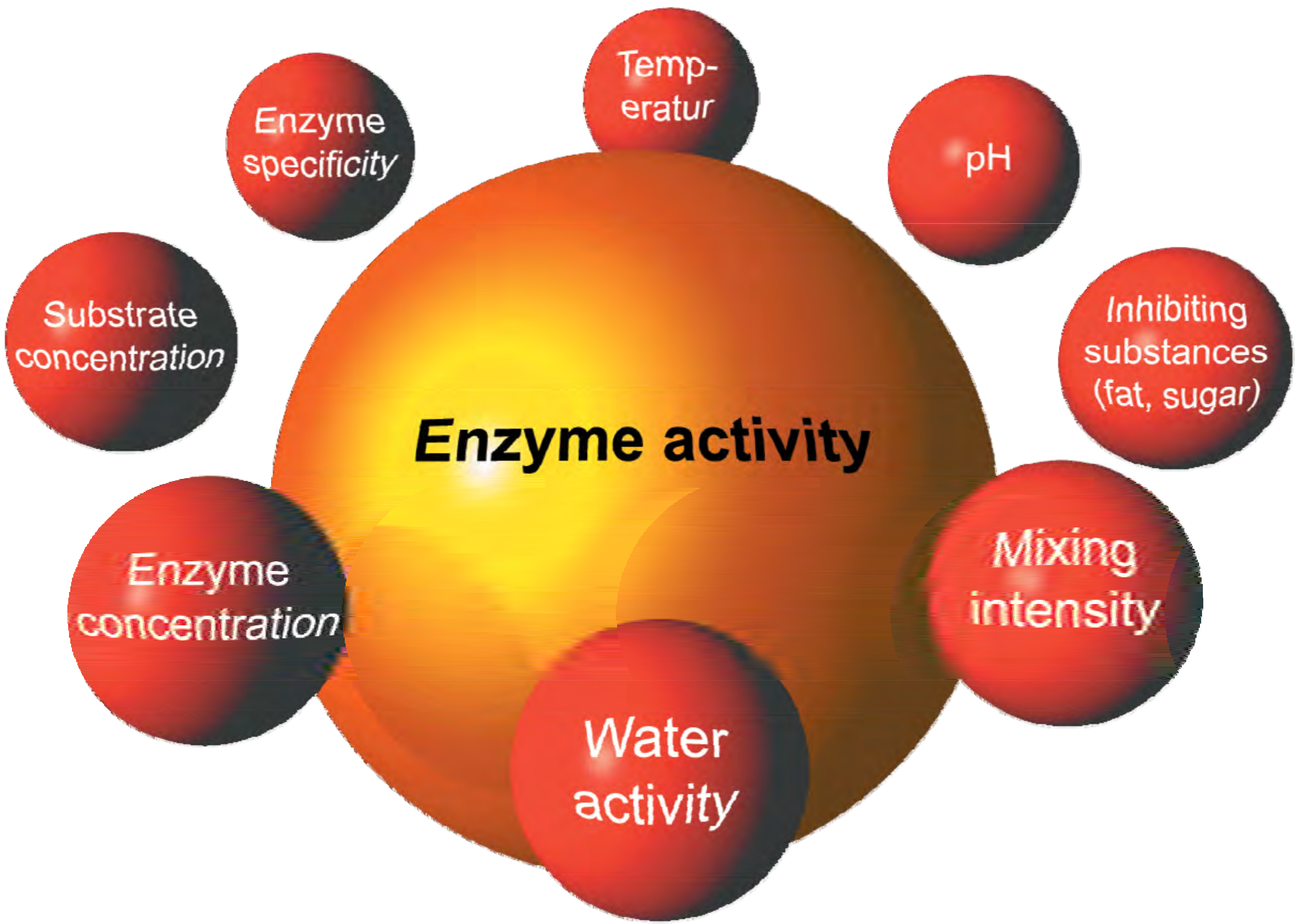
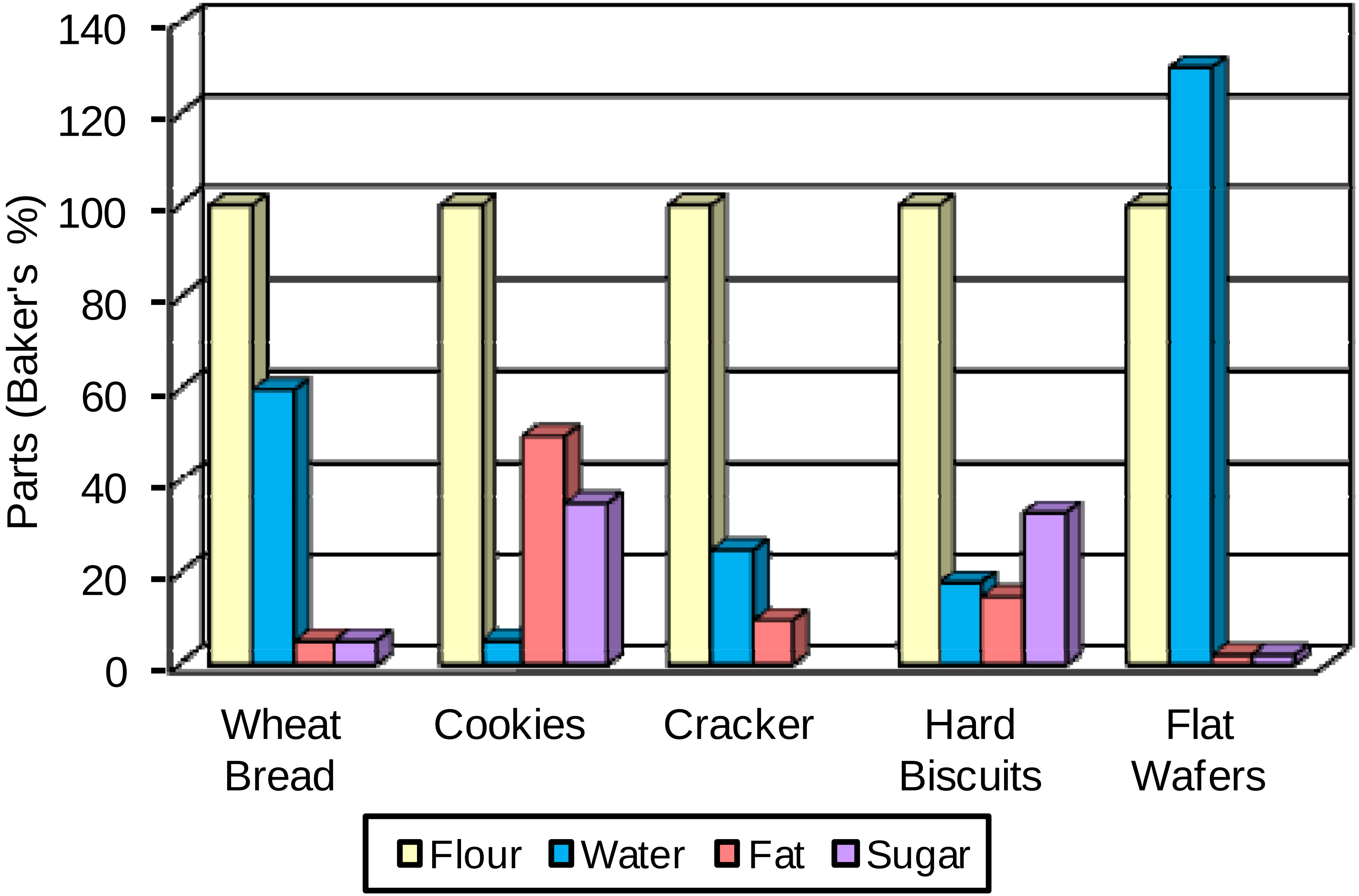
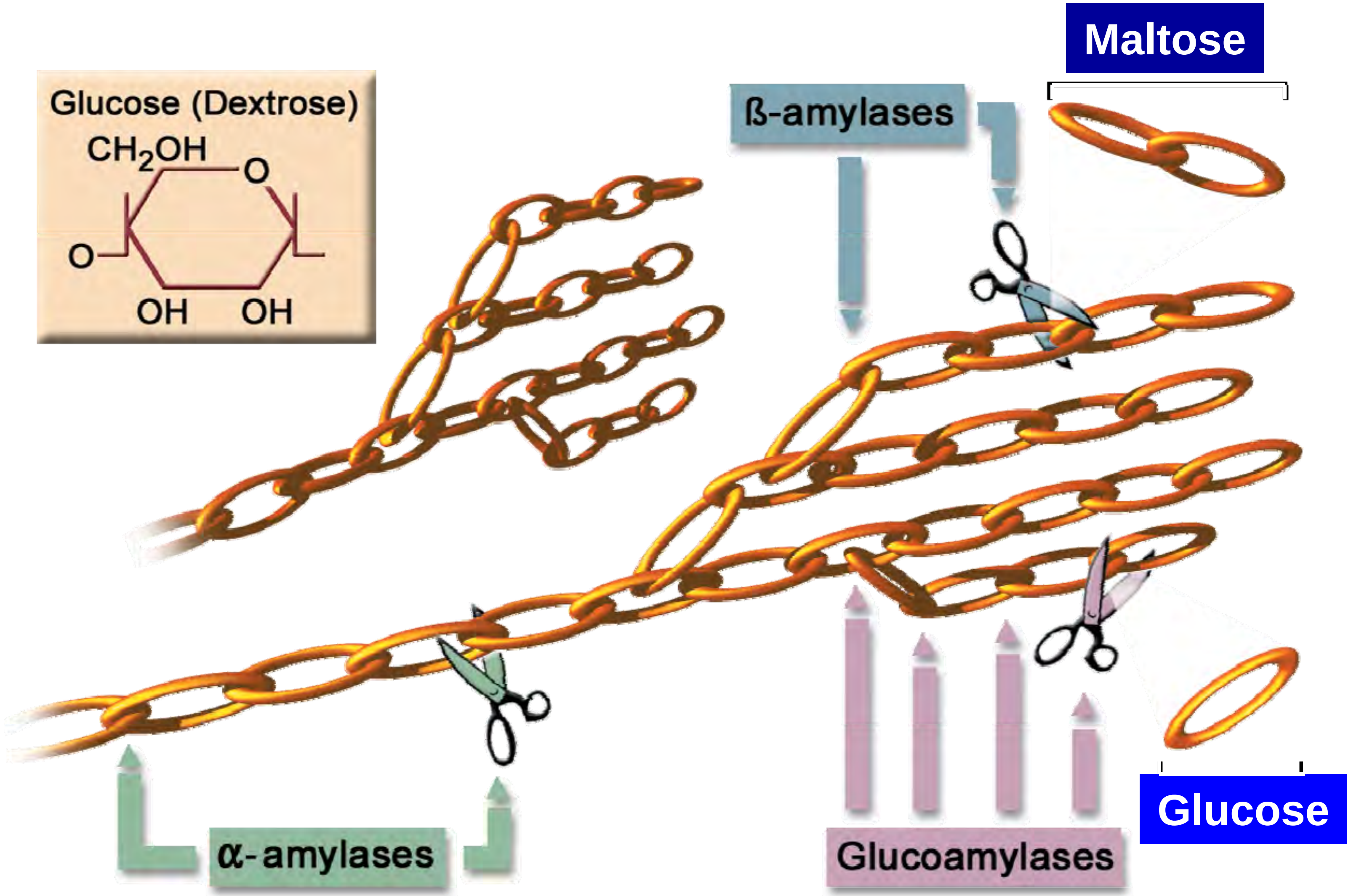


Typical Compositions of Doughs and Batters



Amylolytic Enzymes

Amylolytic Enzymes used in Baking



Effect of α-Amylase on Dough and Baked Good

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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, large pores or weak crumb 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**

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**

Hemicellulases

Pentosanases, Xylanases and Co.

Enzymatic Hydrolysis Sites in Wheat Xylan

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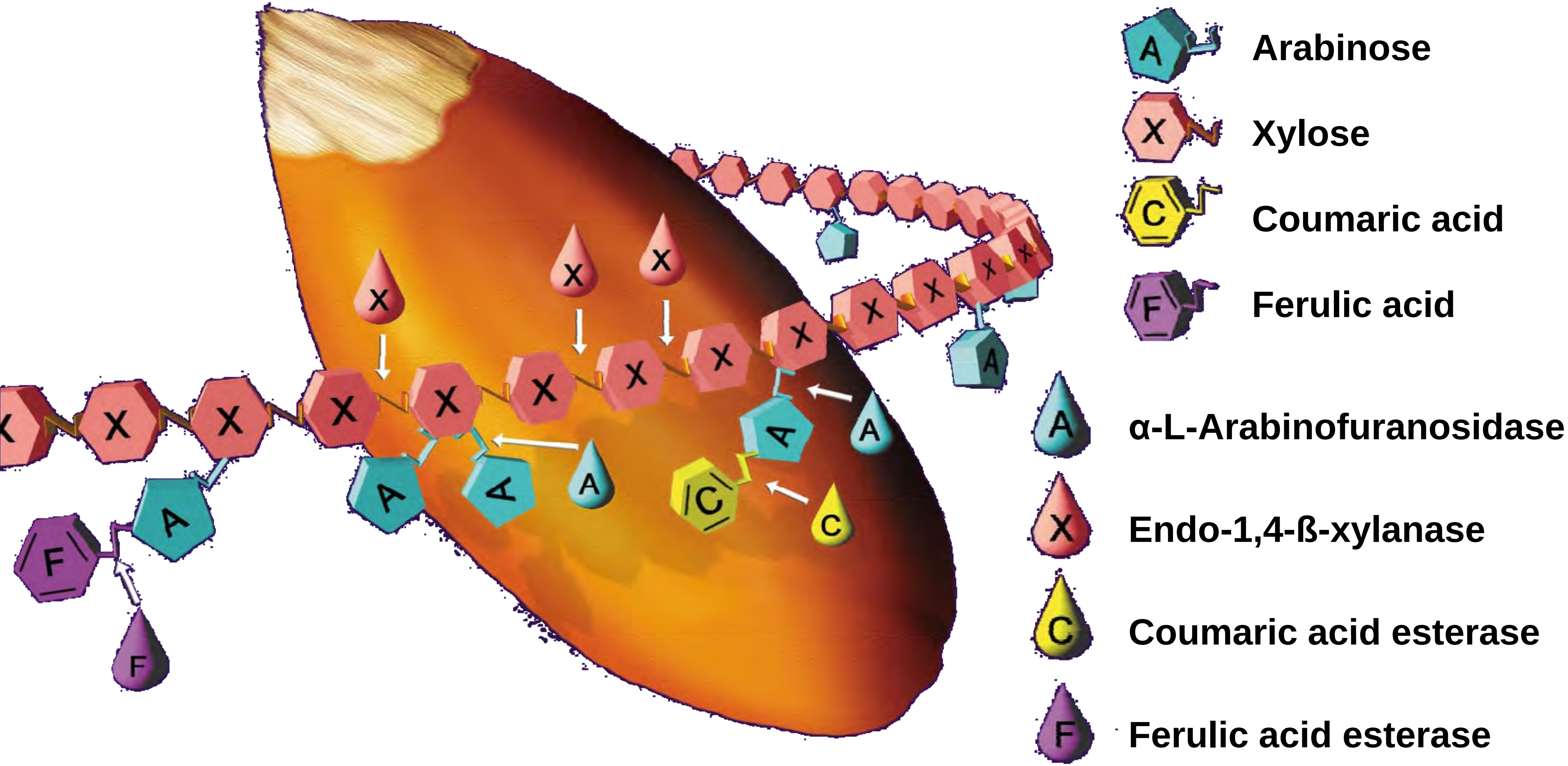
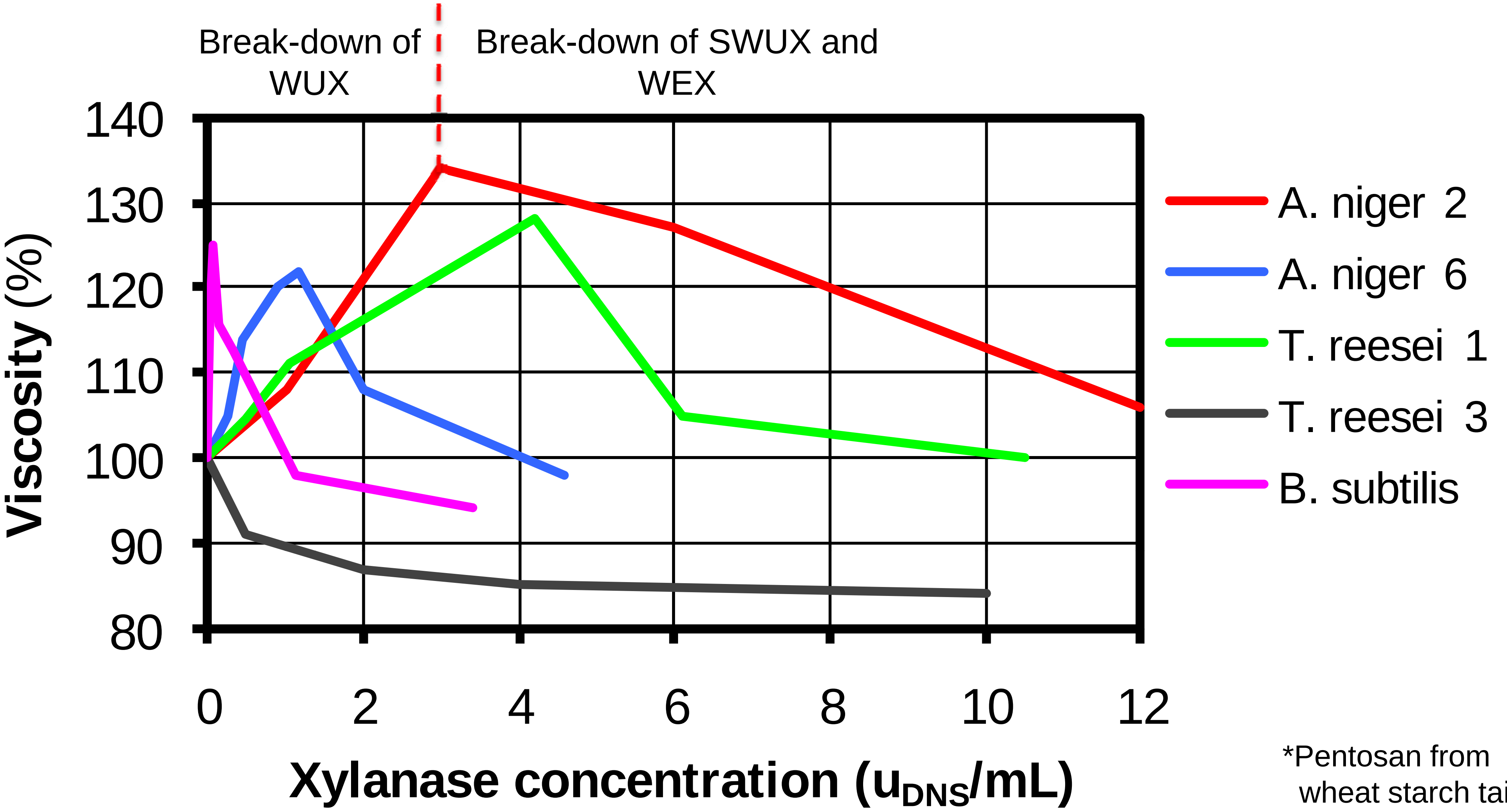


Effect of Various Xylanases on Pentosan* Viscosity



*Pentosan from wheat starch tailings

WUX – water-unextractable xylans WEX – water-extractable xylans
SWUX – solubilized water-unextractable xylans

Summary of the Effects of Xylanases

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- **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

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

Effects of Glucose Oxidase in Dough

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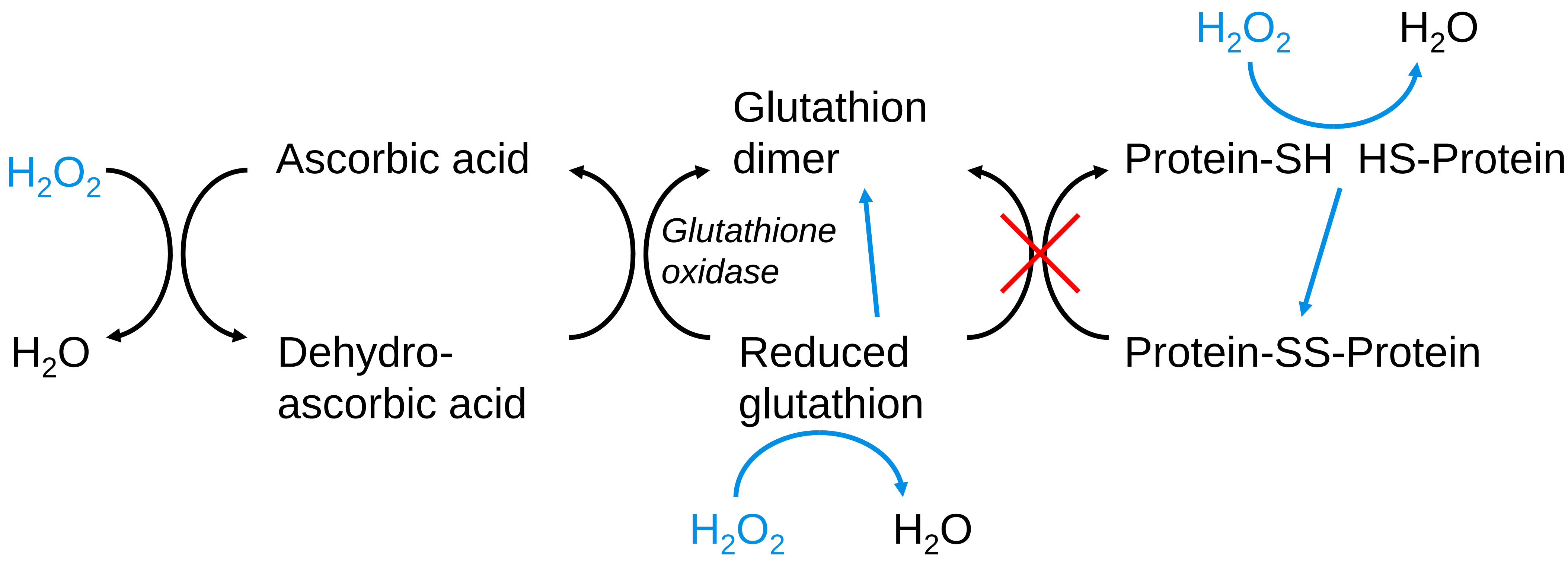
$$\text{Glucose} + O_2 + H_2O \xrightarrow{\text{GOD}} \text{Gluconic acid} + H_2O_2$$



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

Effect of Glucose-Oxidase on Dough Development

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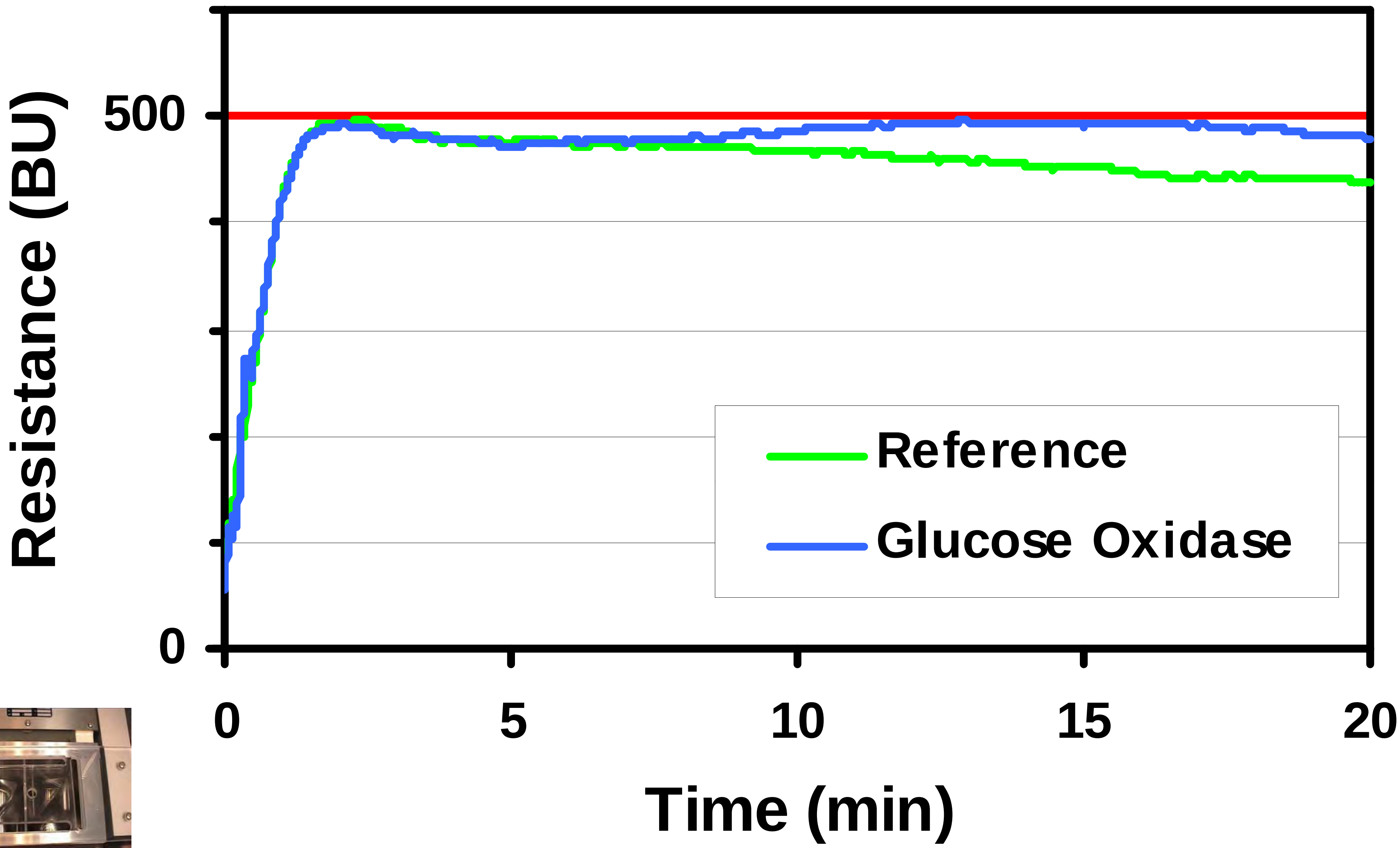

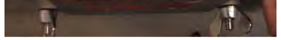

Comparison of Glucose Oxidase in Germany
Breakfast Rolls (over-fermented)

Wheat flour: German soft wheat; SOX from pilot scale production

Summary of the Effects of Oxidases

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- 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.)

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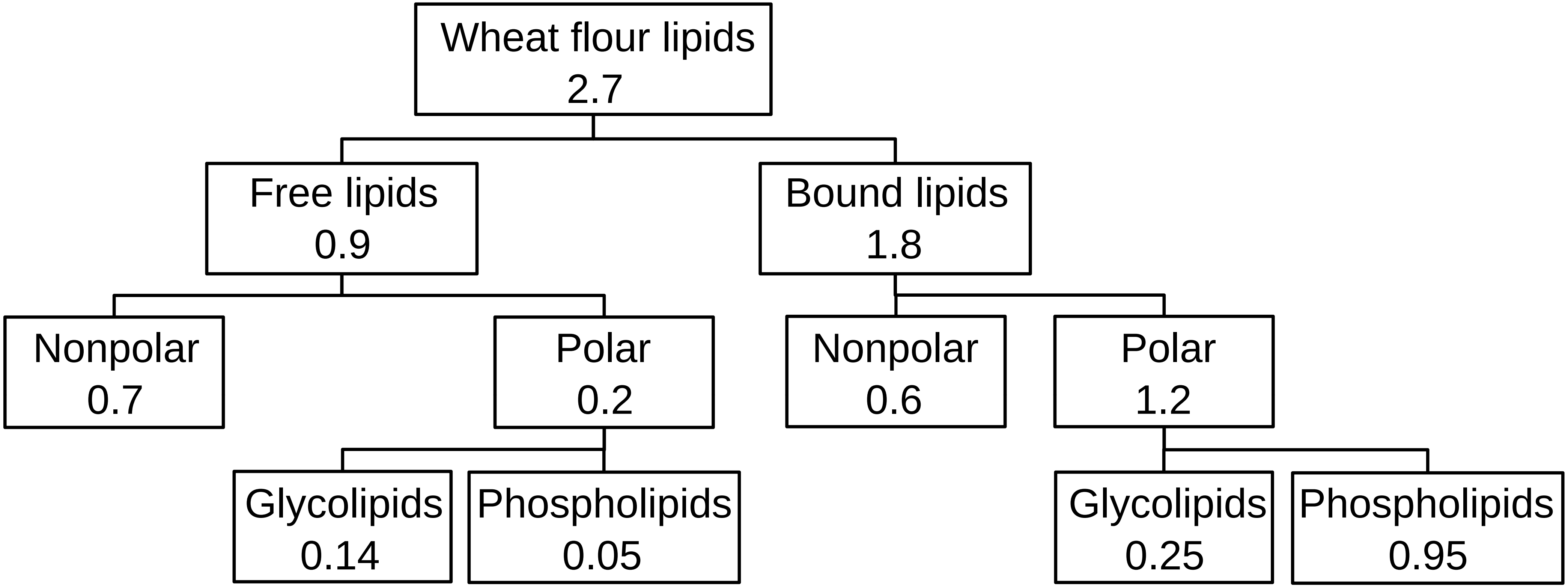
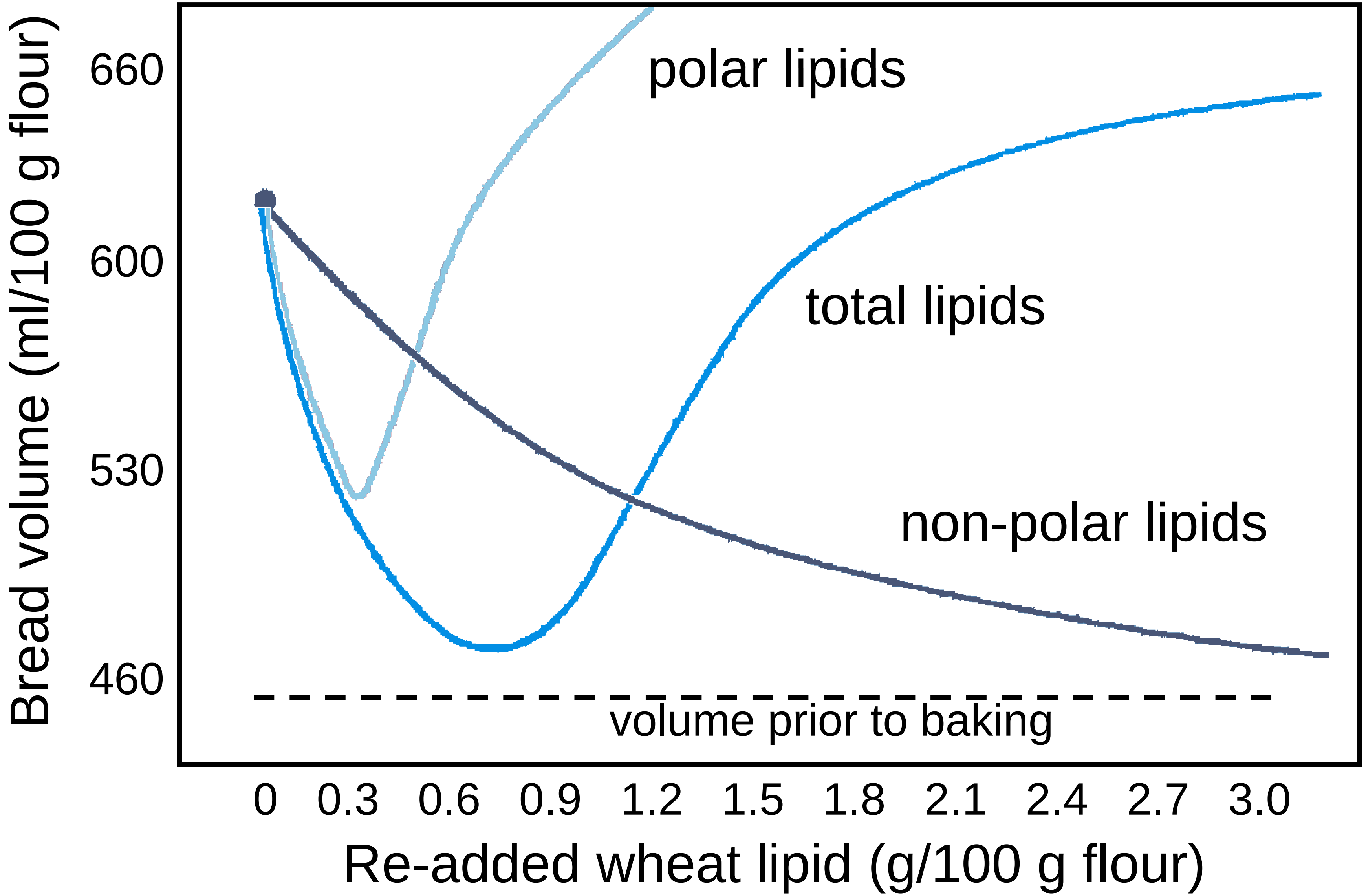


Modif. from Pomeranz & Chung, 1978, using data from Chung & Ohm, 2009

Effect of Wheat Lipids on Volume Yield of Defatted Wheat Flour



Modif. from MacRitchie & Gras, 1973

Effect of Dosage and Proof Time on Baguette Rolls with *Alphamalt EFX Super* (Carboxyl Esterase)

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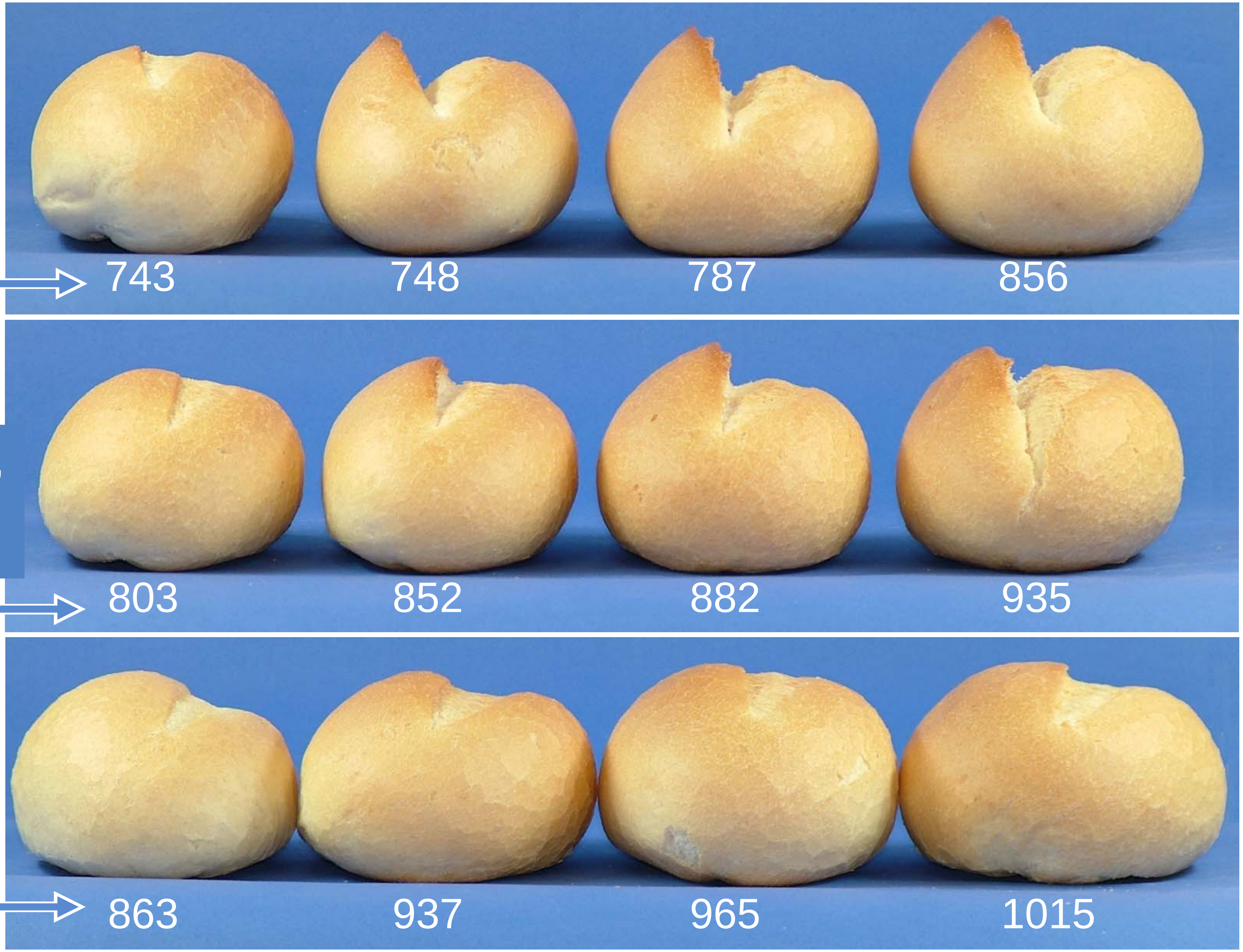
<u>Basic treatment:</u>
FAA, 1 SKB/g
ADA, 40 ppm
Asc., 160 ppm
SSL, 0.3 %

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

Bleaching Mechanism of Triacyl Lipase

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$$\text{Triglyceride} \xrightarrow{\text{Triacyl Lipase}^{(1)}} \text{FFA + Lyso-Lipid}$$

$$\text{FFA} + O_2 \xrightarrow{\text{Lipoxygenase}^{(2)}} \text{R-OOH (hydro peroxide)}$$

R-OOH bleaches the flour pigment and oxidizes the thiol groups of proteins

(1) Intrinsic or added triacyl lipase

(2) Flour lipoxygenase type 1

FFA – free fatty acid (R-H)

Summary of the Properties of Carboxyl Esterases

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- 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

Enzymes Summary

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	++
$\text{Xylanase}_{\text{WUX}}$	+	++	+	+	o	+	(+)
$\text{Xylanase}_{\text{WEX}}$	-	+	-	-	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
WUX – water-unextractable xylans WEX – water-extractable xylans

Synergies of Improvers

Combined Effect of Ascorbic Acid Enzymes

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German wheat flour Type 550, harvest 2003

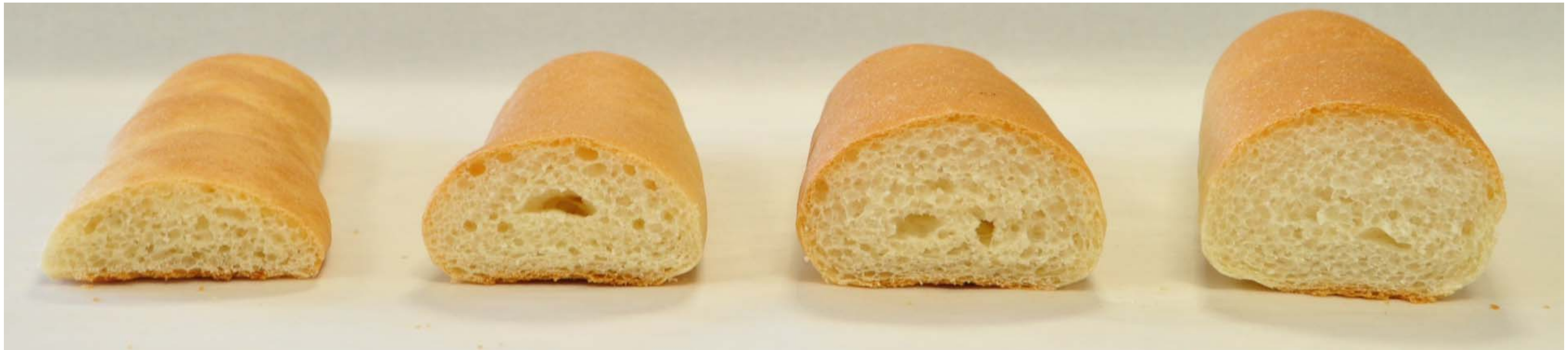
Untreated	Asc. 4 g	Asc.+Amyl. 8 g + 30 g	Asc.+(Amyl.+Xyl.) 8 g + 10 g

490 mL*	820 mL	950 mL	970 mL

* Volume yield in mL per 100 g flour

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**

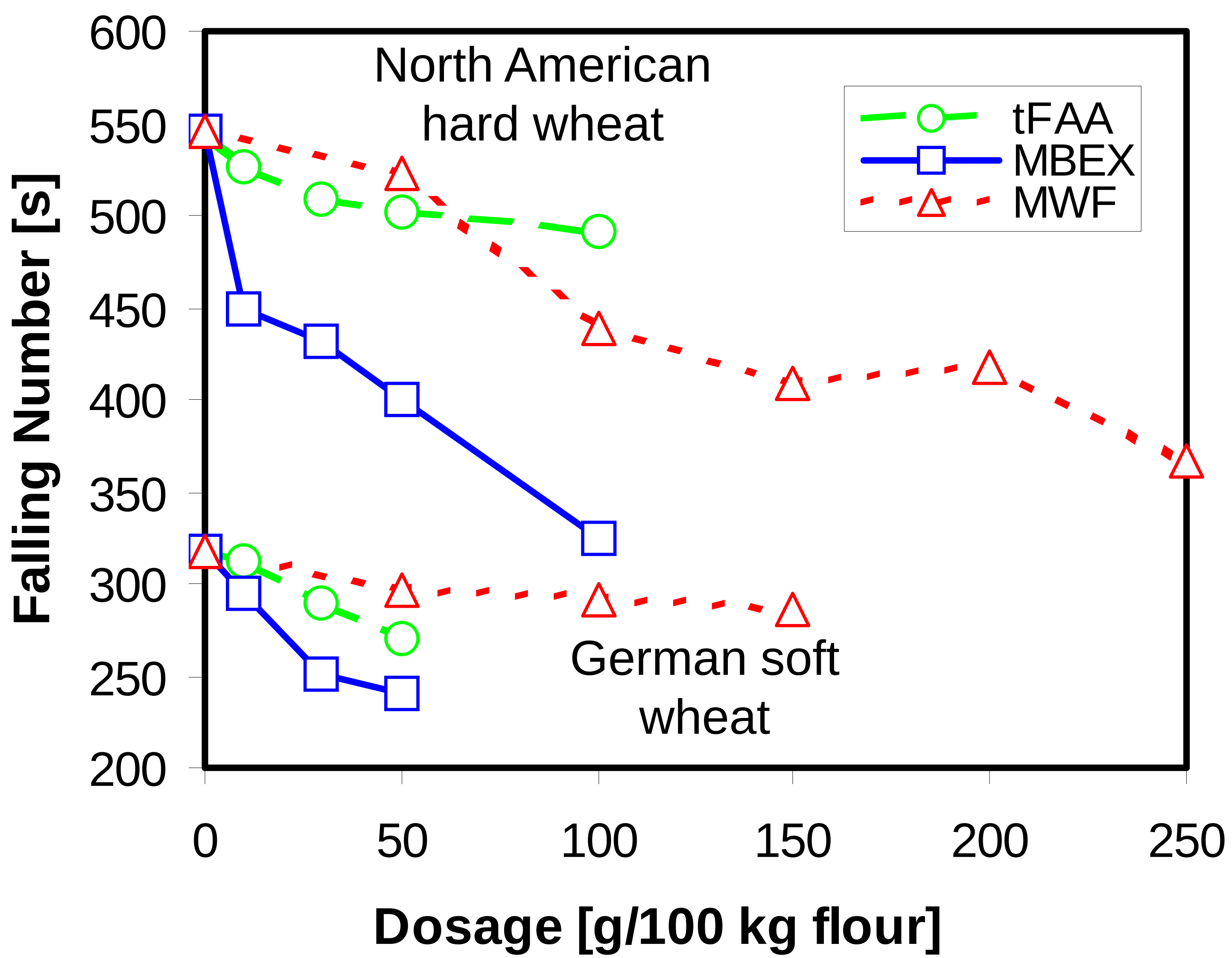


Reference	ELCO, 50 ppm A 15140, 10 ppm	ELCO, 50 ppm A 15140, 10 ppm HC 13045, 30 ppm	ELCO, 40 ppm A 15140, 10 ppm HC 13045, 30 ppm Gloxy 14080, 20 ppm EFX Mega, 10 ppm

Effects of Flour Improvers on Rheology

Falling Number

Effect of Amylases on Falling Number



A New Amylase for Falling Number Control

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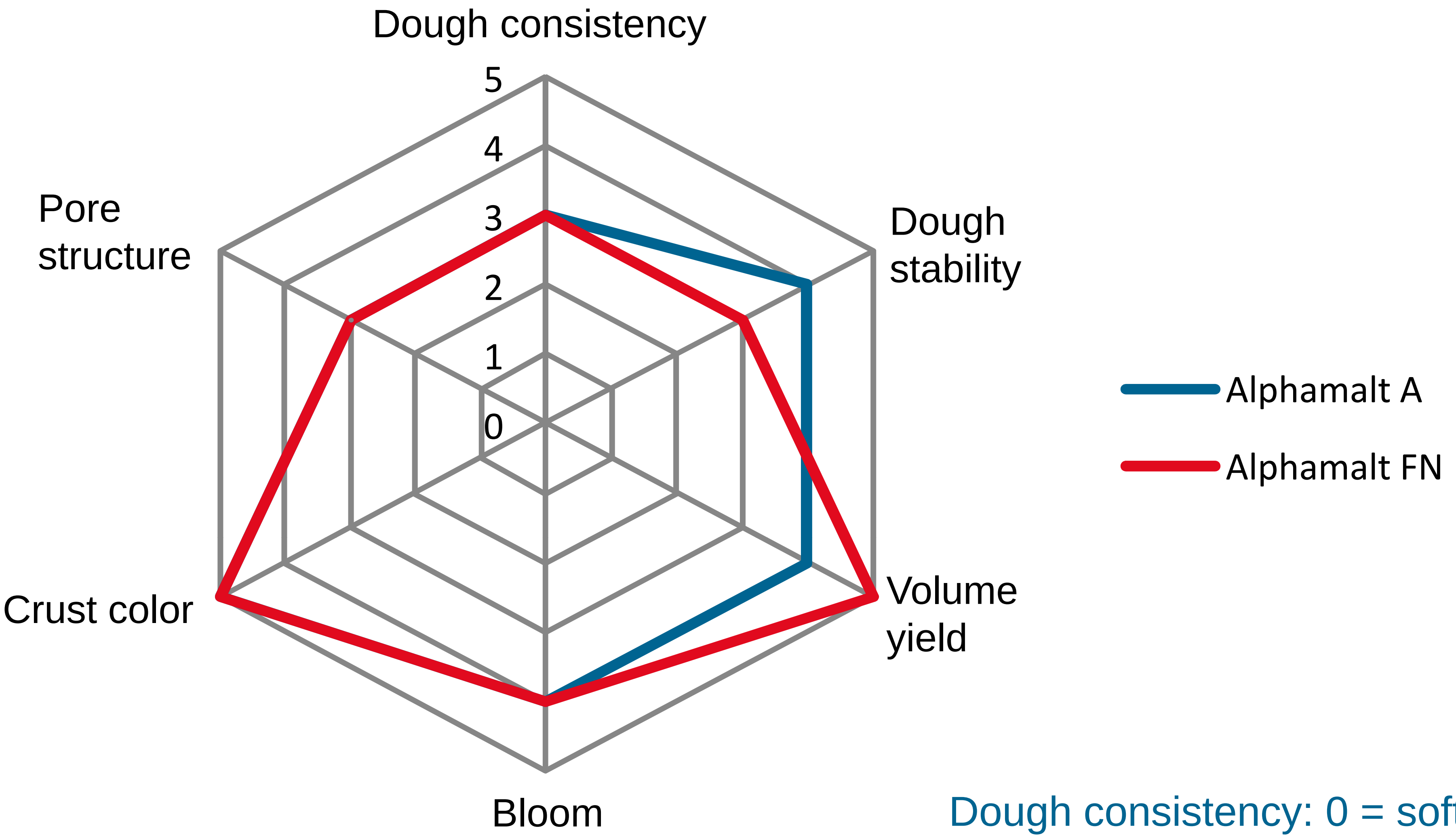
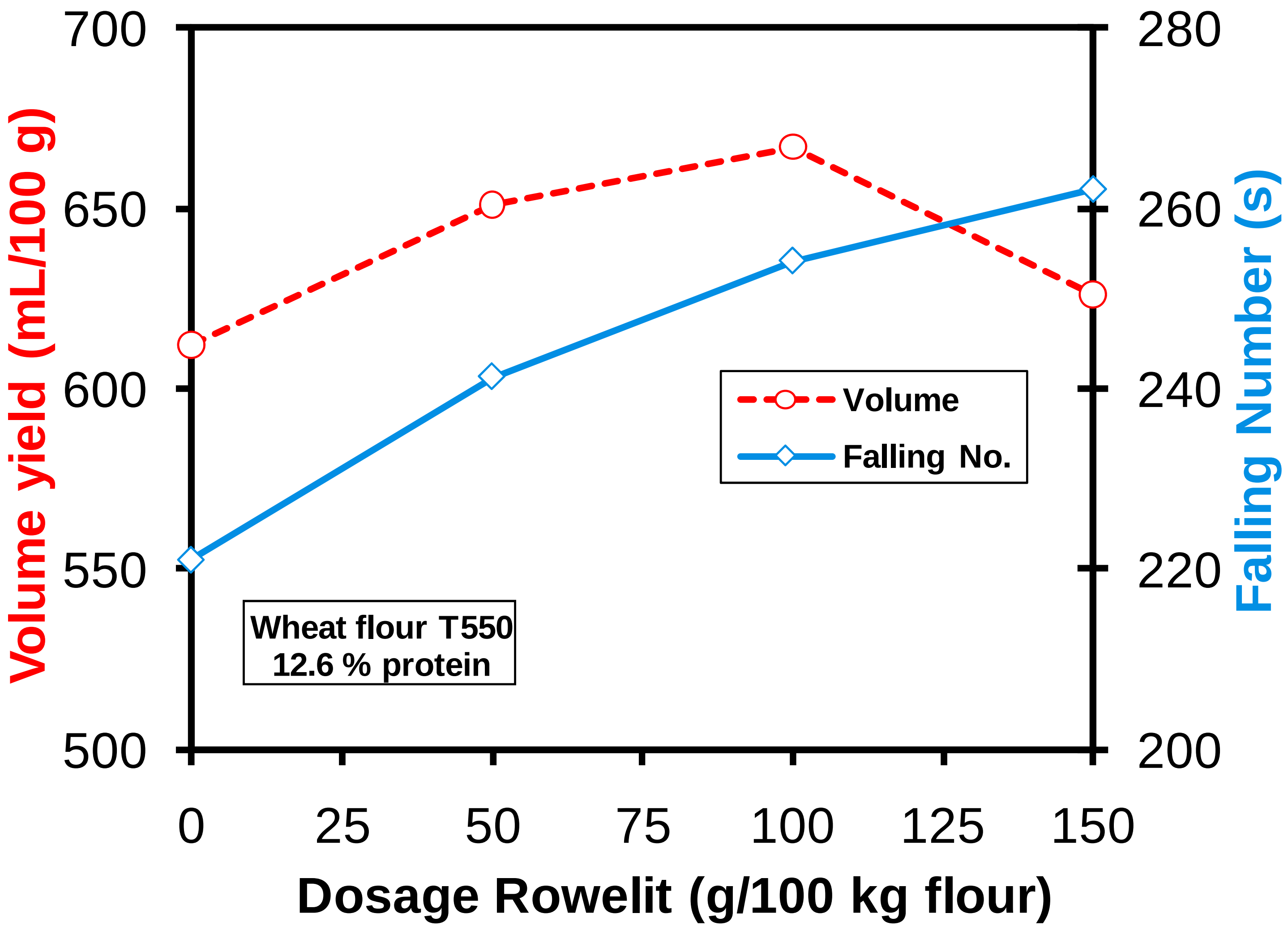


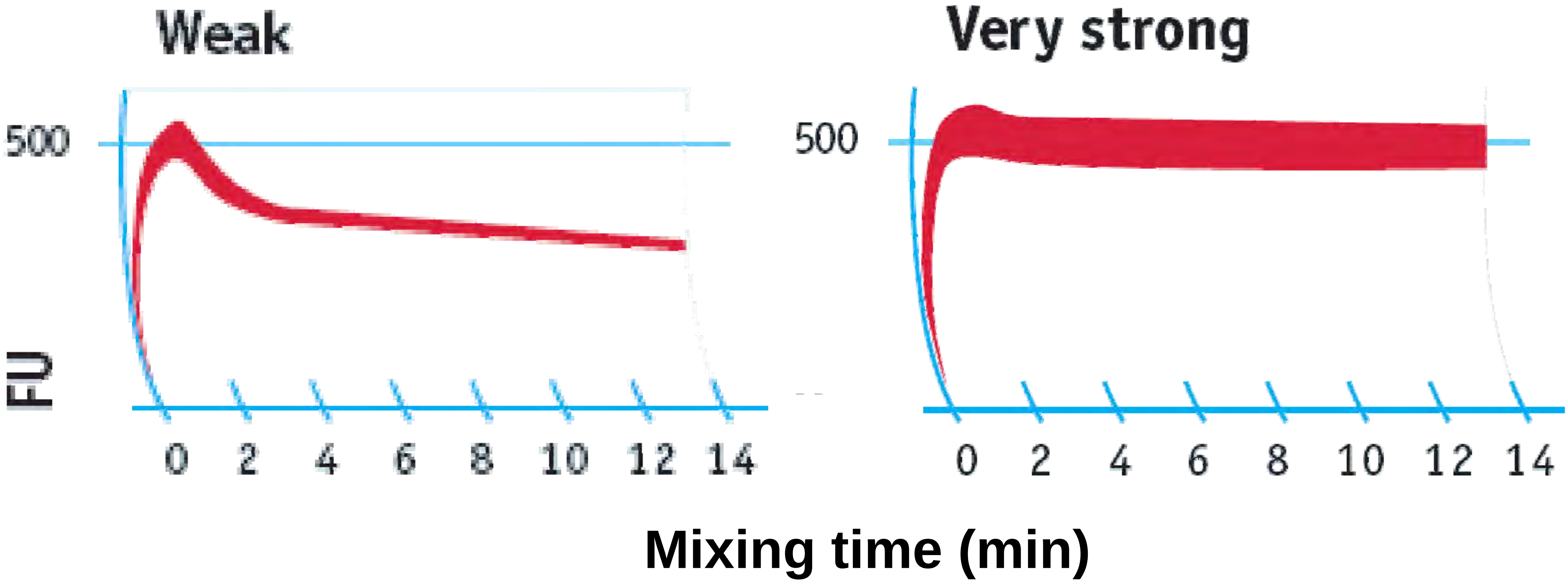
Dough consistency: 0 = soft; 5 = firm
Pore structure: 0 = fine; 5 = coarse

Effect of Rowelit on Falling Number and Baking

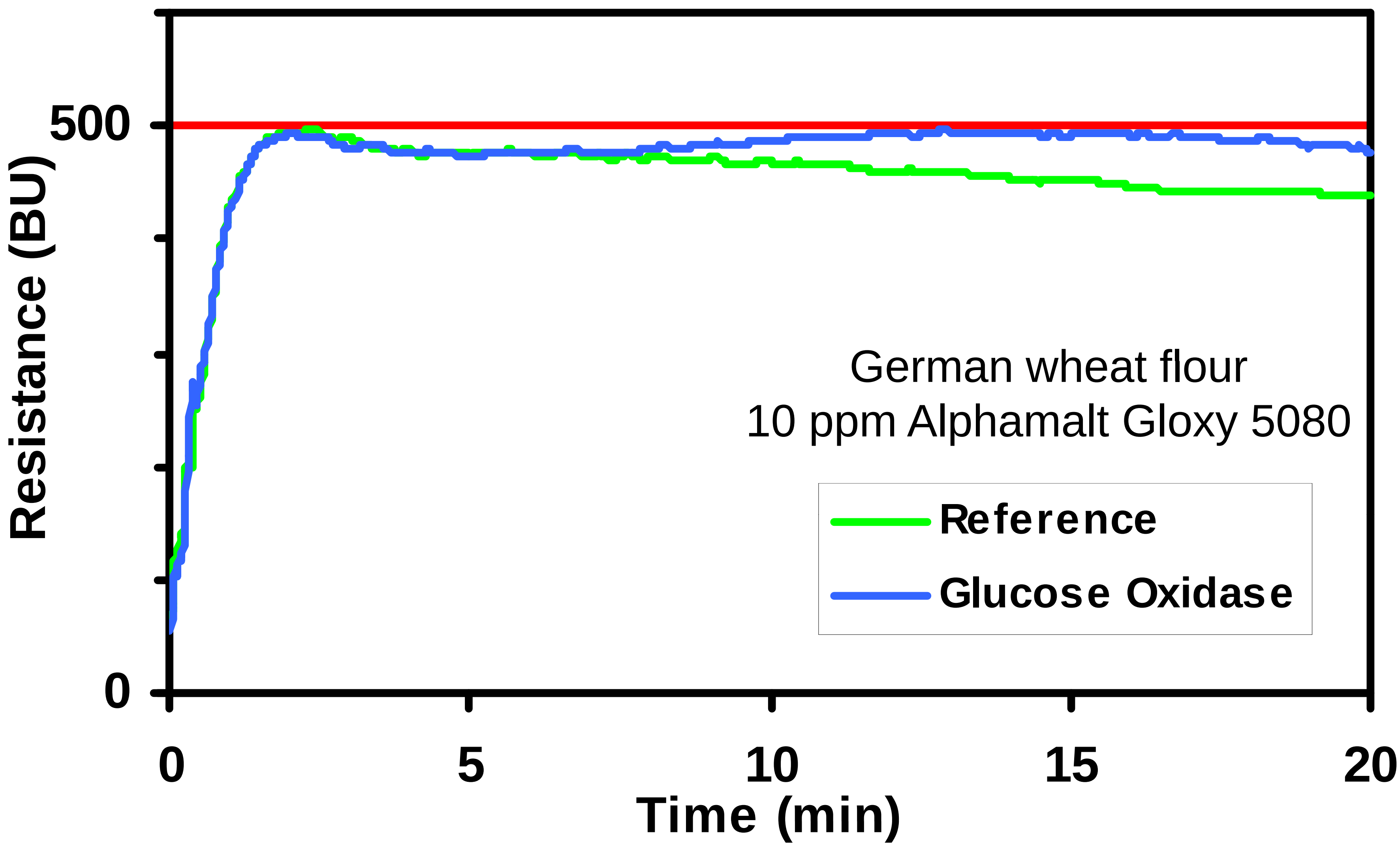


The Farinogram [Mixolab Curve]

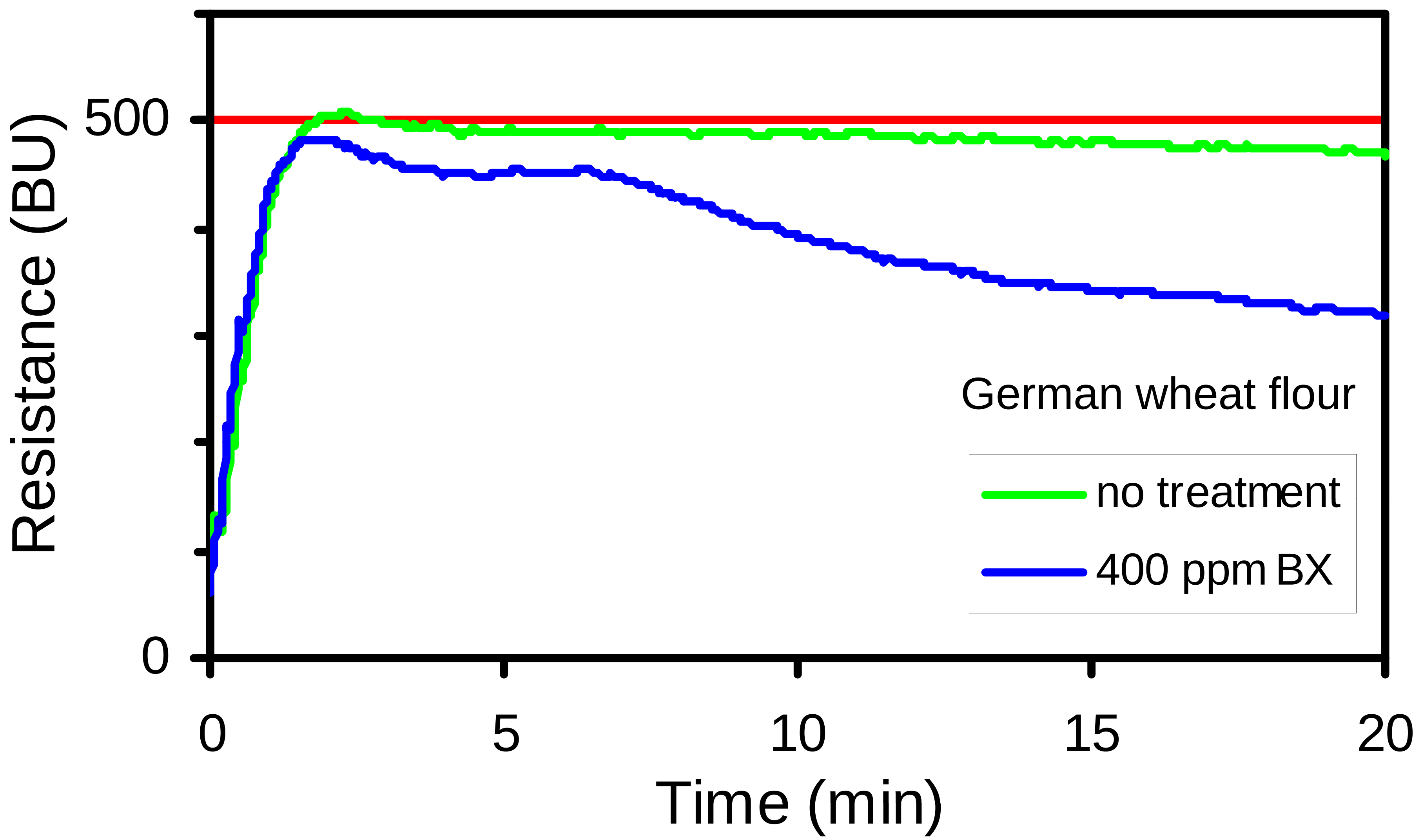
Farinograph Examples for Weak & Strong Flour



Effect of Glucose Oxidase on the Farinogram



Effect of Alphamalt BX on the Farinogram



Effect of Flour Treatment on Farinogram

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Oxidation, ppm	Enzyme, ppm	WA %	Developm. min	Stability min	Softening B.U.
untreated		59.8	3.0	4.5	30
AA, 10		59.8	3.5	10.0	10
AA, 20		59.8	3.0	12.0	0
AA, 40		59.8	2.5	12.0	10
AA, 80		59.5	3.0	12.0	20
PBr, 10		60.0	3.5	5.0	30
PBr, 20		60.1	3.0	7.0	25
PBr, 40		60.0	3.0	7.0	20
PBr, 80		60.1	3.5	7.5	20
	A 10033, 50	59.8	3.0	4.5	30
	A 10033, 100	59.8	3.0	3.5	50
	A 10033, 150	59.8	3.5	2.0	60
AA, 20	A 10033, 100	59.5	2.5	3.0	30
AA, 40	A 10033, 100	59.3	3.0	1.0	25
AA, 80	A 10033, 100	59.8	2.5	1.0	45
	BX, 100	59.5	3.0	10.5	20
	BX, 200	59.6	2.5	8.5	25
	BX, 400	59.3	3.0	7.0	70

AA=ascorbic acid, PBr=potassium bromate,
A 10033=amylase/xylanase compound,
BX=multiple enzymes/maturing agents compound

The Alveograph

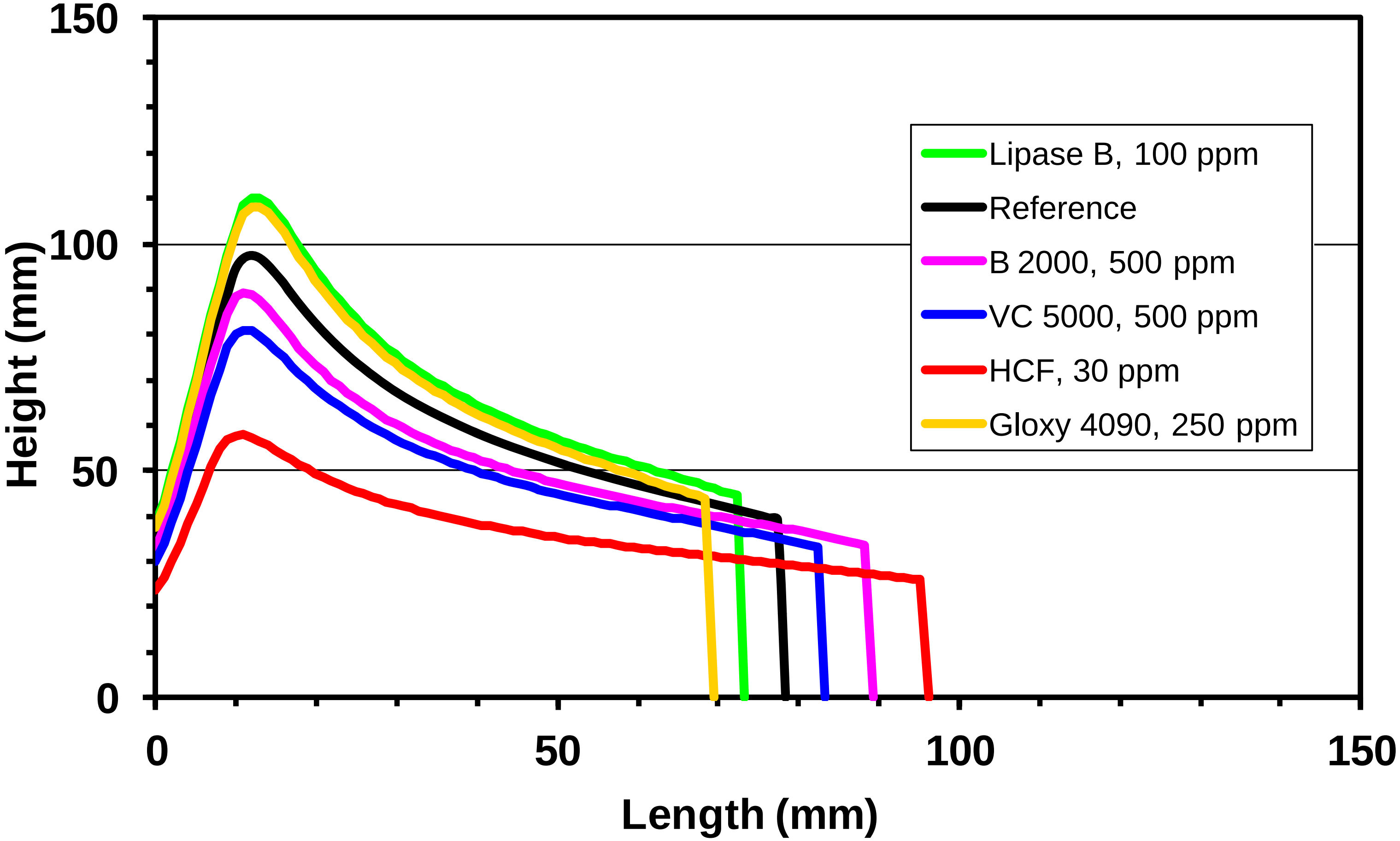
Effect of Various Flour Additives on Alveograms

Treatment	P	L	P/L	W	Remarks
untreated	83	97	0.86	209	
Ascorbic acid (1)	+	-	+	++	
Potassium bromate	++	-	+	++	
Cysteine (2)	-	+	-	-	
Sodium metabisulfite	-	-	-	-	
alpha-Amylase (3)	--	++	--	-	
Hemicellulase, AN	-	o	-	-	
Hemicellulase, TR	--	+	-	-	
Hemicellulase, BS	-	-	+	-	
Protease, fungal (4)	-	+	-	-	
Glucose oxidase (5)	+	-	+	o	
Alphamalt A 6003	-	+	-	-	
Alphamalt A 9029	-	+	-	-	
Wafer enzyme (6)	--	+	--	--	
Alphamalt BX	++	--	++	+	
Alphamalt BX + cysteine	++	--	++	+	softer than BX
Vital wheat gluten (7)	+	-/o	+	++	

(1) ELCO C-100
(2) EMCEsoft P
(3) Alphamalt A 4050
(4) Alphamalt Pro
(5) Alphamalt Gloxy 4092
(6) Alphamalt LQ 4020
(7) EMCEvit C

AN = Aspergillus niger
TR = Trichoderma reseei
BS = Bacillus subtilis

Effect of Various 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 Ascorbic Acid on Alveograms

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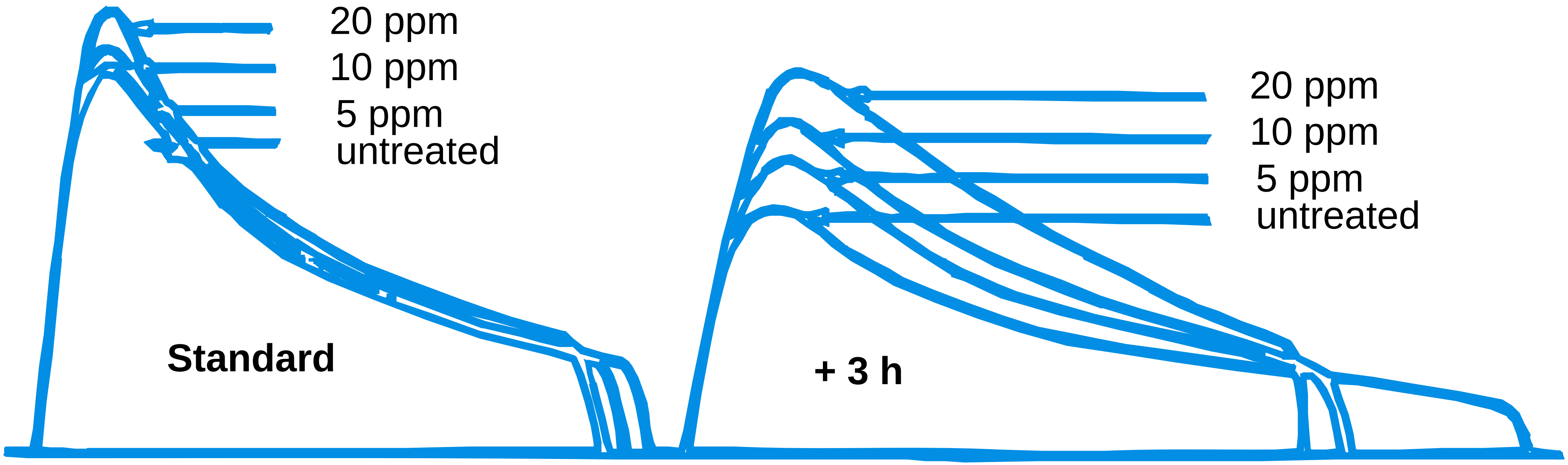

After Faridi & Rasper, 1987

Effect of Alphamalt BX on the Alveogram

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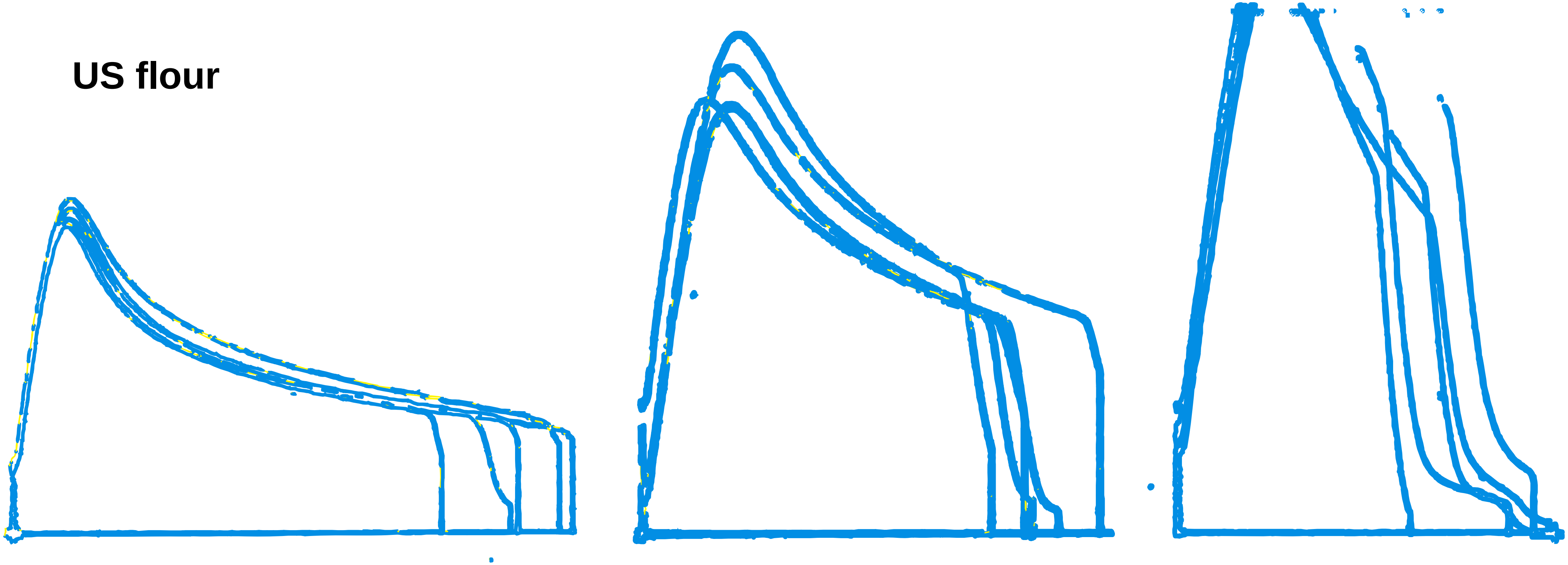
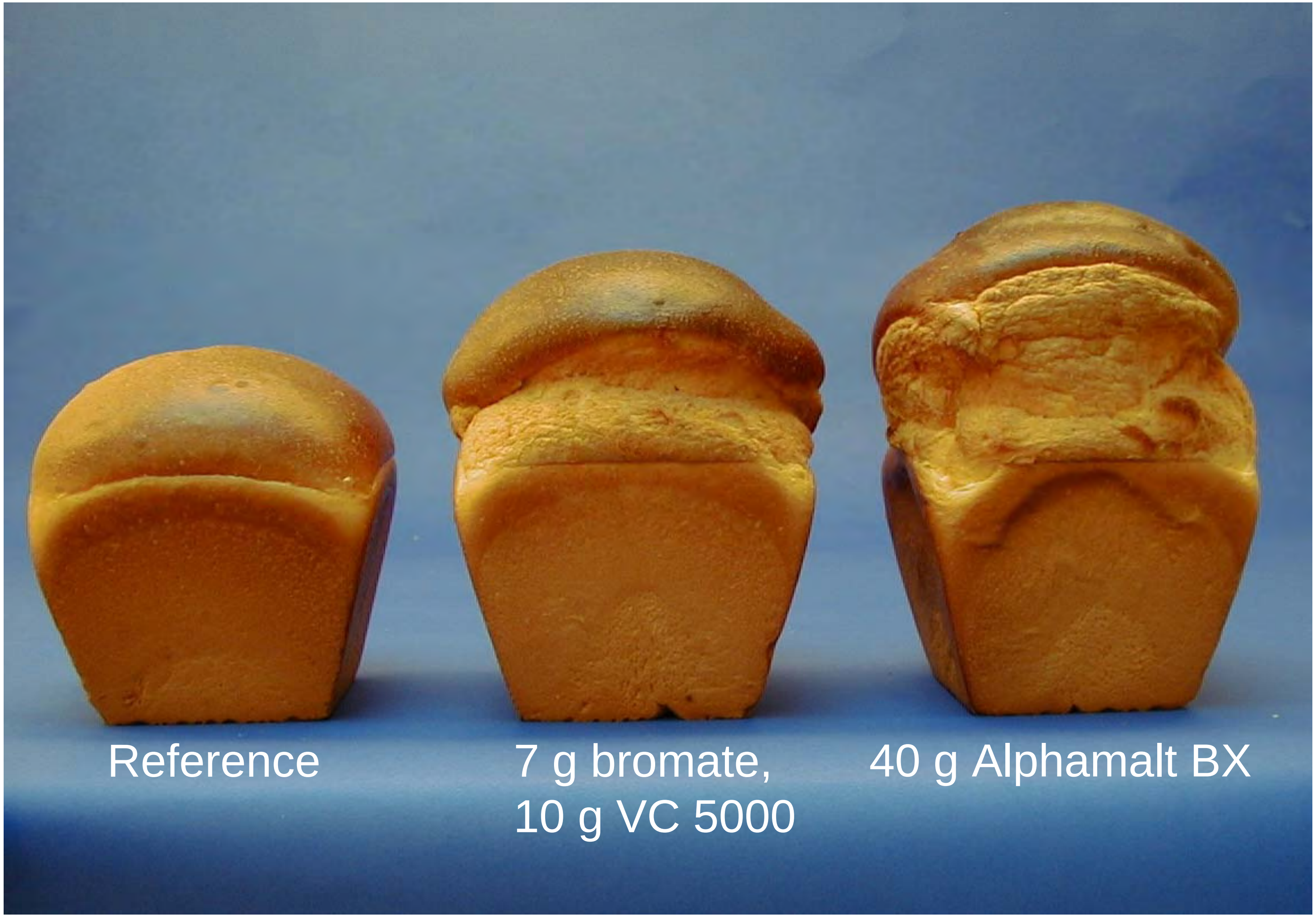
US flour



untreated 200 ppm 400 ppm

Replacement of Potassium Bromate



The Extensogram

Effect of Protein Content on Alveo- & Extensograms

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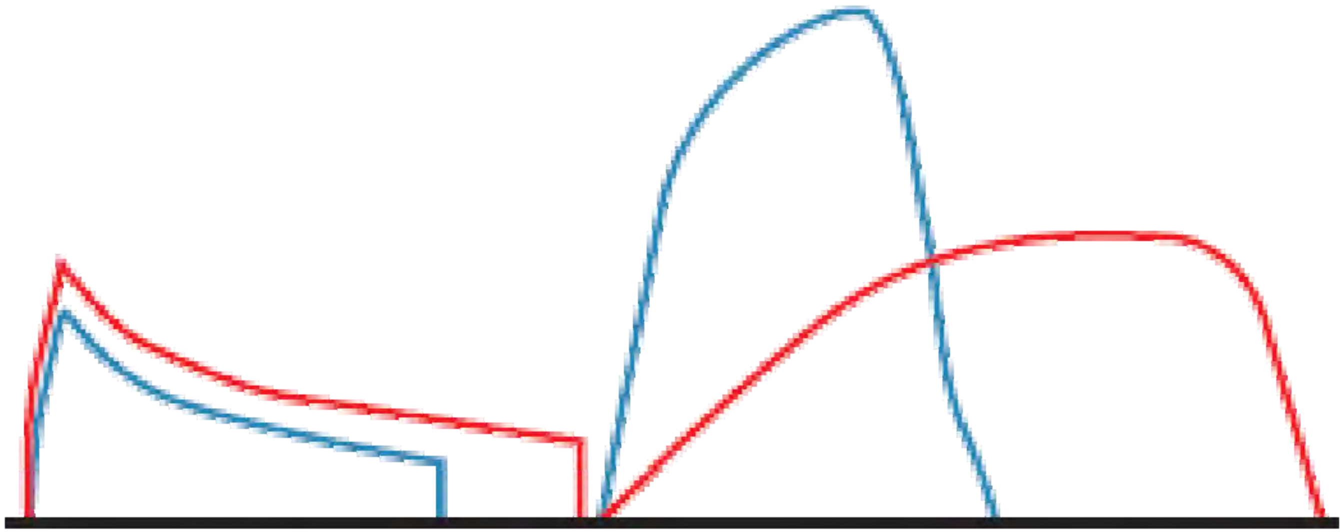
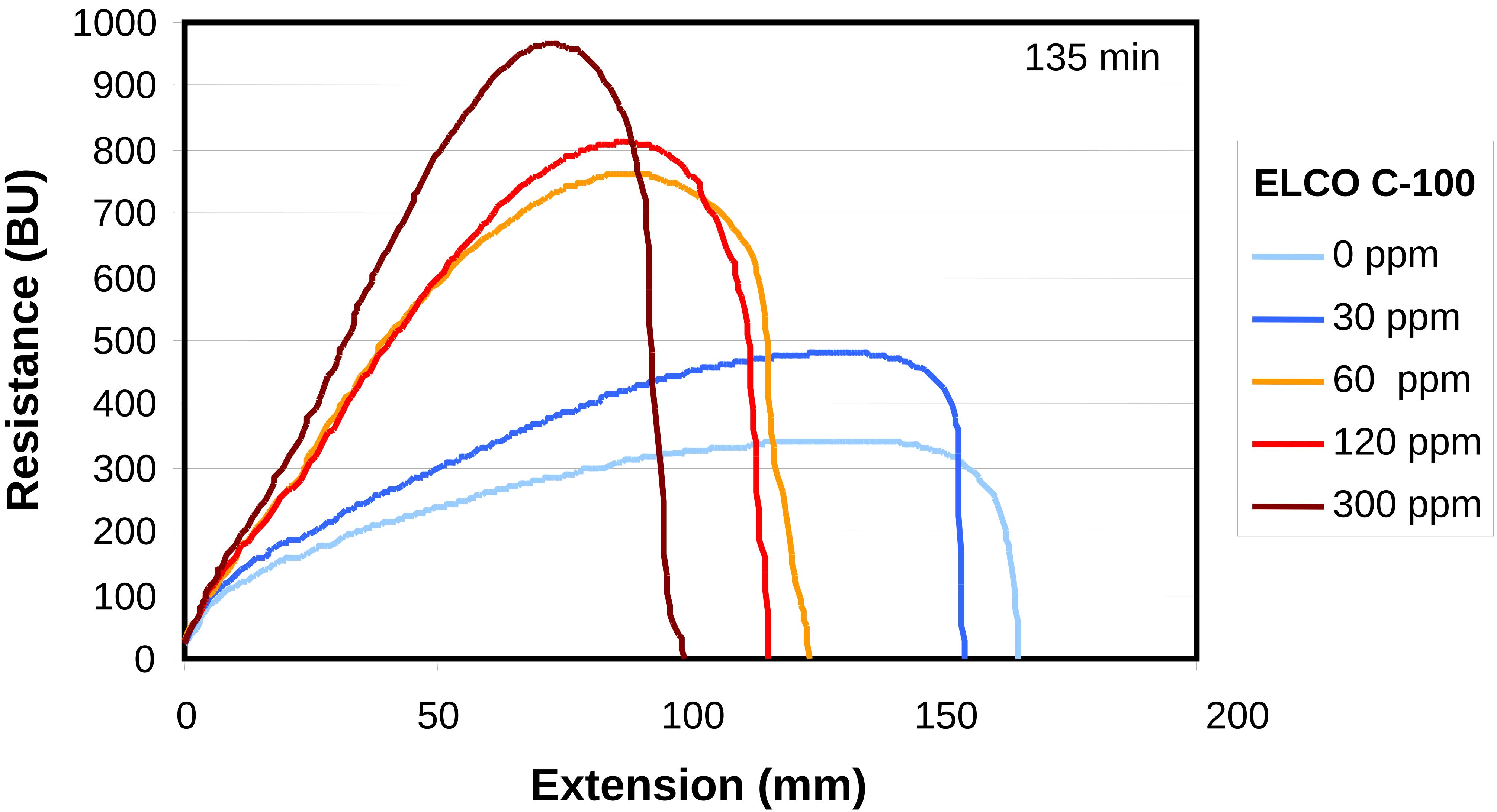
DIPLOMAT (normal, silky)

Protein	%	WA,%	DP	VY
low	11.5	51.8	16	598
high	18.0	59.6	9	863



W	P/L	G	E	R/E
245	0.56	25	134	2.2
158	0.56	22	130	7.1

Effect of Ascorbic Acid on the Extensogram



The MC Navigator

A Quick Guide through the Action of Flour Improvers

The MC Navigator, an Orientation Chart for Baking & Rheology Additives

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1 MC Navigator Baking

2 MC Navigator Rheology

1 MC Navigator Baking (1)

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Active ingredient	MC quality	Dosage per 100 kg flour	Water absorption	Mixing time	Dough resting and fermentation time	Extensibility	Dough stability	Dry dough surfaces	Dough softening	Machinability	Fermentation stability	Fermentation tolerance	Proof times	Oven rise	Baking time
			Improving the production of baked goods												
Enzyme Systems															
Amylases	ALPHAMALT V	5 – 40 g	↓	○	↓	↗	○	↓	↗	↘	○	↘	↓	↑	○
	ALPHAMALT VC 5000	2 – 10 g	↓	○	↓	↗	○	↓	↗	↘	○	↘	↓	↗	○
	ALPHAMALT A 5070	0.5 – 2 g	↓	○	↓	↗	○	↓	↗	↘	○	↘	↓	↗	○
	ALPHAMALT F 9023	20 – 60 g	○	○	○	○	○	○	○	○	○	○	○	○	○
Amylase–hemicellulase complexes	POWERZYM 5000	6 – 12 g	↘	○	○	↗	↘	↘	↗	↗	○	○	○	↗	○
	POWERZYM 6000	6 – 15 g	↘	○	↘	↗	↘	○	↗	↗	○	○	↘	↑	○
	ALPHAMALT A 5005	10 – 20 g	↘	○	○	↗	↘	↘	↗	↘	○	↗	○	↗	○
	ALPHAMALT A 6003	8 – 15 g	↘	○	○	↑	○	○	↗	↗	○	↗	○	↑	○
	ALPHAMALT T 8006	10 – 20 g	↘	○	○	↗	↗	↗	↗	↗	↗	↗	○	↗	○
	ALPHAMALT A 9029	10 – 20 g	↘	○	○	↑	○	○	↗	↗	○	↗	○	↑	○
	ALPHAMALT A 14888	10 – 20 g	↗	○	○	○	↗	↗	↘	↗	↗	↑	↗	↑	○
Beta-amylase	BETAMALT 25	10 – 50 g	↓	↘	↘	↗	↘	↘	↗	↘	○	○	↘	↑	↘
Glucoamylase	ALPHAMALT GA 5071	1 – 10 g	↘	↘	↘	↘	↘	↘	↗	○	○	↘	↘	↗	○

1 MC Navigator Baking (2)

Mühlenchemie
makes good flours even better

Active ingredient	Improving the baked goods								Problem flours / composite flour								Biscuit flours / wafer flours				
	Volume	Shelf-life	Browning and flavour	Texture, fine	Crumb structure more stable / more elastic	Bleaching effect	Crispness	Tenderness (biscuits)	Low-enzyme flour	Heat-damaged flour	Low-protein flour	Ropiness	Bug-damaged flour	Sprout-damaged flour	10 % cassava flour	90 % rye flour	Extensibility	Browning	Prevention of breakage	Prevention of shrinkage	Prevention of cracking
Enzyme Systems																					
Amylases	↑	↑	↑	↓	↓	○	↑	↑	🟢	🟢	🟢	🟡	🟡	🔴	🟡	🟢	🟡	🟢	🟡	🟡	🟡
	↑	↗	↗	↓	↓	○	↑	↑	🟢	🟢	🟢	🟢	🟡	🔴	🟢	🟡	🟡	🟡	🟡	🟡	🟡
	↑	↗	↗	↓	↓	○	↑	↑	🟢	🟢	🟢	🟡	🟡	🔴	🟡	🟡	🟡	🟡	🟡	🟡	🟡
	○	↑	○	○	○	○	○	○	🟢	🟢	🟢	🟡	🟡	🔴	🟢	🟡	○	○	○	○	○
Amylase–hemicellulase complexes	↑	↗	↗	○	○	○	↗	○	🟢	🟢	🟡	🟡	🟡	🔴	🟢	🔴	🟢	🟢	○	🟡	🟢
	↑	↗	↗	↗	○	○	↗	○	🟢	🟢	🟡	🟡	🟡	🔴	🟢	🟡	🟢	🟢	○	○	○
	↗	↗	↗	↘	↘	○	↗	○	🟢	🟢	🟢	🟡	🟡	🟡	🟢	🟡	🟢	○	○	○	○
	↑	↗	↗	○	○	○	↗	○	🟢	🟢	🟢	🟡	🟡	🟡	🟢	🟡	🟢	🟢	○	○	○
	↗	○	○	○	↗	○	↗	○	🟢	🟢	🟢	🟡	🟡	🟡	🟢	🟢	🟡	🟢	○	○	○
	↑	↗	↗	↗	○	○	↗	○	🟢	🟢	🟡	🟡	🟡	🔴	🟢	🟡	🟢	🟢	○	🟡	🟡
	↑	↗	↗	↗	↗	○	↗	○	🟢	🟢	🟢	🟡	🟡	🟡	🟢	🟢	○	🟢	○	○	○
Beta-amylase	↗	↑	↑	↓	↓	○	↑	○	🟢	🟢	○	🔴	🔴	🔴	🟢	🟢	○	🟢	○	○	○
Glucoamylase	↗	○	↗	↘	↘	○	↗	○	🟢	🟢	○	○	○	🔴	🟢	🟢	○	🟢	○	○	○

1 MC Navigator Baking (3)

Strongly raising, increasing effect	Use not recommended
Slightly raising, increasing effect	Benefit doubtful
No significant change	Use recommended
Slightly lowering, reducing effect	
Strongly lowering, reducing effect	