Studies on the storage stability of beet white sugar depending on its quality

Philipp Bruhns

Prof. Dr. Lothar W. Kroh

Institute of Food Technology and Food Chemistry

Department of Food Chemistry and Food Analysis

Dr. Timo Koch

Pfeifer & Langen GmbH & Co. KG

Content

- Introduction into the problem of color development during storage of beet white sugar
- Influence of temperature and moisture
- Influence of non-sucrose compounds
- Conclusion

Sugar Storage

Problem: color development during storage of white sugar

- Normal color increase during 1 year in a silo: 2 – 3 IU
- Sometimes higher increase without any obvious reason

Sugar Storage

2 cases of color increase during storage

Big Bag

26 IU → (2 years) → 54 IU

Silo

25 IU → (2 years) → 44 - 56 IU

- Controlled temperature and humidity in the big bag warehouse and the silo
- Color and ash content during production did not show any reason for a high color development

Sugar Storage

Types of browning reactions in sugar crystals

Caramelization
- Browning of sugars

Maillard reaction
- Reaction of amino acids with saccharides to melanoidines

Oxidative browning
- Oxidation of phenols

External influences:
Temperature
Moisture/humidity

Impurities in the crystals:
Monosaccharides
Amino compounds
Organic acids
Polyphenols

What kind of reaction is responsible for the color development?

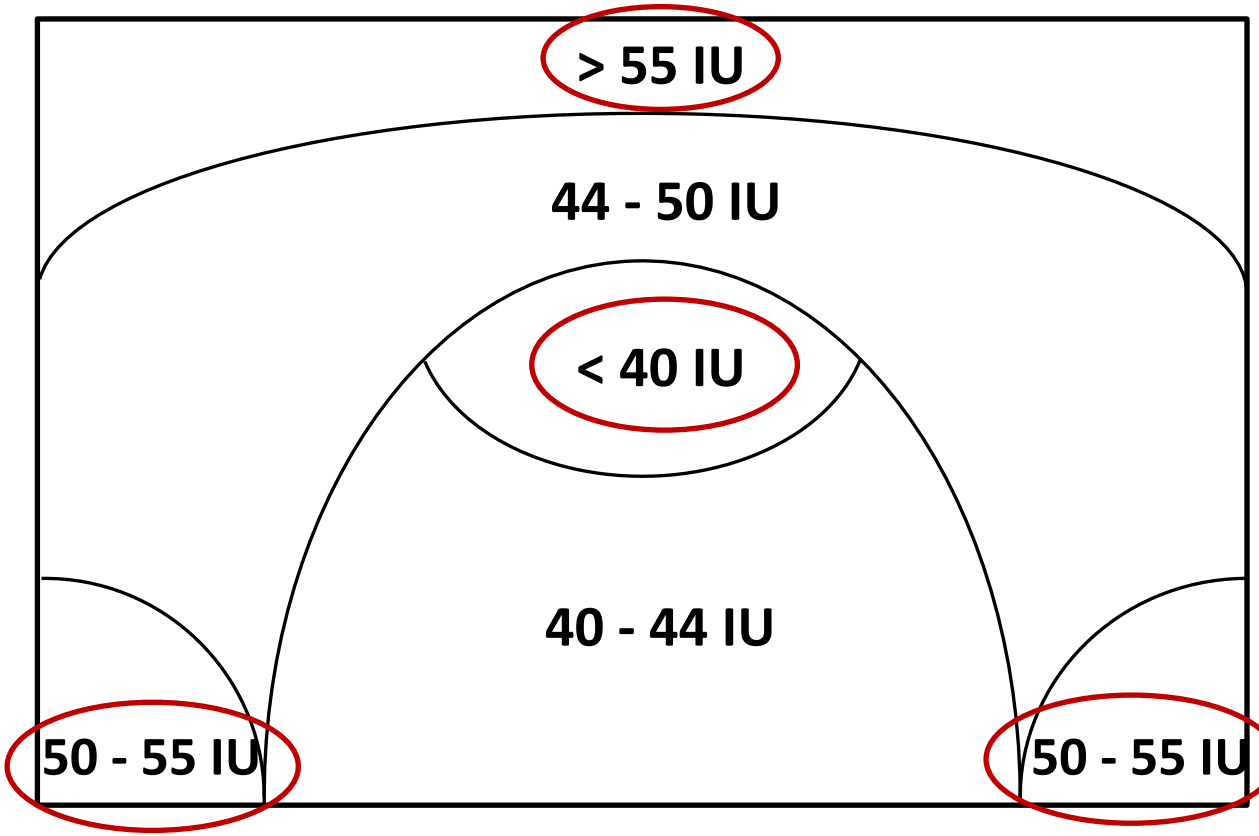
External Influences - Moisture

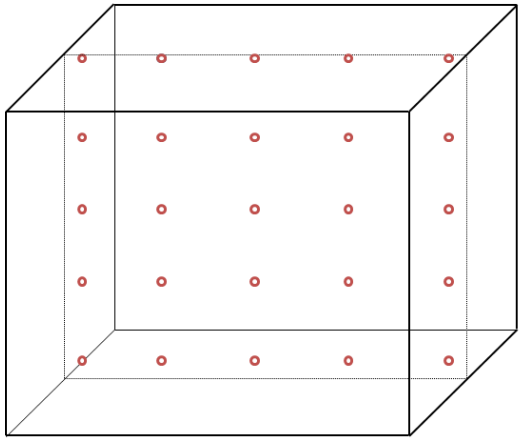
Big Bag: increase in color from 25 IU to 55 IU in 2 years

- Influences due to moisture on color development should be visible in an uneven color distribution in a Big Bag
- The sides of the Big Bag are more exposed to the air

External Influences - Moisture

Big Bag: increase in color from 25 IU to 55 IU



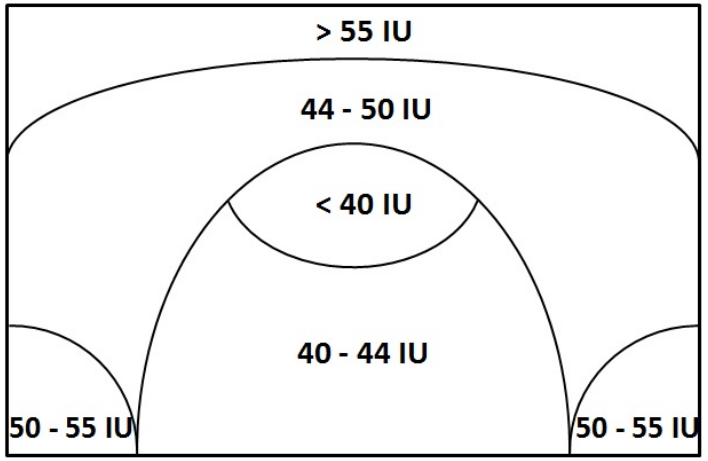


sample location

- High color intensity at the top and at the edges, 50 - 55 IU
- Less color intensity in the center, < 40 IU

External Influences - Moisture

- Uneven color distribution
  - High colors at the edges
  - Low color in the center



⇨ Storage conditions affect the color development

Influence of moisture

- Moisture from the outside
- Insufficient conditioning before Big Bag filling

External Influences - Temperature

Storage test

- Sugar storage test for 1 year at 4 °C, 30 °C and 50 °C in a sealed container

		12 month		
		4 °C	30 °C	50 °C
	[IU]	[IU]	[IU]	[IU]
EU No. 2 a	22	24	28	37
EU No. 2 b	22	25	27	33
EU No. 2 c	15	16	20	29
EU No. 1	8	9	10	14

4 °C: Little color increase

30 °C: Color increase up to 5 IU, comparable to silo storage

50 °C: Color increase up to 15 IU

External Influences - Temperature

Color development depends on

- Temperature
- Sugar quality, EU No. 2 > EU No. 1

- Color after storage test < color of big bag and silo sugar

→ The higher the temperature and humidity the higher the color increase

Temperature and humidity favor the reaction but are not the cause of color development

Internal Influences - Color

Color distribution in the sugar crystal

- Color of sugar crystals is distributed in the crystal unevenly
- High color in dried syrup layer on the crystal surface
- High color due to syrup inclusions in the crystal

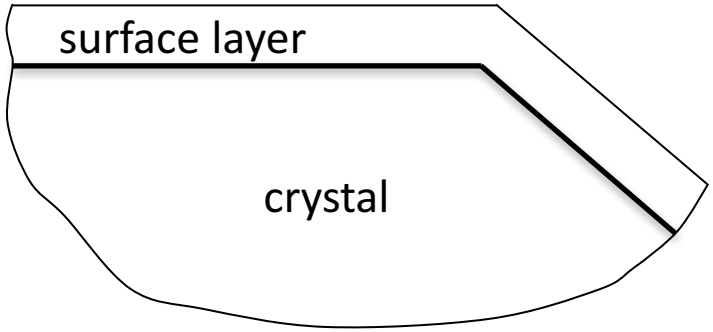
Analyses:

Dissolving the crystals layer by layer due to affination with different mixtures of ethanol and water

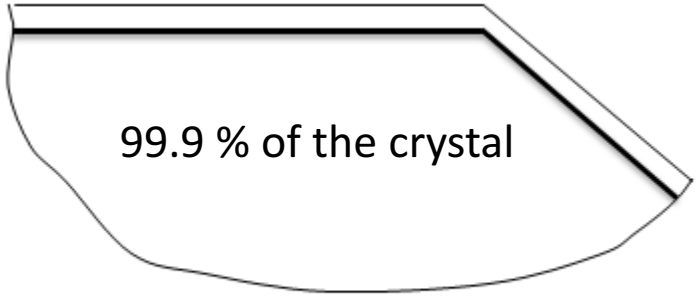
McKee M.: Triche R.; Godshall M. A.; Richard C. (2011): color Formation in White Beet Sugars In: Proceedings ASSBT
Shore, M.; Broughton, N. W.; Dutton, J. V.; Sissons, A. (1984): Factors affecting white sugar color. In: *Sugar Technol. Rev.* 12 (1), S. 1–99.

Internal Influences - Color

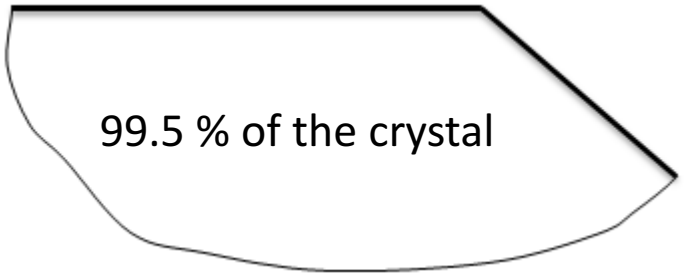
Affination Method*



96 % Ethanol
Affination



Affination
92 % Ethanol

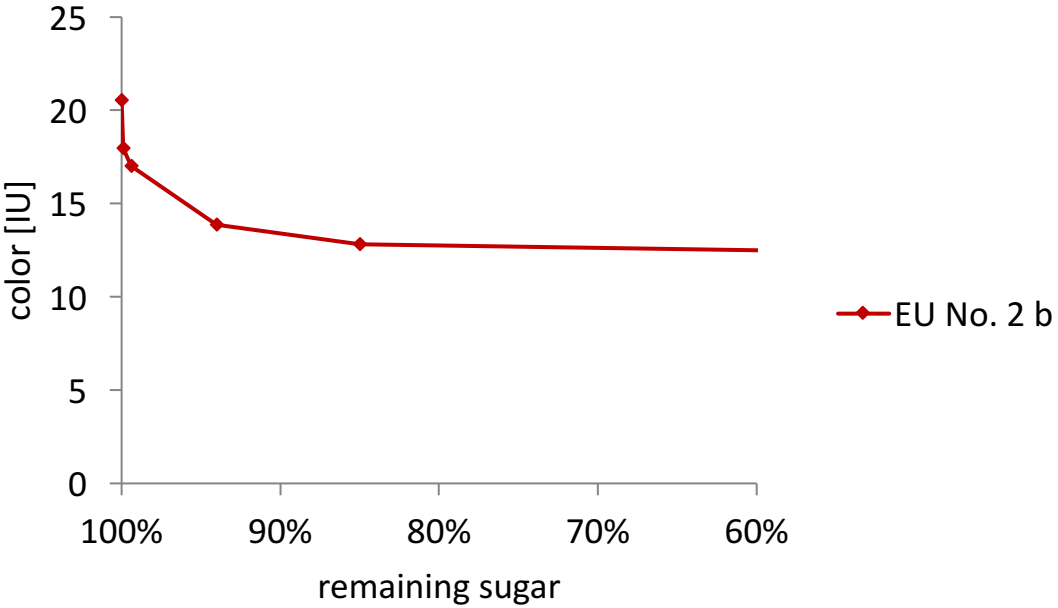


ethanol concentration	sugar
96 %	0.1 %
92 %	0.5 %
81 %	7.5 %
75 %	15 %
66 %	35 %

*Shore, M.; Broughton, N. W.; Dutton, J. V.; Sissons, A. (1984): Factors affecting white sugar color. In: *Sugar Technol. Rev.* 12 (1), S. 1–99.

Internal Influences - Color

Color distribution in the sugar crystal

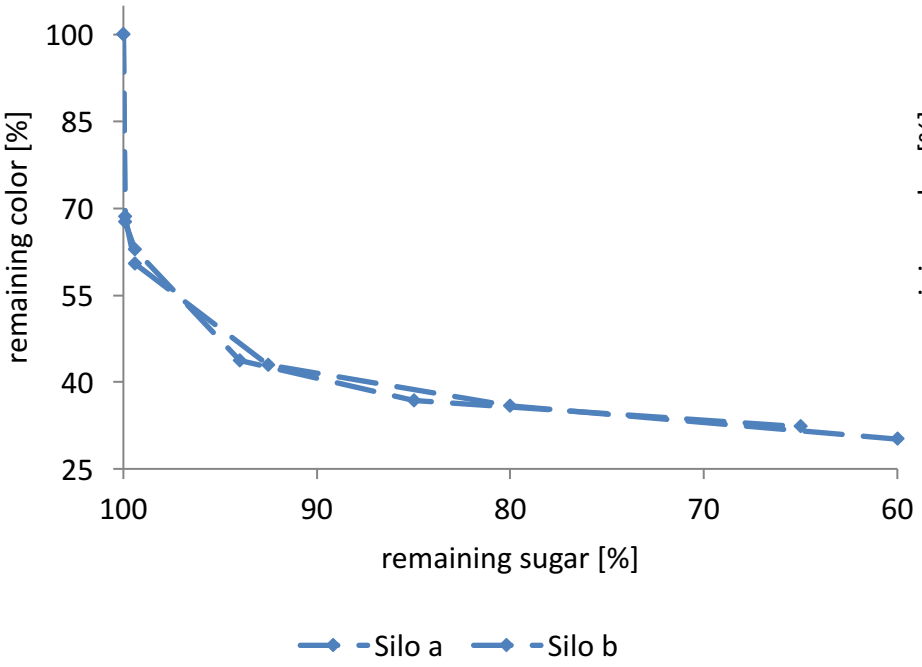


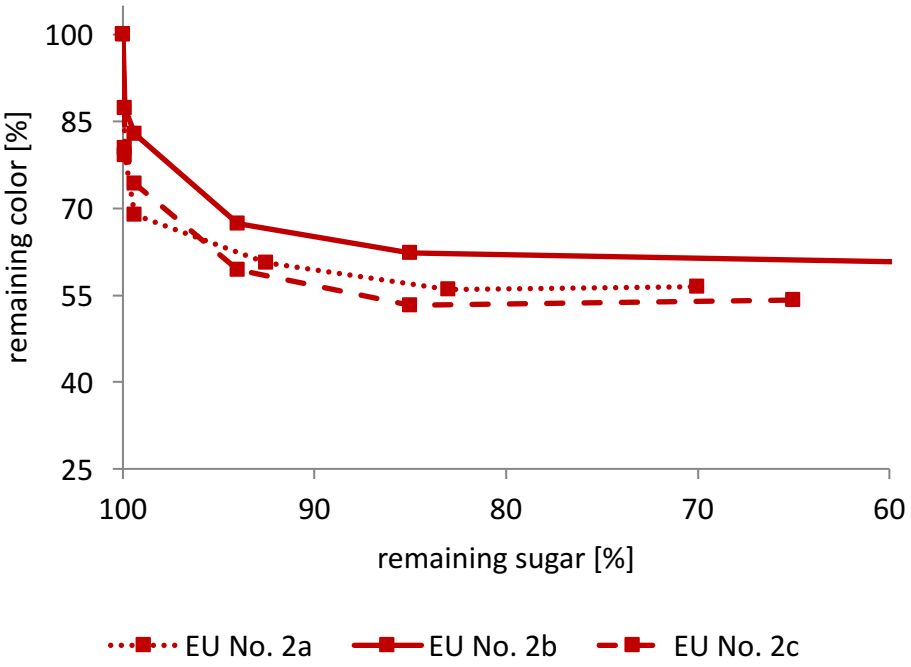
remaining sugar	color [IU]	remaining color
0 %	20	100 %
99.5 %	16	79 %
94 %	13	67 %
85 %	12	62 %
40 %	12	60 %

- 25 % of color in the outer 0.5 % of the crystal
- Same color in the inner 90 % of the crystal

Internal Influences - Color

Color distribution in the silo sugar and white sugar samples



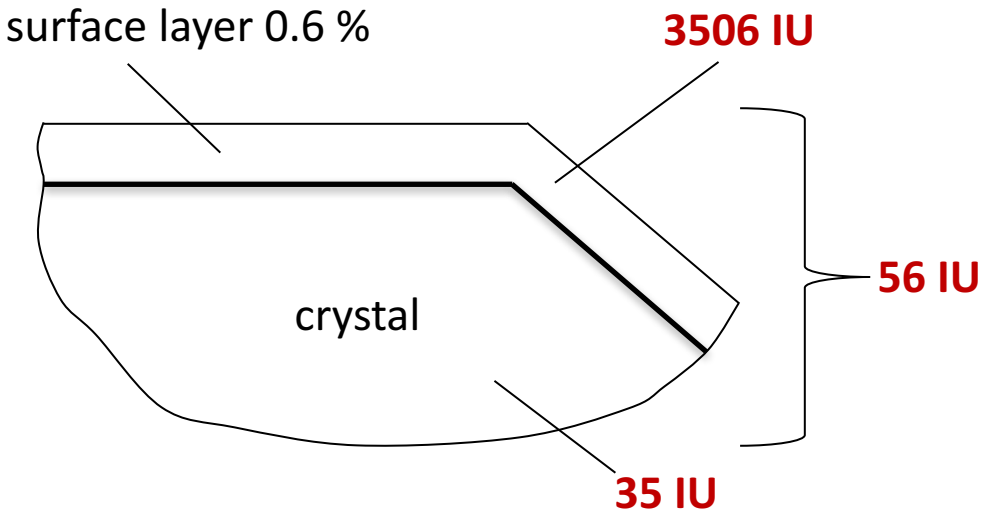


- EU No. 2: color decreases up to 40 – 50 %
- Silo sample: color decreases up to 60 – 70 %

Internal Influences - Color

Calculated color of the solved sugar layers

- Calculation of the color in the dissolved layer from the color differences



Silo Sugar

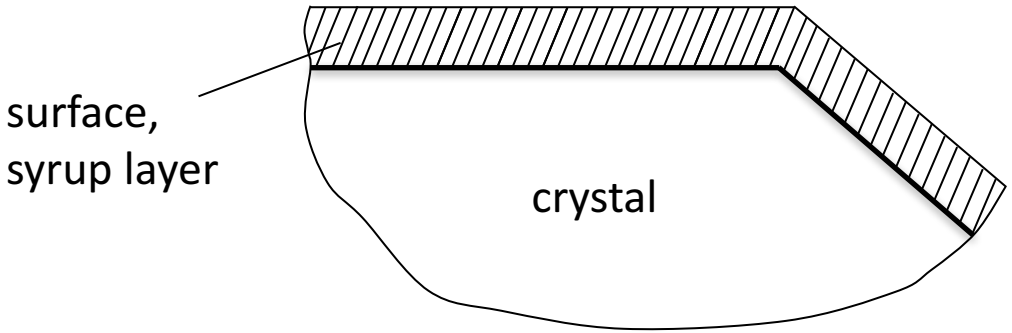
dissolved mass	remaining color [IU]	color of dissolved layer [IU]
	56	
0.6 %	**35**	**3506**
6 %	25	223
15 %	21	61
35 %	18	29

The color increases mainly in the crystal surface during storage

Internal Influences - Color

Color distribution in the sugar crystal

- 40 - 50 % of color in the sugar crystal surface*
- Surface color of a EU No. 2: 500 - 1000 IU
- Color increases mainly in the crystal surface layer during storage, surface color up to 4000 IU
- Crystal surface is more exposed to humidity and contains more non-sucrose components



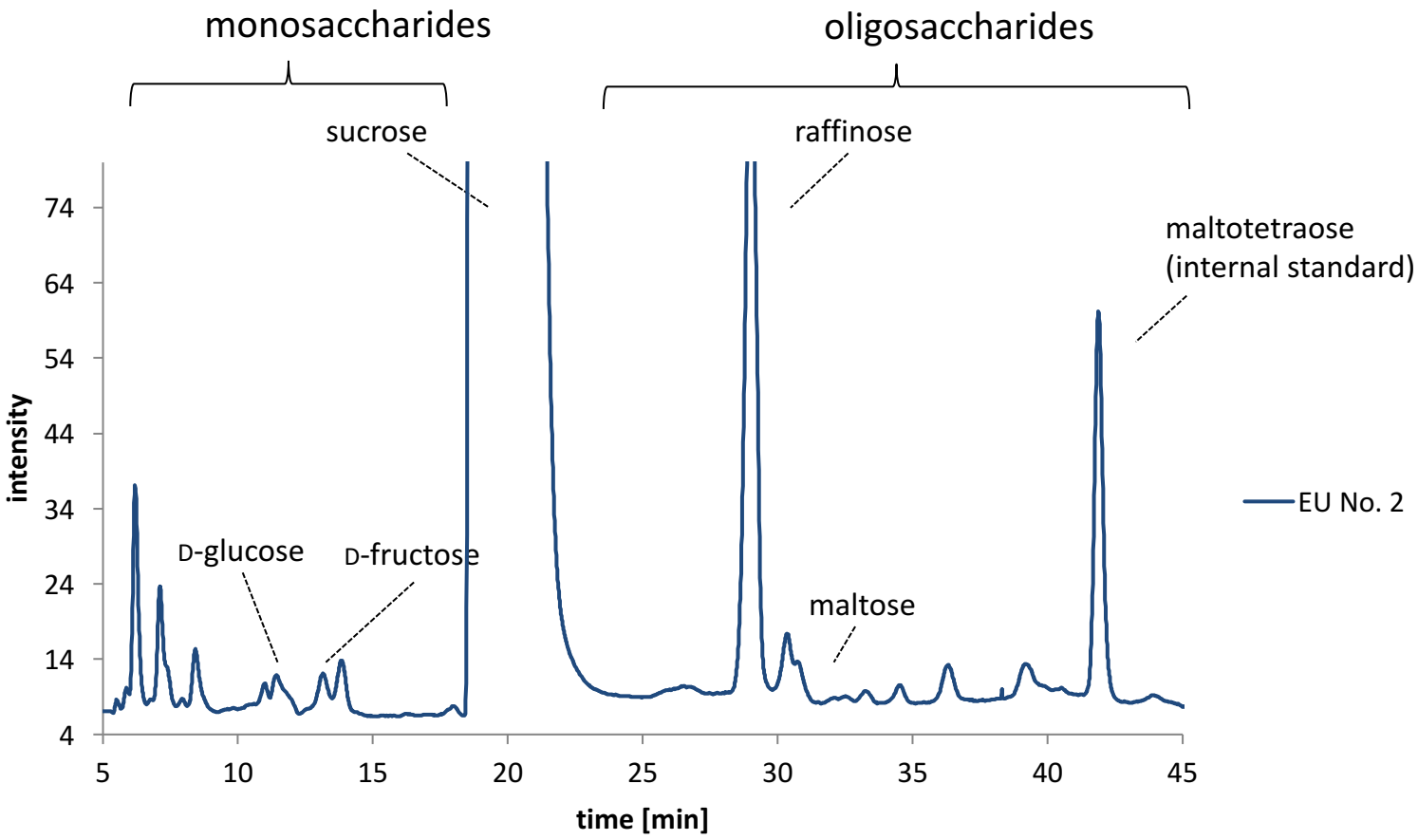
*Crystal surface: 0.5 % of the crystal mass

White Sugar – Crystal Surface

Crystal surface

- Determination of non sucrose components in the crystal surface layer
- Affination of the sugar with ethanol and analyses of the ethanol extracts for
  - Mono- and oligosaccarides with HPAEC-PAD
  - Amino acids after derivatization with GC-MS

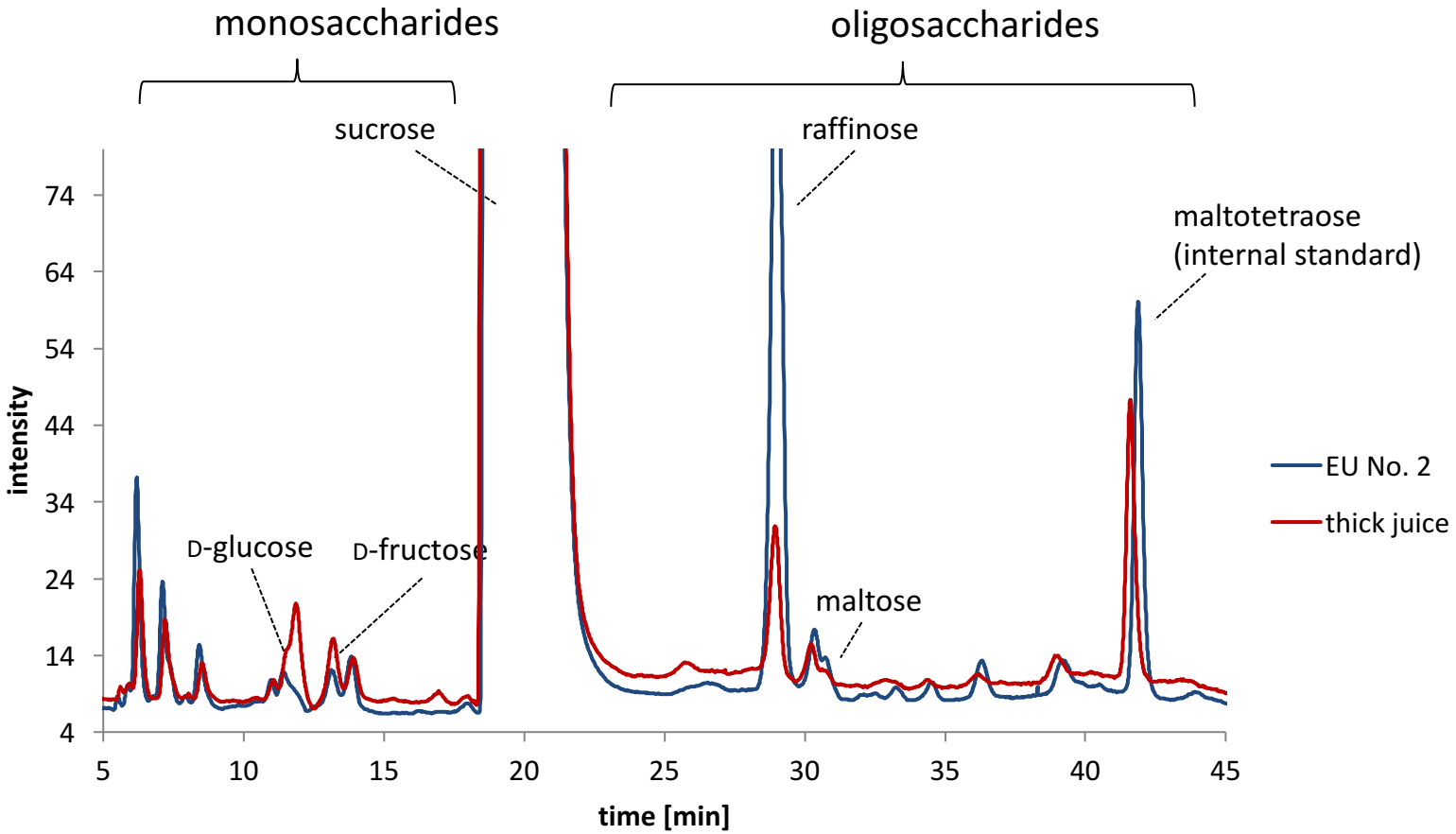
White Sugar – Crystal Surface



- The surface contains several mono- and oligosaccharides beside sucrose

White Sugar – Crystal Surface

Crystal surface – thick juice



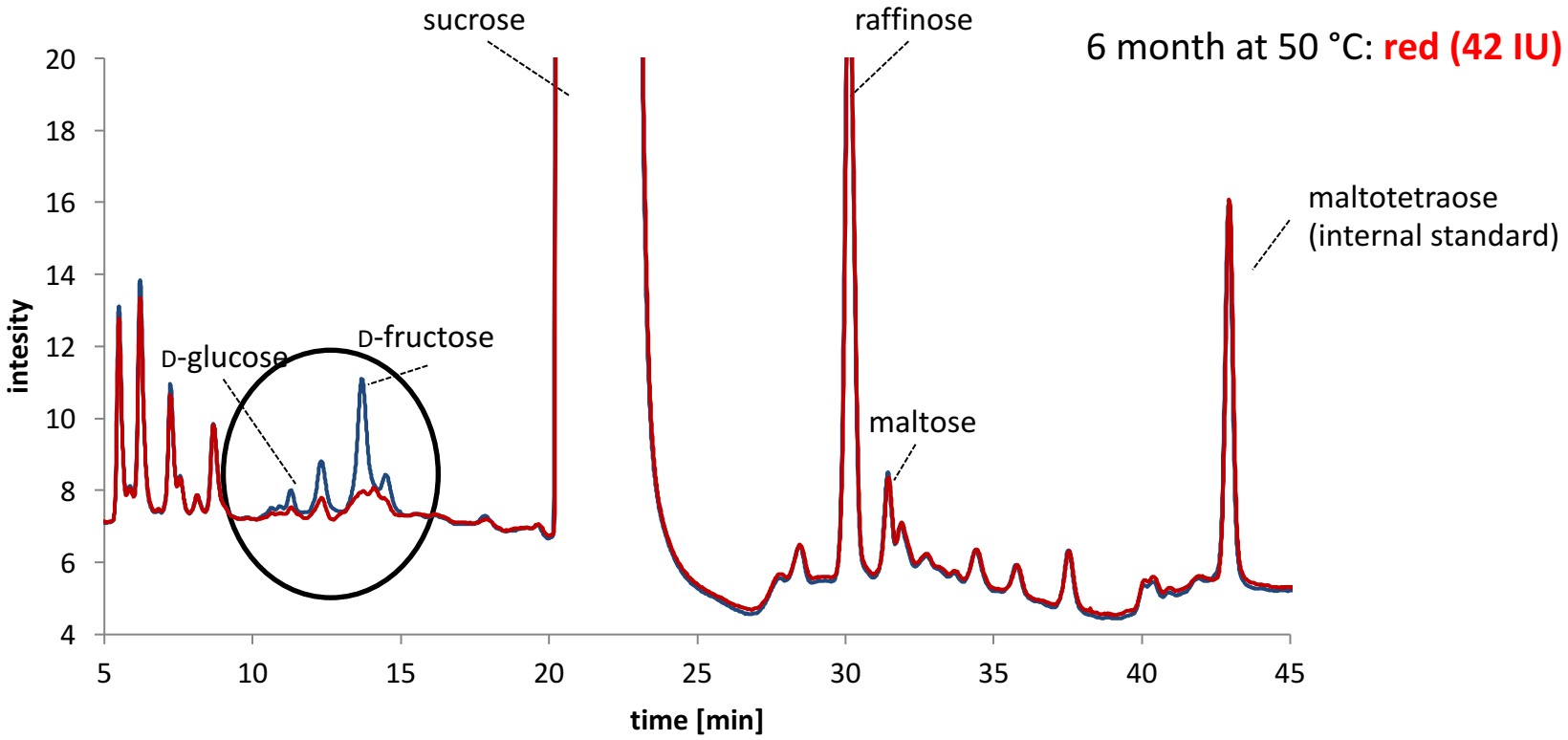
- Same compounds in surface and thick juice
- More oligosaccharides (raffinose) in sugar surface

White Sugar – Crystal Surface

Invert sugar in crystal surface during storage test

before storage: **blue (29 IU)**

6 month at 50 °C: **red (42 IU)**

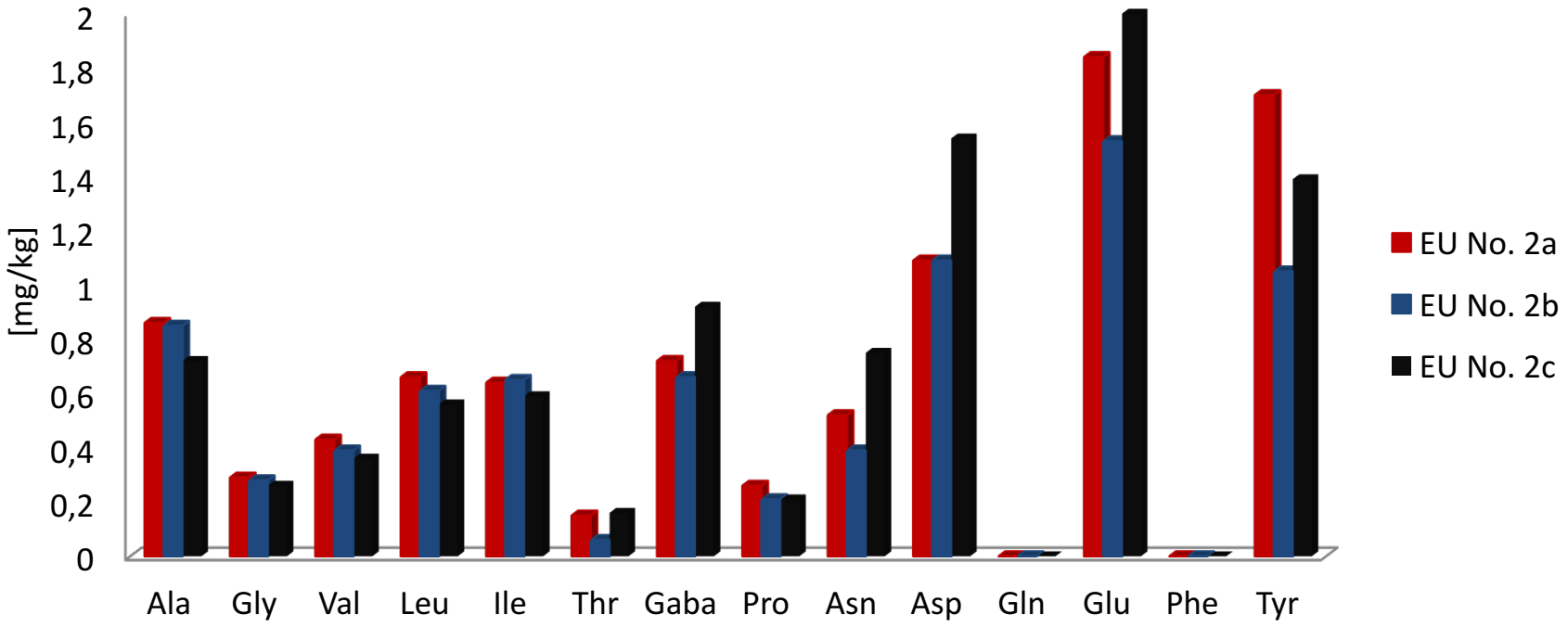


Only monosaccharides decrease during storage

- Indication for caramelization or Maillard reaction

White Sugar – Amino Acids

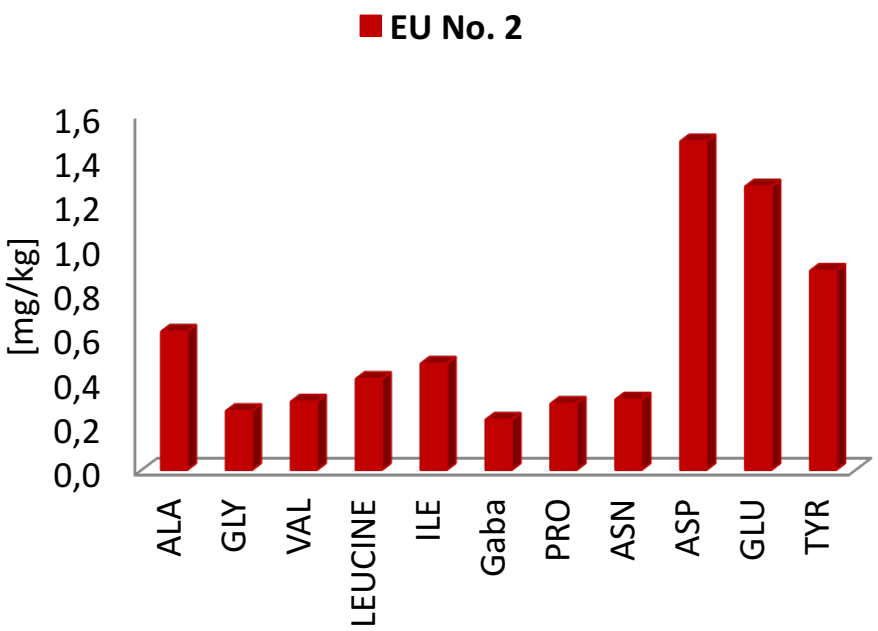
Amino acids in three EU No. 2 sugar

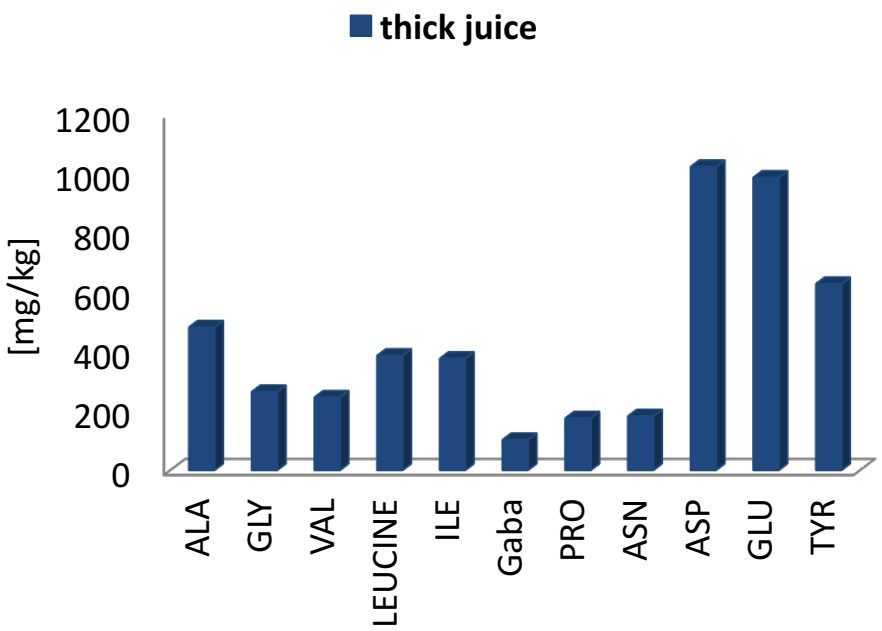


- EU No. 2 contains approx. 10 mg/kg amino acids
- Predominantly glutamic acid, tyrosine and asparagine

White Sugar – Amino Acids

Amino acids in EU No. 2 and thick juice

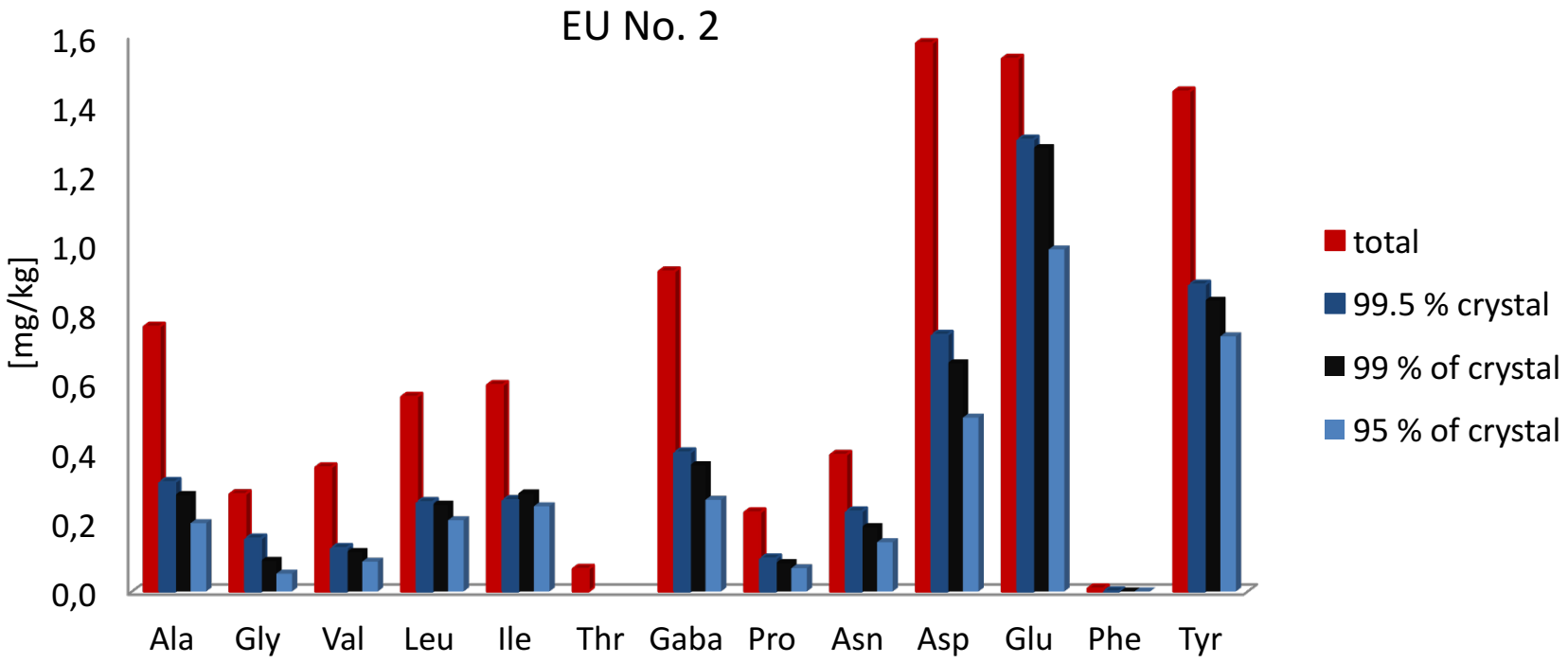




- Same ratio between amino acids in sugar and thick juice
- Concentration in sugar 700 – 1000 times lower as in thick juice

White Sugar – Amino Acids

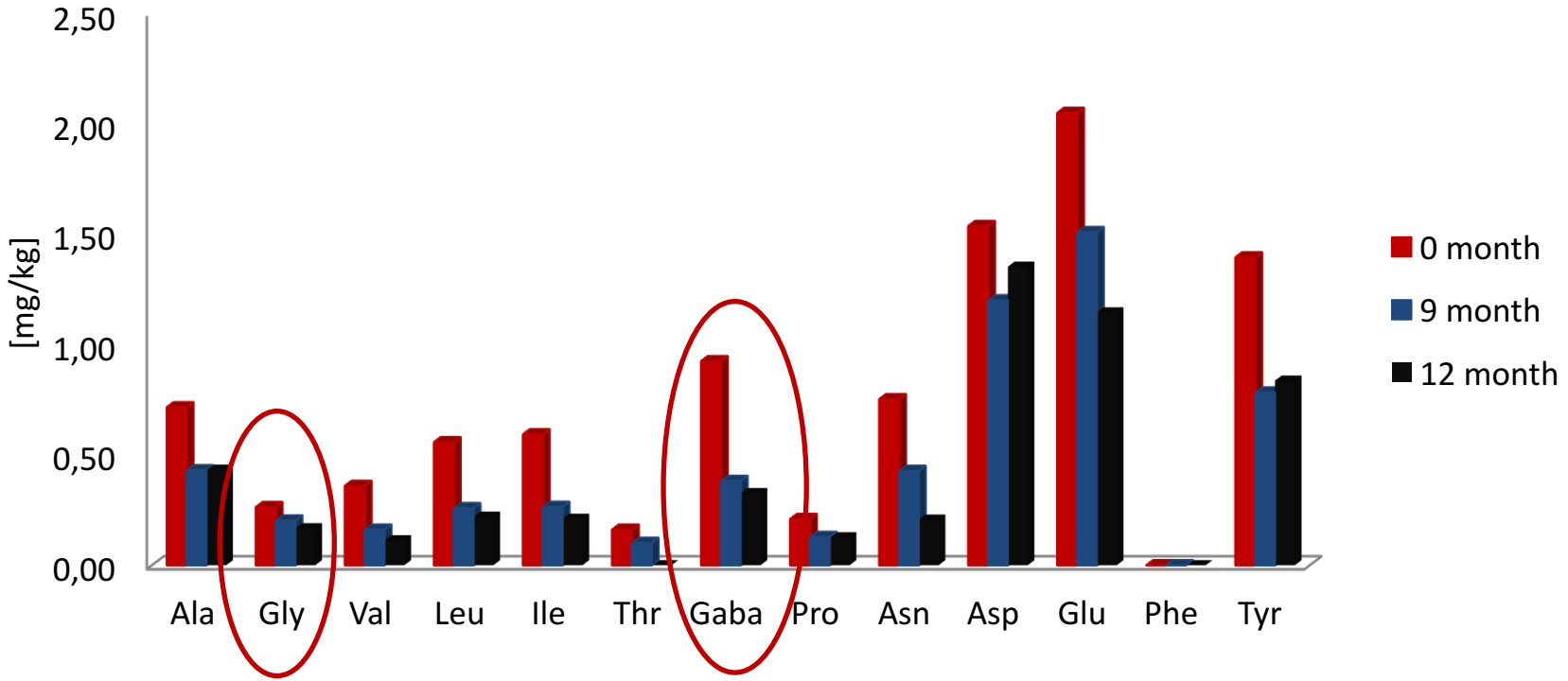
Amino acids distribution in the sugar crystal



- 40 - 60 % of the amino acids are located in the sugar crystal surface
- Amino acids show the same distribution as the color in the crystal

White Sugar – Amino Acids

Changes of amino acid content during storage at 50 °C

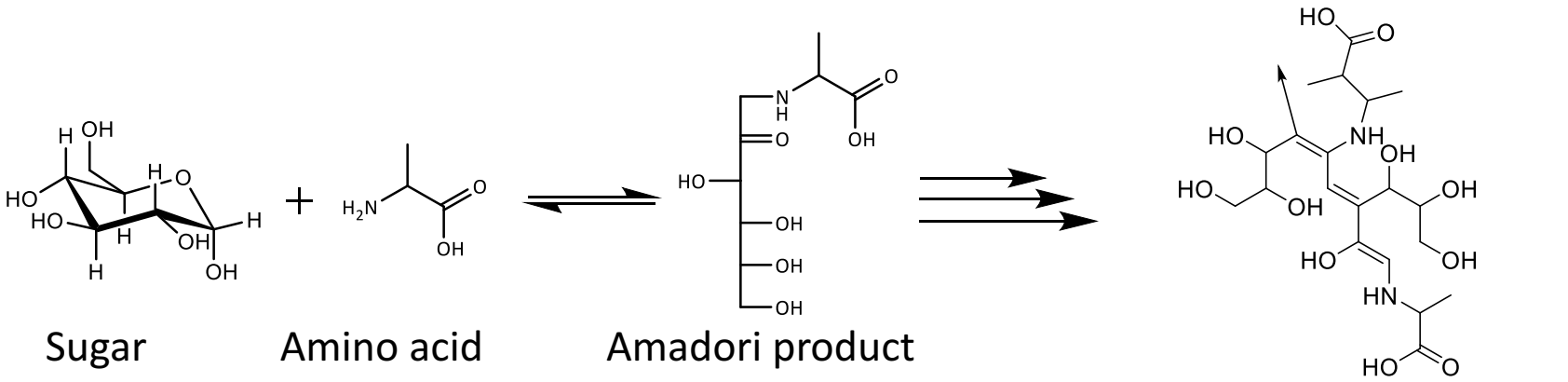


Amino acid content decreases during storage

Conclusion

Changes during storages

- Color increases mainly in the surface
- Monosaccharides and amino acids decrease in the same amount



Temperature and **Moisture** accelerate the color increase but are not the cause

*Cämmerer B.; Jalyschko W.; Kroh L. (2002): Intact Carbohydrate Structures as Part of the Melanoidin Skeleton. In: *J. Agric. Food Chem.* 50, S. 2083-2087.

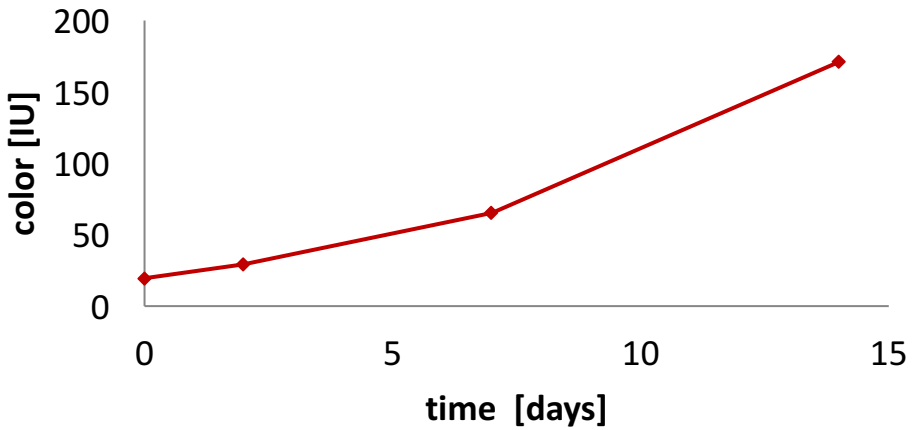
Modell

Modell reaction caramelization:

Storage test of D-glucose at 50 °C: no color development

Modell reaction Maillard reaction:

Storage test of D-glucose with L-alanin at 50 °C:



color increase to 150 IU in 15 days

Maillard reaction is responsible for the increase in color during storage

Summary

- Color
  - 40 - 60 % of the color is located in the crystal surface
  - High surface color between 500 - 1000 IU
  - Color increase mainly in the crystal surface

- Mono- and oligosaccharides
  - High concentration in crystal surface: approx. 400 - 1000 mg/kg of D-glucose and D-fructose
  - Same compounds as in the thick juice
  - Monosaccharides decrease if color increase occurs

Summary

- Amino acids
  - EU No. 2 sugar: approx. 10 mg/kg amino acids
  - High concentration in crystal surface: approx. 1500 mg/kg
  - Same distribution as color in the crystal
  - Same ratio in sugar and thick juice
  - Amino acid decrease if color increase occurs

- Modell system
  - Monosaccharides and amino acids form colored melanoidines at low temperatures

⇨ **Maillard reaction is responsible for the increase in color during storage**

Thank you for your attention