

THE FUNCTIONAL PROPERTIES OF SUGAR

Nigel Sunley

Sunley Consulting / SA Sugar
Association



TODAY WE ARE **NOT** TALKING
NUTRITION!

FOCUS WILL BE ON WHY WE
NEED SUGAR FOR
PRACTICAL REASONS



THE REALITY IS THAT SUGAR ENABLES
US TO PRODUCE A LARGE NUMBER OF
OUR MOST COMMON FOODS IN THE
FORM IN WHICH WE KNOW THEM

THE MOST IMPORTANT FUNCTIONAL PROPERTIES OF SUGAR IS PRETTY OBVIOUS!

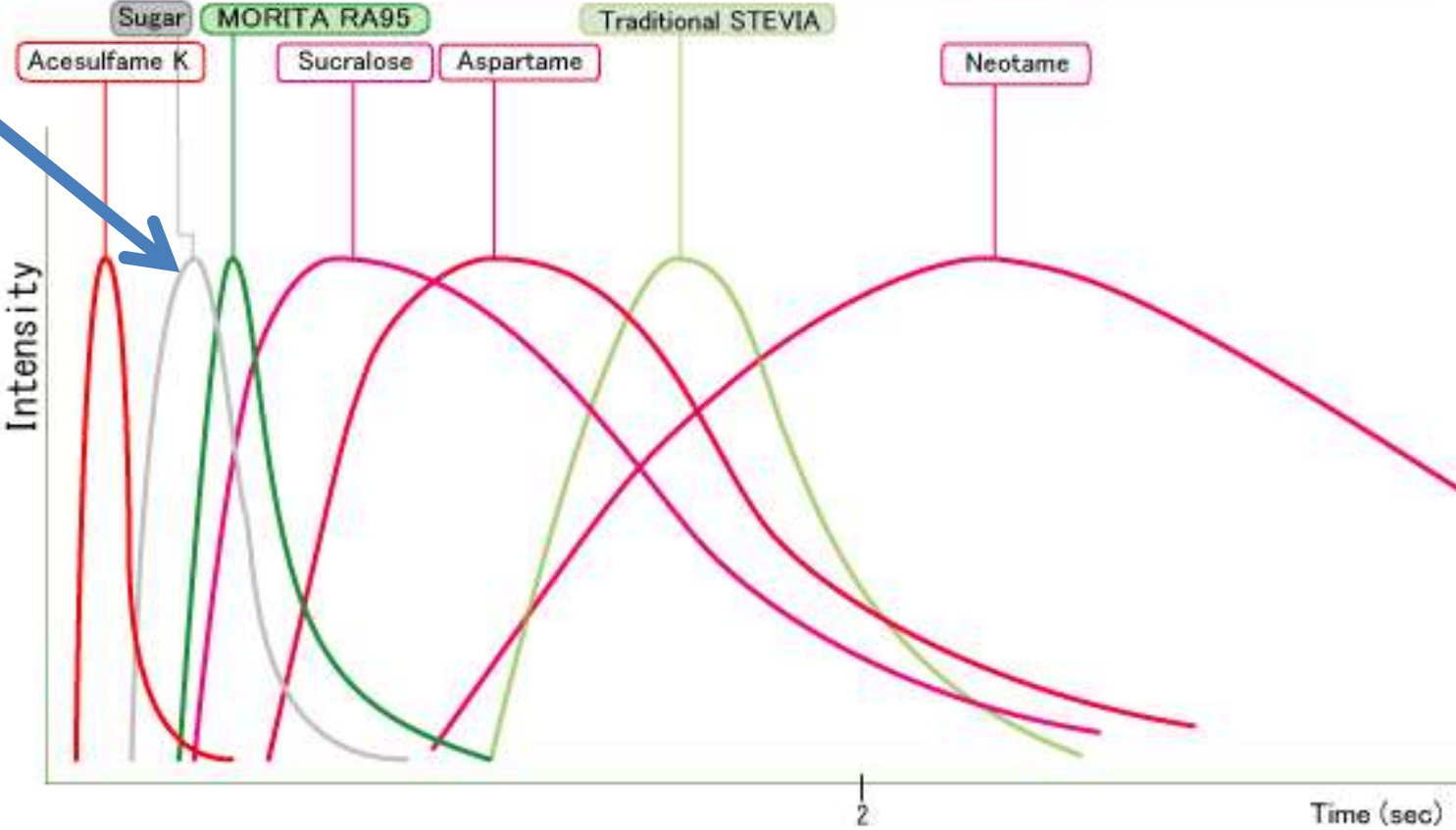
- Sweetness!!!
- Sucrose provides a sweetness flavour profile which is consistently liked by consumers at an economical cost
- Any decision to replace sugar with non-nutritive sweeteners for reasons other than nutritional requirements or functionality will be driven largely by cost considerations



HOWEVER DIFFERENT SWEETENERS HAVE DIFFERENT TASTE PROFILES

Technical Data: Time-Intensity Profile

Equivalent to 3% of Sugar



BE CAREFUL WHEN REPLACING SUGAR FOR COST REASONS

- Usually only cost-effective when lower quality non-nutritive sweeteners (e.g. saccharin, cyclamate) are used
- This can result in:
 - Loss of quality
 - Significant changes in sweetness profile
 - Potential regulatory constraints (particularly for cyclamate)
- Partial replacement may be the answer

THE OTHER BROAD-BASED FUNCTIONAL PROPERTY OF SUGAR IS PRESERVATION

- Microbiological spoilage is unquestionably the greatest cause of food quality deterioration and safety
- Essential to keep A_w below 0.90 to minimise risk of pathogens & below 0.75 to minimise risk of other spoilage organisms
- Sugar has a key role in controlling the water activity of a wide range of foods

TYPICAL A_w VALUES OF SUGAR SOLUTIONS

Sucrose (g)	Water (g)	% Sucrose	A_w
0	100	0	1.00
20	100	16.7	0.998
40	100	28.6	0.969
60	100	37.5	0.955
80	100	44.4	0.941
100	100	50.0	0.927
120	100	54.5	0.913
140	100	58.3	0.900
160	100	61.5	0.888
180	100	64.3	0.876
200	100	66.7	0.860

PRODUCTS WITH HIGH SUGAR CONTENT ARE INHERENTLY SAFER FROM A MICROBIOLOGICAL PERSPECTIVE

PRACTICAL IMPLICATIONS OF USING SUGAR TO CONTROL A_w

- To bring A_w below levels for survival of pathogens, typically need $\pm 60\%$ sucrose in the product
- This may not be practical when used in isolation other than in products such as sugar confectionery
- However it is a key component in hurdle effect e.g.
 - Used in conjunction with preservatives in baked goods
 - Used in conjunction with reduced pH in jams

SUGAR IN BAKED GOODS

- Interaction with protein & starch during mixing & baking
- Tenderising effect
- Caramelisation
 - ‘As is’
 - Via Maillard reaction
- Substrate for yeast activity / leavening
- Creaming

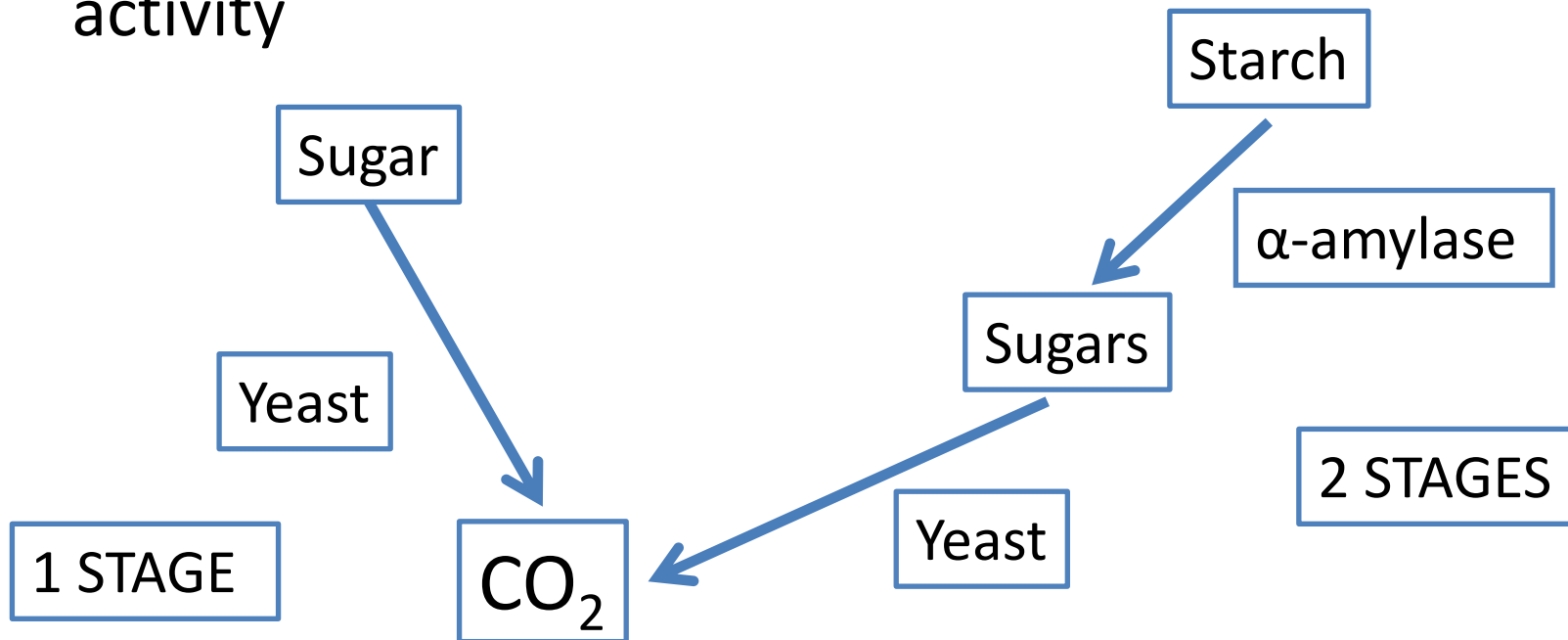


SUGAR IN GLUTEN DEVELOPMENT

- During dough mixing, sugar competes with gluten for available water
- Hydration of proteins essential for formation of dough structure
- HOWEVER if gluten over-develops, dough can become tough and rigid → unacceptable texture
- Sugar reduces level of gluten development and ensure tenderness in finished product by maintaining elasticity in the dough → better gas retention & improved volume

SUGAR IN LEAVENING

- Sugar is a 'quick & easy' substrate for yeast activity
- Sugar directly added to a dough will be more rapidly available for yeast activity during leavening than that produced from starch in the flour by α -amylase activity



THE EFFECT...

- Presence of sugar increases speed of leavening
- Dough rises faster
- Dough rises more consistently as less dependent on 2-stage production of CO₂



SUGAR IN CREAMING

- When sugar & fat (shortening) are creamed together, sugar crystals become interspersed among the fat molecules
- Air trapped in the sugar crystals is incorporated into the mixture as small bubbles and prevented from escaping by the fat
- During baking the bubbles will expand and enhance texture of the finished product



SUGAR IN BAKING

- Sugar has a wide range of functions in the actual baking process:
 - Gelatinisation
 - Protein coagulation
 - Caramelisation
 - Maillard reaction
 - Surface cracking



SUGAR IN GELATINISATION CONTROL

- Starch + water + heat = gelatinisation
- Sugar competes with starch for water
- This slows the gelatinisation process and thus slows viscosity increase in the batter
- This in turn allows more time for expansion of gas cells (air or CO₂) and ensures a finer and more uniform texture in the baked product
- Particularly important for cakes – role in bread is less clear but applicable for high sugar breads

SUGAR IN PROTEIN COAGULATION

- Sugar does play a role in the control of gluten coagulation by competing for water however this is more important during the dough development process
- In products containing other proteins e.g. egg, sugar is dispersed among the egg protein molecules and slows the process of protein coagulation by inhibiting bonding of protein molecules



THE ROLE OF SUGAR IN CARMELISATION

- 2 separate effects:
 - Caramelisation 'as is'
 - Maillard reaction
- Important to understand that these are 2 entirely different mechanisms!



CARAMELISATION 'AS IS'

- Sugars will degrade above certain temperatures due to pyrolysis:

Sugar ↕	Temperature ↕
Fructose	110°C, 230°F
Galactose	160°C, 320°F
Glucose	160°C, 320°F
Sucrose	160°C, 320°F
Maltose	180°C, 356°F

- Process is chemically complex and involves breakdown of sucrose to mono-saccharides, condensation reactions, isomerisation, fragmentation & dehydration reactions
- Process is pH sensitive

MAILLARD REACTION

- Results from the reaction between proteins and reducing sugars
- Reaction is between the carbonyl group of the sugar and the amino groups of the amino acids in the protein followed by Amadori re-arrangement to give ketosamines which then react further to give a wide variety of end products with characteristic flavours and textures e.g. nitrogenous polymers and melanoidins



IMPORTANT!

- Sucrose is NOT a reducing sugar and cannot participate directly in the Maillard reaction (although other disaccharides such as lactose & maltose ARE reducing sugars)
- Most browning in baking therefore comes from the 'as is' route when sucrose is the only sugar present
- However Maillard reaction is still important when:
 - Other reducing sugars are present in the product
 - Some of the sucrose has been broken down into reducing sugars due to enzymatic activity or pH induced inversion
 - Baking temperature is lower than that required to directly caramelize sucrose
- Difficult to therefore proportionally attribute browning of baked goods to the 2 different routes

SUGAR IN SURFACE CRACKING

- High sugar content of certain biscuit products results in sugar crystallisation on the surface of the biscuit
- Surface layer is brittle due to crystalline nature of sugar
- Release of leavening gases causes cracking of surface layer to give characteristic appearance



ROLE OF SUGAR IN CONFECTIONERY

- We can make chocolate confectionery and certain types of sugar confectionery without using sucrose (at a price!)
- However sucrose has particular properties which make it particularly important for the manufacture of sugar confectionery
- Science of sugar confectionery hinges on the behaviour of different sugars when cooked and cooled as syrups

WHY SUCROSE?

- Sucrose is crystalline in nature and is highly unstable and hygroscopic when used as a 'glass'
- However when blended with other sugars (mainly glucose and invert sugar syrup) it imparts particular characteristics to finished products
- Glucose and invert sugar are used to control the crystallisation characteristics and sweetness level of the product but cannot be used in finished products on their own as product would be extremely hard and hygroscopic due to their extremely low A_w values
- Texture is controlled by boiling temperature and ratio of sucrose to other sugars in the recipe



SUCROSE ALSO PLAYS A ROLE IN BROWNING

- Most of the browning occurring during sugar confectionery production comes from Maillard reaction as temperatures required for pyrolysis of sugar are not reached during processing
- Sucrose therefore acts as:
 - Minor source of reducing sugars due to inversion during cooking if pH is low or enzymatic hydrolysis using invertase occurs
 - Matrix for encapsulation of Maillard reaction products i.e. caramel (lower sucrose content & fudge (higher sucrose content)



OTHER SUGAR CONFECTIONERY PRODUCTS

- Nougat – sugar / glucose syrup beaten to incorporate air with whipping proteins and / or gelatine to stabilise the aerated structure
- Marshmallow - sugar / glucose syrup beaten to incorporate air with whipping proteins and / or gelatine but with much higher level of aeration. Sucrose level is lower than for nougat hence A_w levels need to be controlled carefully
- Fondant – mixture of sucrose & glucose syrups beaten to give very fine crystals with a particular texture and mouthfeel, typically used in assortment centres
- Sucrose is sometimes used to deliberately induce crystallisation or ‘graining’ in sugar confectionery.



COULD WE MAKE SUGAR CONFECTIONERY WITHOUT SUCROSE?

- Yes, but at a price:
 - Alternatives (maltitol, isomalt, polydextrose etc) are all significantly more expensive
 - Crystallisation characteristics of alternatives are significantly different to sucrose and require formulation and process changes
 - Finished products are typically more hygroscopic than sucrose-based equivalents and require higher barrier packaging



OTHER FUNCTIONAL BENEFITS OF SUGAR

- Dispersion – acts as a diluent base for highly functional ingredients when these cannot be incorporated directly in concentrated form e.g. starches, gelling agents
- Foam stabilisation where it increases the viscosity of the liquid fraction e.g. meringues
- Mouthfeel in beverages – may have to incorporate gums or other viscosity inducing materials in non-sugar containing beverages to impart acceptable mouthfeel



SO...COULD WE DO WITH OUT SUGAR FROM A FUNCTIONAL PERSPECTIVE?

- Realistically no!
- Substitution possible in many cases but with major negative implications such as cost, quality, flavour, shelf properties and ease of processing
- Sugar sometimes gets a bad press from a nutritional perspective but...

BUT...

The reality is that a moderate amount of sugar is perfectly acceptable in a balanced diet

AND

Sugar has significant functional properties without which we would be unable to produce many of our most commonly consumed foods

THANK YOU

