

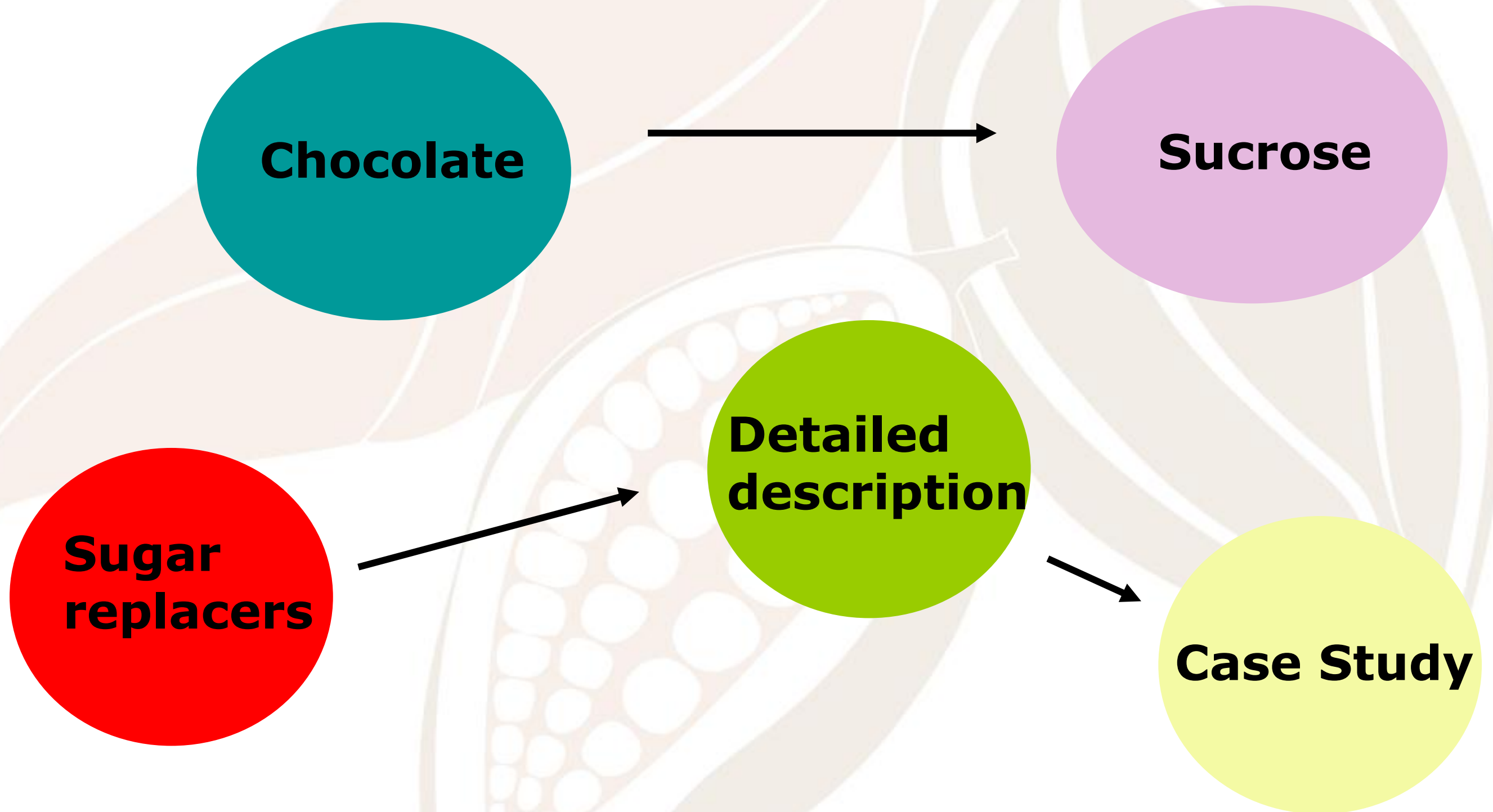


# SUGAR REPLACERS *in chocolate*

**11<sup>th</sup> September 2013**

**MSc. Roger AIDOO**

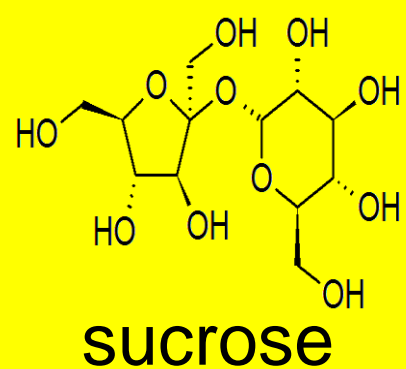
Aidoo et al., (2013). Industrial manufacture of sugar-free chocolates – Applicability of alternative sweeteners and carbohydrate polymers as raw materials in product development. Trends in Food Science and Technology 32: 84 - 96



A dense suspension of sugar particles, cocoa solids, milk powder (depending on type) dispersed in cocoa butter as a continuous phase

Popularity – unique texture, taste and eating pleasure

~ 60%  
confectionery



35-50%





- Bulking agent
- Mouthfeel modifier
- Texture modifier
- Flavor enhancer
- Preservative

## Health implications

- Tooth decay
- Diabetes
- Obesity, . . .



# *Alternative Sweetening Solutions*

- Sweet taste plays an important role in food preferences
- Sucrose prevails in traditional food industry

**“Gold standard”**

- Increasingly consumers are concerned about sugar and caloric content of confectionery products

**“Light” and “sugar-free”**  
Products growing in popularity



- **Light**

Food product provides less than 40 calories per serving

- **Sugar-free**

Food product provides less than 0.5g of sugars per serving

*Aidoo et. al. (2013)*

- Numerous offer of sweeteners for manufacturers

Nutritive  
sweeteners

Non-nutritive  
sweeteners



- Substances with very intense sweet taste to replace sweetness of sugar

Non-nutritive sweeteners

Intense sweeteners

High Potency Sweeteners

## Non-nutritive sweeteners

### ARTIFICIAL

- ✓ Acesulfame K
- ✓ Aspartame
- ✓ Neotame
- ✓ Saccharin
- ✓ Cyclamate
- ✓ Sucralose
- ✓ Neohesperidine-dihydrochalcona

### NATURAL

- ✓ Stevia - Steviolglycosides
- ✓ Thaumatin
- ✓ Luo han guo
- ✓ Brazzeïne
- ✓ Glycyrrhizine
- ✓ Monatine

	Aspartame	Acesulfame-K	Saccharin	Sucralose	Neotame
<b>Sweetness</b> (x sucrose)	180-200	130-250	300-500	500-700	8,000-13,000
<b>Taste profile</b>	Slow onset, lingering sweetness. Little to no after taste	Quick onset, no significant lingering sweetness. Can have bitter aftertaste	Quick onset, no significant lingering sweetness. Bitter aftertaste	Clean sweetness, slow onset and lingering sweetness	Slow onset, lingering sweetness. Little to no aftertaste
<b>Stability</b>	Limited at high temp and low pH	Good at high temps and low pH	Good at high temps and low pH	Good at high temps and low pH	Limited at high temp and low pH
<b>Blending options</b>	Good synergy with Ace-K & saccharin	Good with aspartame & sucralose	Good with aspartame & sucralose	Good synergy with Ace-K & saccharin	Good with Ace-K & saccharin
<b>Advantages</b>	Cost effective, widely used	Stable and synergies with other HPs	Stable and cost effective	Sweetness profile & stability	Good sweetness profile

Jamieson (2008)



- Substances that substitute for both **BULK** and **SWEETNESS** of sucrose
- Often called “**sugar replacers**” or “**bulk sweeteners**”

Sugar alcohols (polyols)

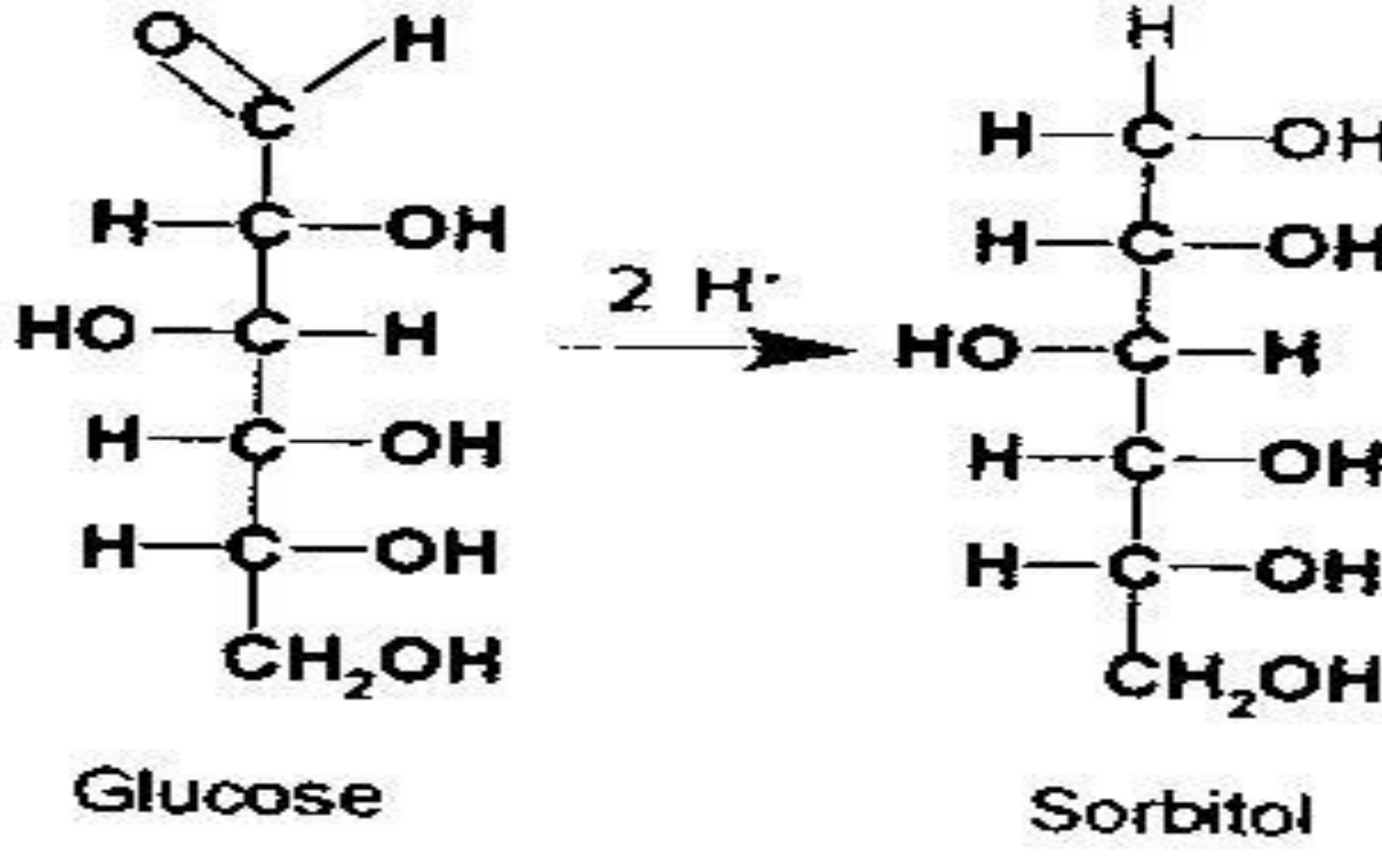
Trehalose

Isomaltulose

Tagatose

Similar in function to the polyols but are sugars rather than polyols

- Reduction of aldehyde or ketone function



- Reduction of aldehyde or ketone function
- They retain much of sugar's structure, bulk and function since only reactive groups are changed.

Makes them ideal for 1:1 bulk sugar replacement.



- They vary in sweetness from half as sweet to about as sweet as sucrose, providing almost zero to half the calories of sugar on per weight basis.
- They have a unique property of cooling effects. This may be a welcomed property in mints and chewing gum but not in chocolates.

**Sorbitol**

**Mannitol**

**Xylitol**

**Isomalt**

**Maltitol**

**Lactitol**

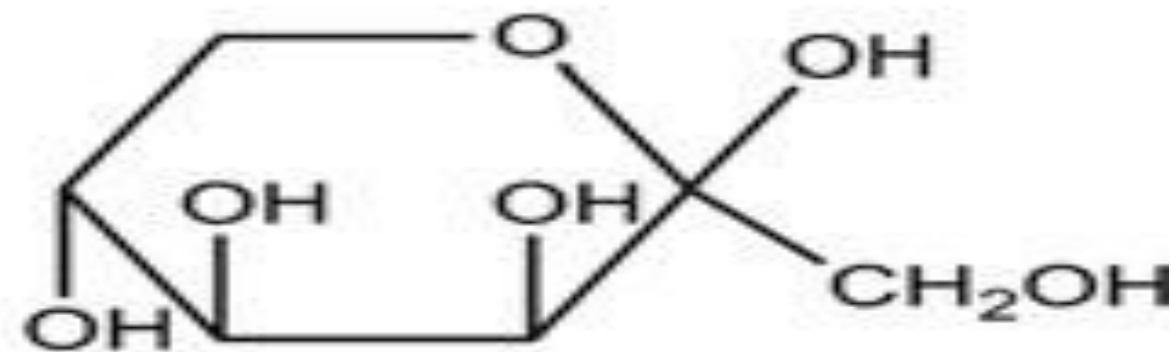
**Hydrogenated starch hydrolysates**

**Erythritol**

- An isomer of D-galactose and stereoisomer of D-fructose.
- Naturally occurring

Sterculia setigera gum, powdered cow's milk, cheese and other diary products

- GRAS status since 2001





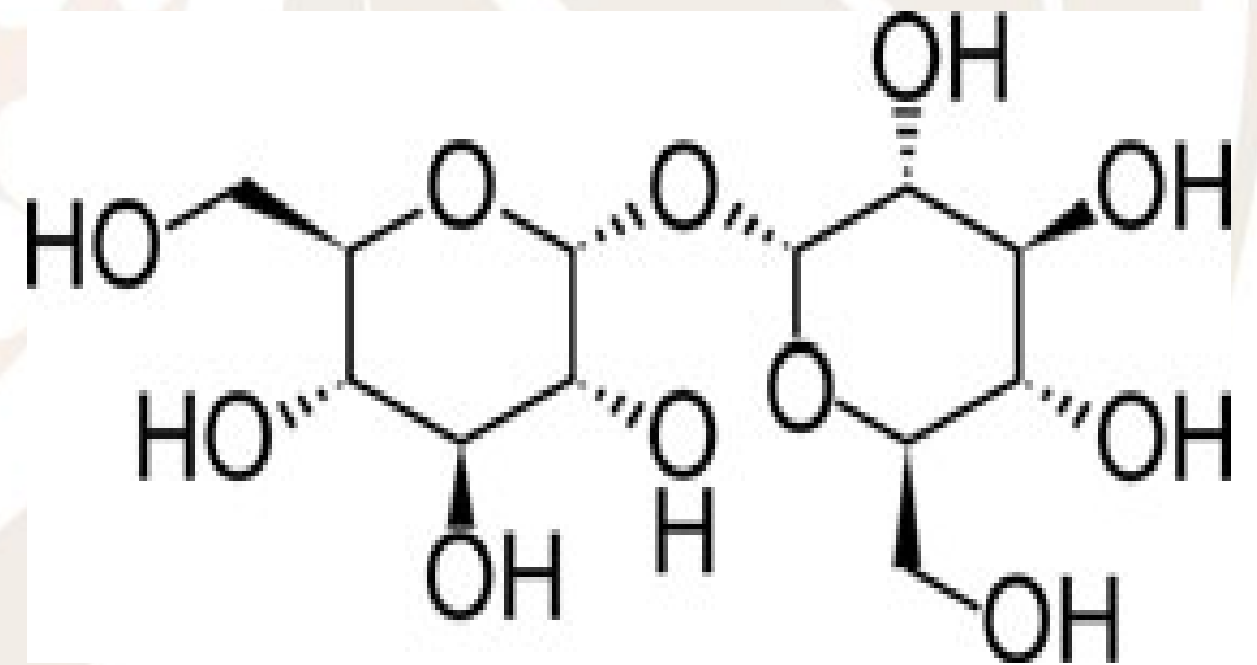


# Tagatose



- Relative sweetness – 92%  
(sucrose-like taste/ no cooling effect/ no aftertaste)
- Caloric value of 2.4kcal/g [EU 2008/100/EC]
- Has prebiotic properties  
– provide health benefits to consumers.
- Applications: Carbonated drinks, bakery pdts, hard candies, gum,.....

- Also called mycose, is a natural alpha-linked disaccharide.
- Naturally found in insects, plants, fungi and bacteria
- Non reducing, very stable, inert in interactions with proteins [ability to stabilize proteins]
- GRAS status since 2000
- Regulatory approval as food ingredient in Europe (2001)



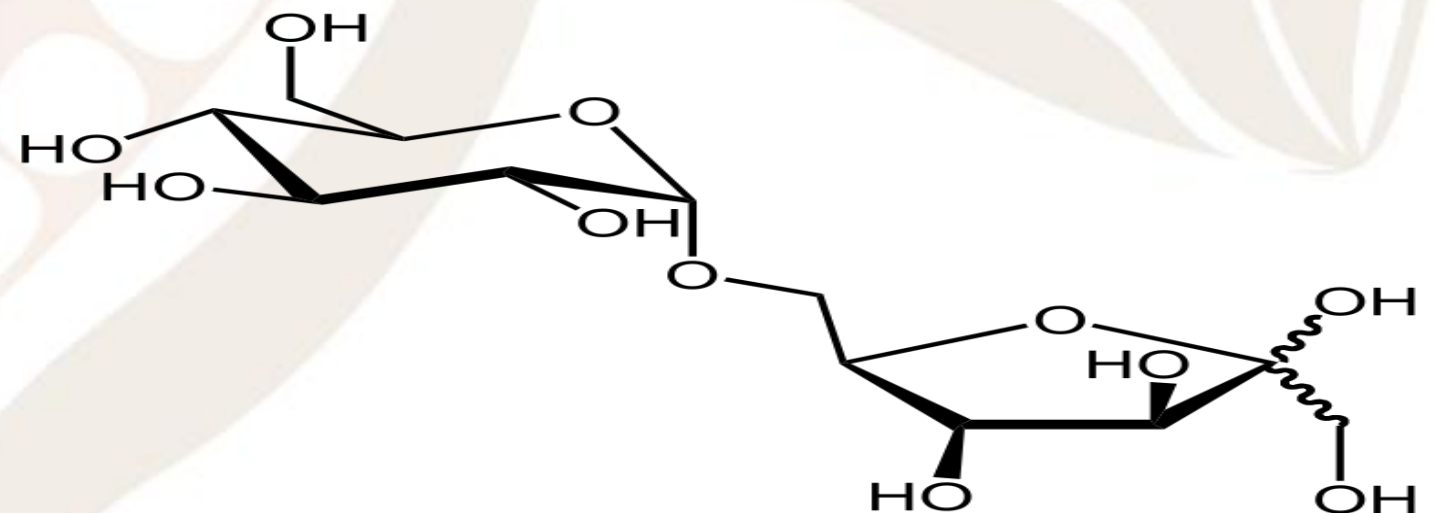
$\alpha, \alpha$ -1, 1-glucoside linkage of 2  $\alpha$ -glucose units

- Use in food limited by cost until recently
  - new technologies (from starch – enzymatic process)
- Relative sweetness – 45%
  - lower sweetness / longer persistence
- Human consumption up to 50g per serving recommended as safe.



- Also called Palatinose<sup>®</sup> or Lylose<sup>®</sup>, is a reducing disaccharide
  - glucose + fructose  $\alpha$ -1,6 glycosidic bond
- Naturally found in sugar-cane extract and honey
  - a promising substitute for sucrose
- Relative sweetness – 50% (mild sweet taste/no aftertaste)

- GRAS status in 2006



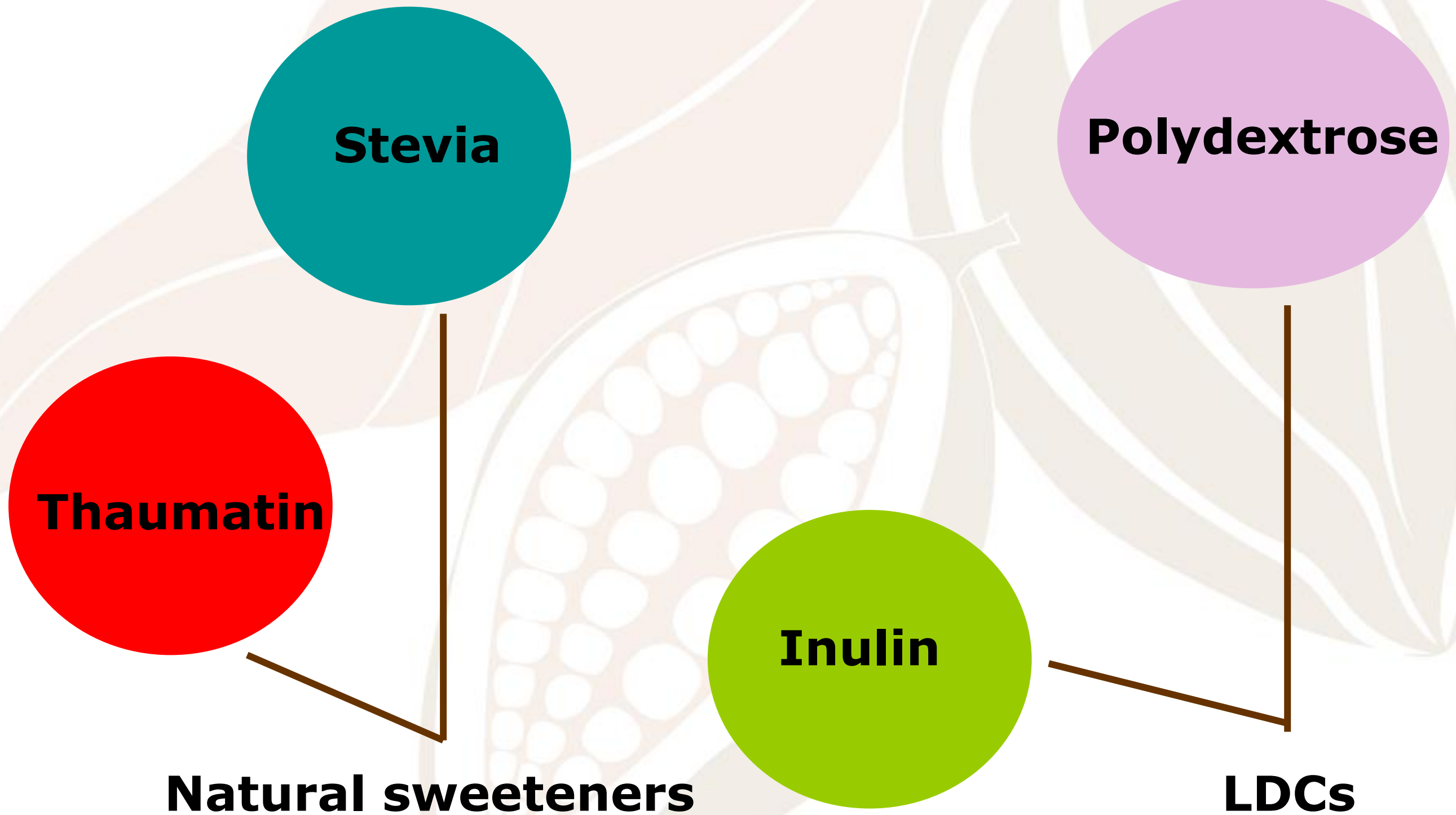
- Industrially produced from sucrose by enzymatic rearrangement of linkages followed by crystallization
  - Sweetness profile similar to sucrose
- Comparable gastrointestinal tolerance to sucrose even at high doses
- Metabolized much more slowly than sucrose  
=> low glycemimetic and insulinemic response
- Applied as a sugar replacer in confectionery, bakery products, chewing gum, sports drinks.

# *Low digestible Carbohydrates (LDCs)*



- Fibre or fibre-like ingredients.
- Composed of sugars such as glucose, mannose and fructose, linked together in such a way that their digestibility, as well as caloric contribution is significantly reduced.
- Can be naturally occurring or man-made.

- Although used for decades by diabetics, the landscape of ingredients available today – as well as their understanding – has changed greatly
- This has opened the door for product developers to create sugar-free products of higher quality that look and taste like traditional confections.
- LDCs provide not only bulk but are typically more slowly digested yielding lower calories.
- Polydextrose, Inulin, oligofructose and resistant maltodextrin





- Natural sweeteners have received great attention lately due to consumer demand for better tasting healthy foods

## Stevia



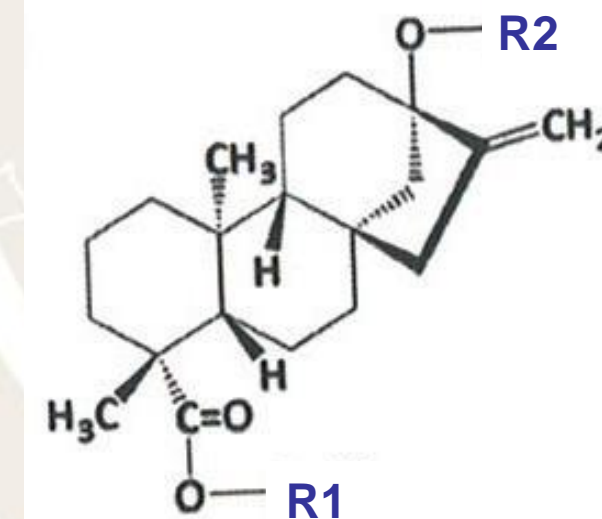
- Extracts of leaves of ***Stevia rebaudiana* (Bertoni)**

A perennial shrub of the family Asteraceae native to Brazil and Paraguay.

- ~300 times sweeter than sucrose / zero calorie / 100% natural
- Major constituents in leaves are potent sweet diterpene glycosides

**stevioside, rebaudioside A and D, and dulcoside A**

Name	R1	R2
Steviol	H	H
Steviolbioside	H	Glu-1,2-Glu
<b>Stevioside</b>	Glu	Glu-1,2-Glu
<b>Rebaudioside A</b>	Glu	Glu-1,2-Glu   1,3-Glu
Rebaudioside B	H	Glu-1,2-Glu   1,3-Glu
Rebaudioside C	Glu	Glu-1,2-Rham   1,3-Glu
<b>Rebaudioside D</b>	Glu-1,2-Glu	Glu-1,2-Glu   1,3-Glu
Rebaudioside E	Glu-1,2-Glu	Glu-1,2-Glu
Rebaudioside F	Glu	Glu-1,2-Xyl   1,3-Glu
<b>Dulcoside A</b>	Glu	Glu-1,2-Rham



***Glu-Glucose,***  
***Rham-Rhamnose,***  
***Xyl-Xylose***

**Woelwer & Lankes (2010)**



- Purified extracts sold today mainly contain Stevioside (>80%) or Rebaudioside A (>90%)

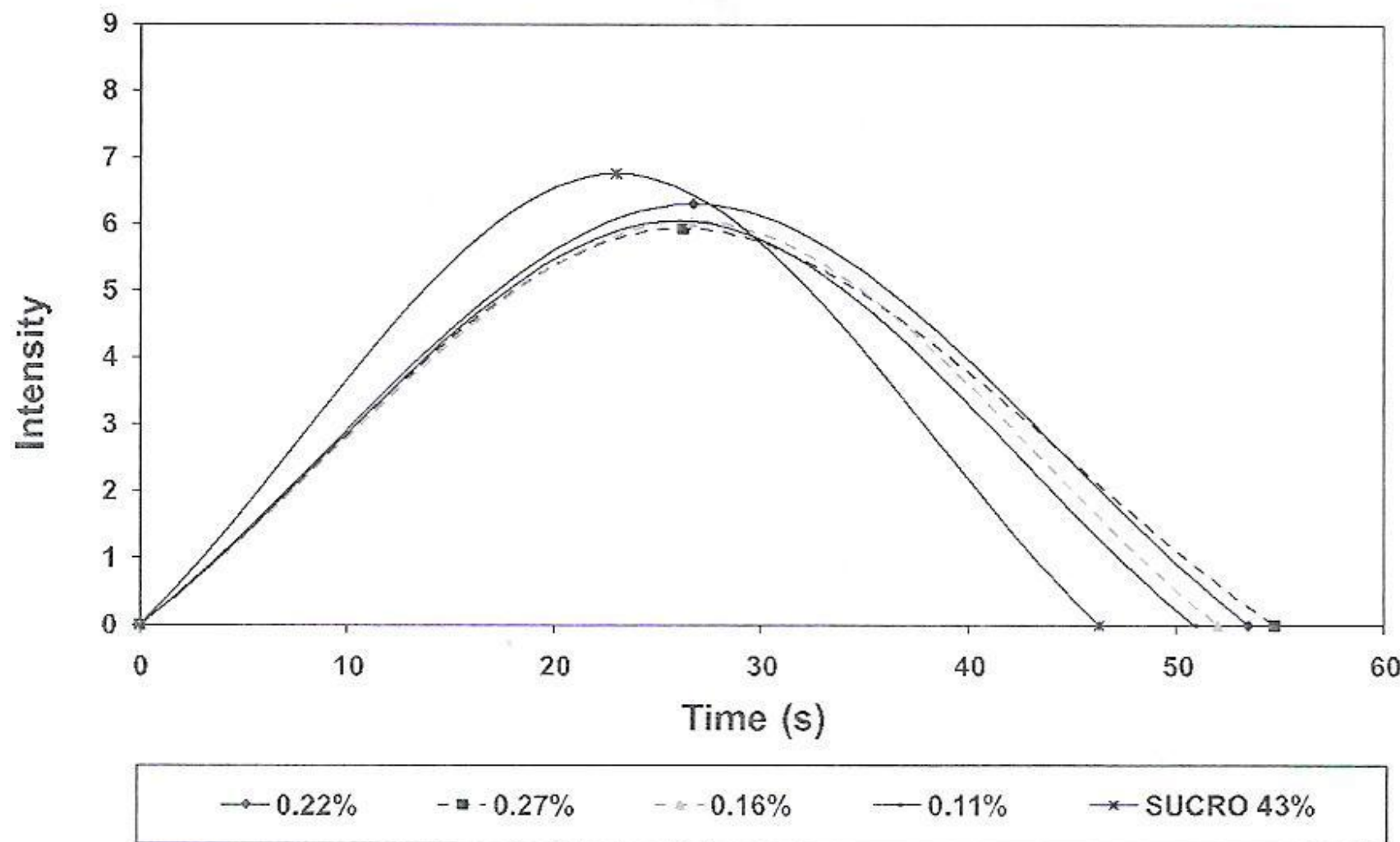
- Similar structures: Reb A has one extra glucose moiety.
- Reb A is the sweetest and most stable.
- Products containing high level of Rebaudioside A are known as rebiana.



Along with sweetness, stevia glycosides possess some bitterness and undesirable aftertaste.



- Bitter residual taste increase with concentration



*Time-intensity curves for sweet taste stimuli of milk chocolate with different Reb A conc. and with sucrose. (Palazzo et al., 2011)*

# Thaumatococcus



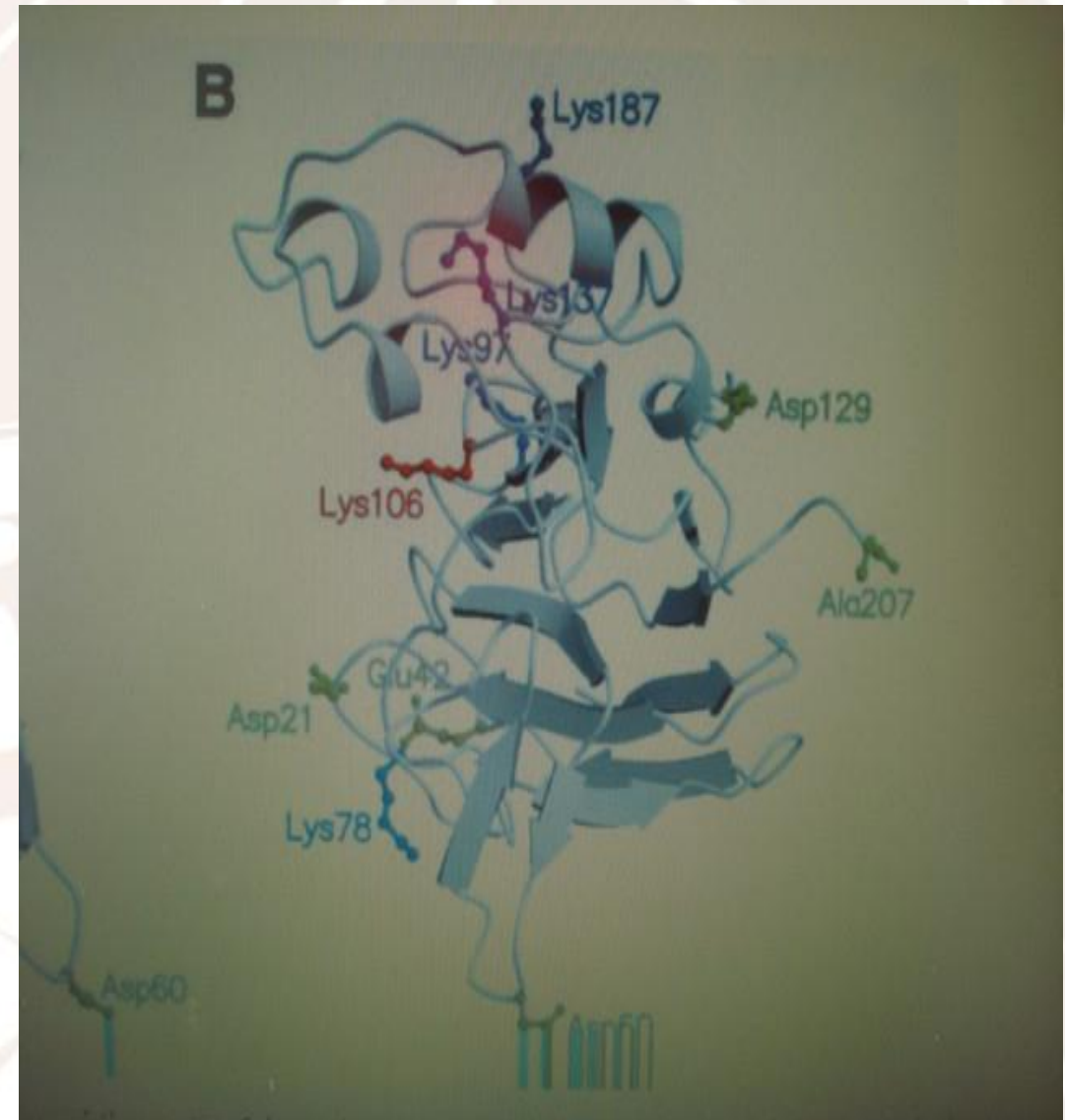
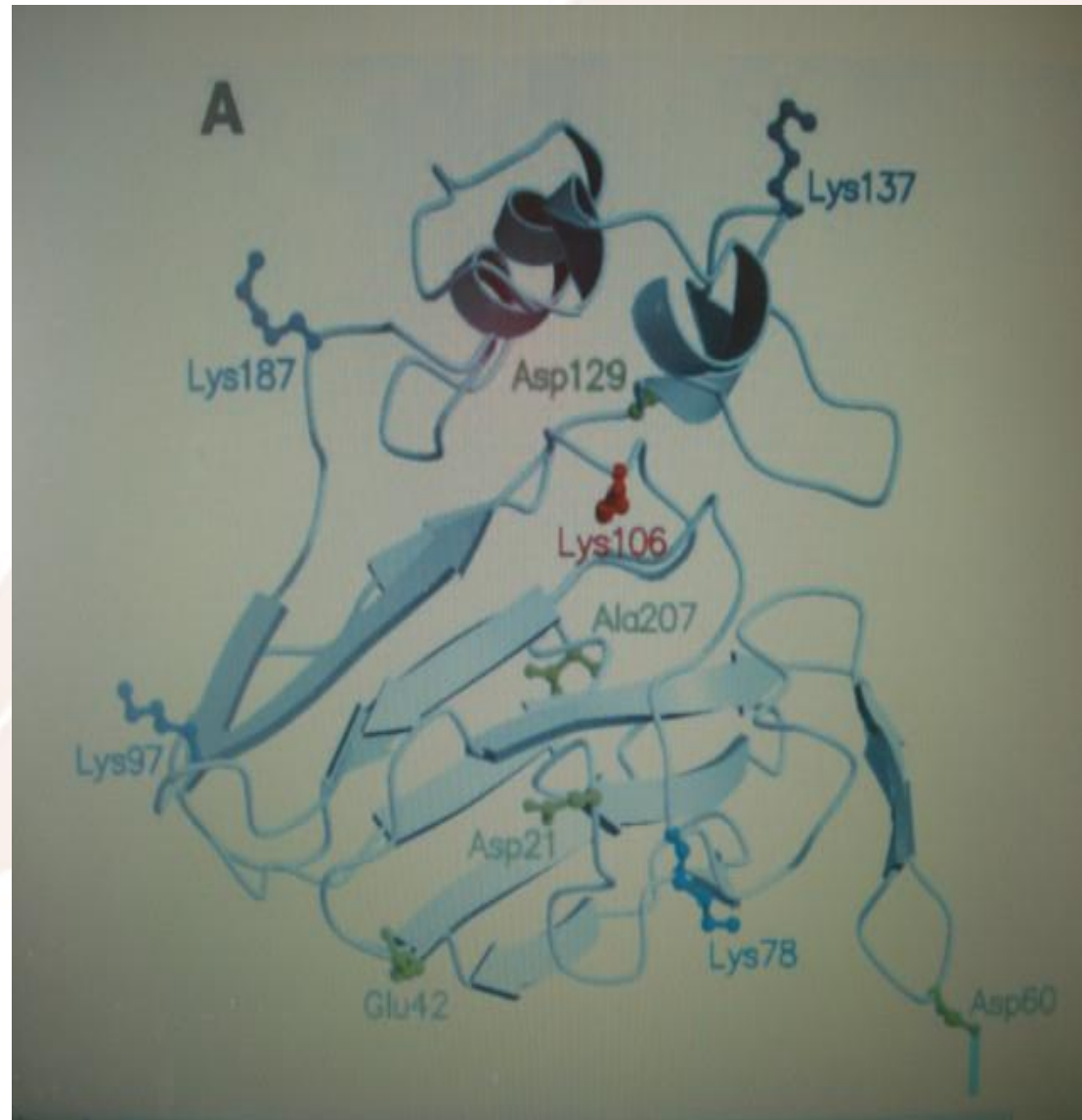


- A sweet-tasting **protein** isolated from the arils of *Thaumatococcus daniellii*, a plant native to tropical West Africa.  
(Zaire, Sudan , Ghana and Uganda)
- Consists of six closely related proteins (I, II, III, a, b, and c), all with a molecular mass of 22kDa (207 Amino acids)
- ~ **2000** X sweeter than sucrose on weight basis ( $10^5$  X on molar basis)  
=> most intensely sweet substances known
- 4cal/g as a protein  
=> not provided (small qty)

- Thaumatococcus is sweet, with a slow onset, lingering sweetness and a licorice after-taste.
- Very water-soluble and heat-stable
- Commercially available as a sweetener, flavor enhancer, additive to pharmaceuticals, chewing gum and animal feeds.
- JECFA has given an ADI of "not specified",  
=> can be used according to GMP



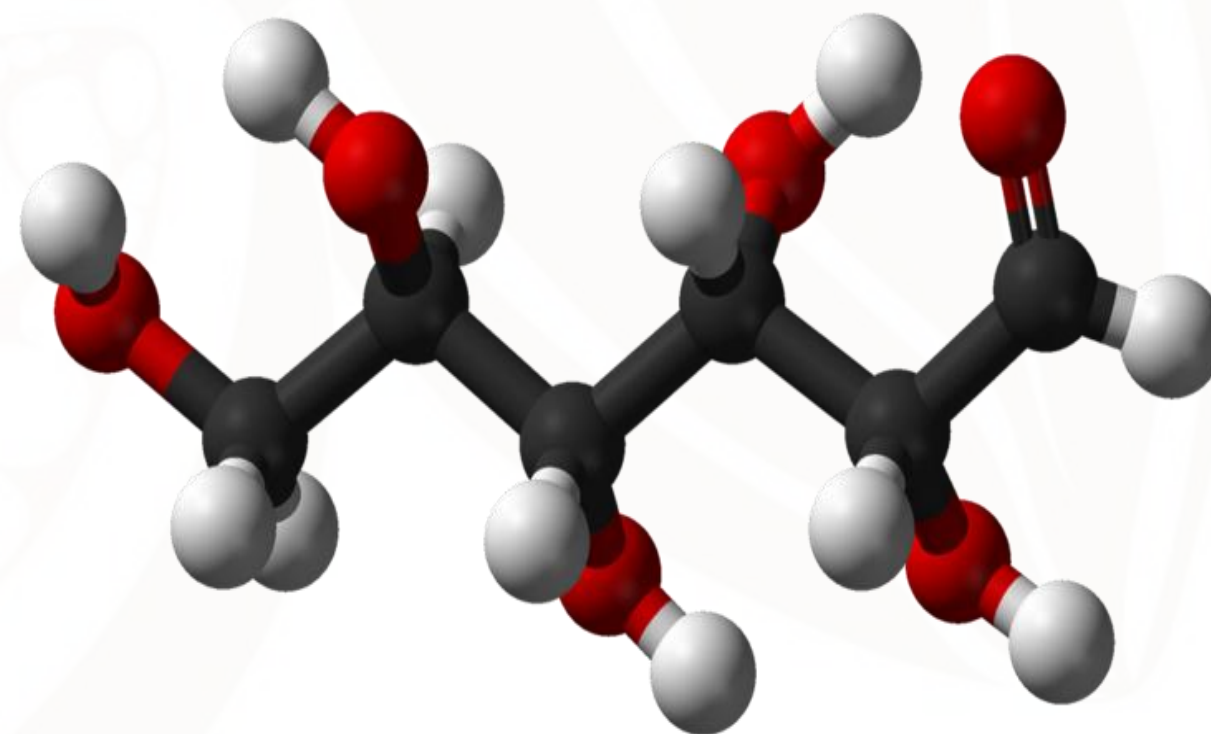




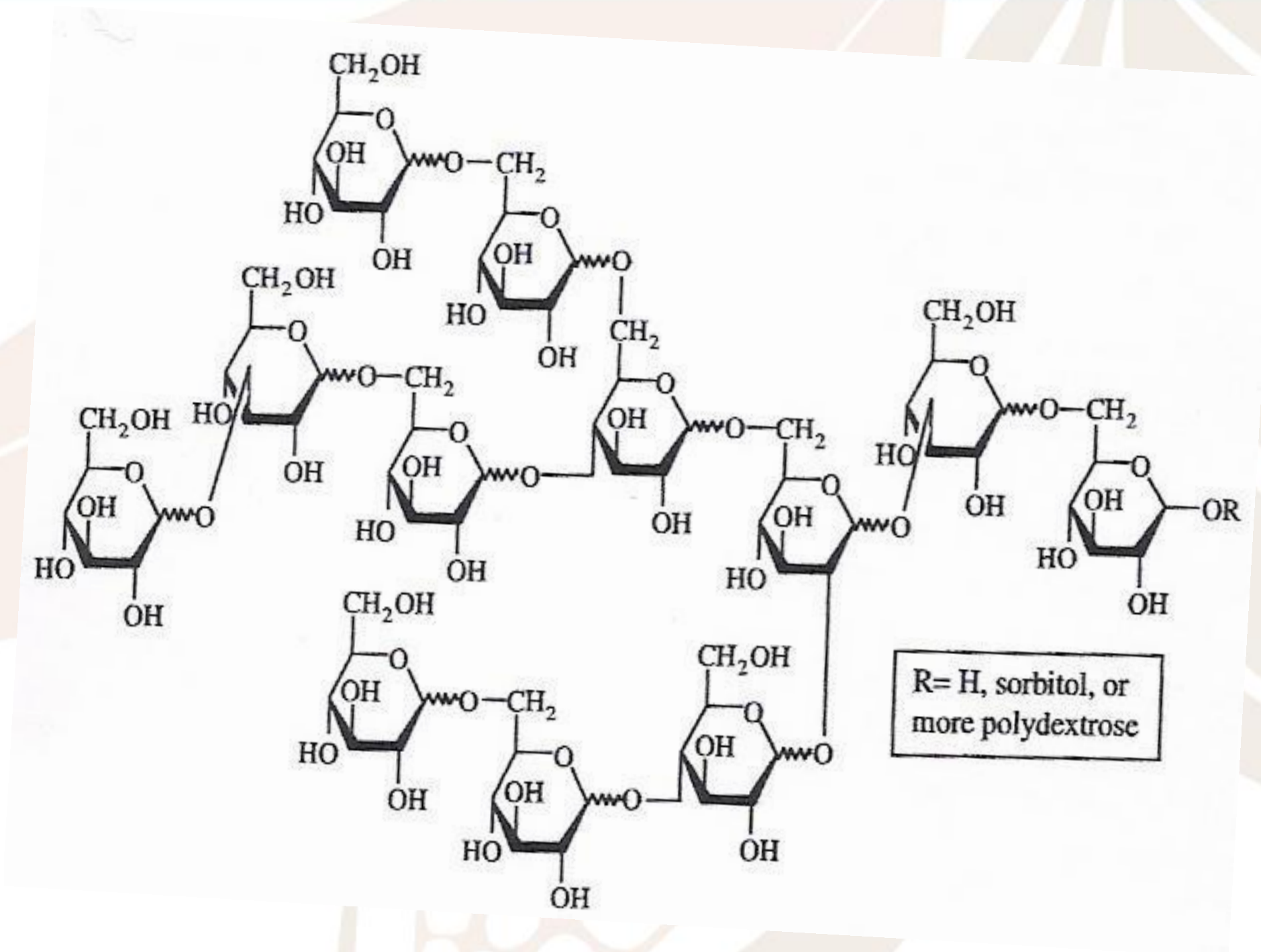
Schematic representation of thaumatin in two different orientations (front view (A) and side view (B)). (Kaneko and Kitabaki (2001))  
 [ $\alpha$ -helices – belts; helical ribbons and strands of  $\beta$ -sheets - arrows]



# Polydextrose



- A water-soluble polymer of glucose, provide foods bulk and texture of sucrose at only one-quarter caloric value.
- Multi purpose food ingredient classified as soluble fibre
- Produced from glucose in the presence of sorbitol and catalytic amounts of citric or phosphoric acid, resulting in a randomly linked polymer.
- Available in several forms: trade name Litesse®, are more purified forms of polydextrose.



=> Its low caloric value (2kcal/g) and its laxative properties



- Several clinical studies suggest polydextrose have a laxative effect (not diarrhoeal effect).
- Mean laxative threshold of 90g/day (1.3g/kg bw) or 50g as a single dose concluded by (JECFA).

# Inulin

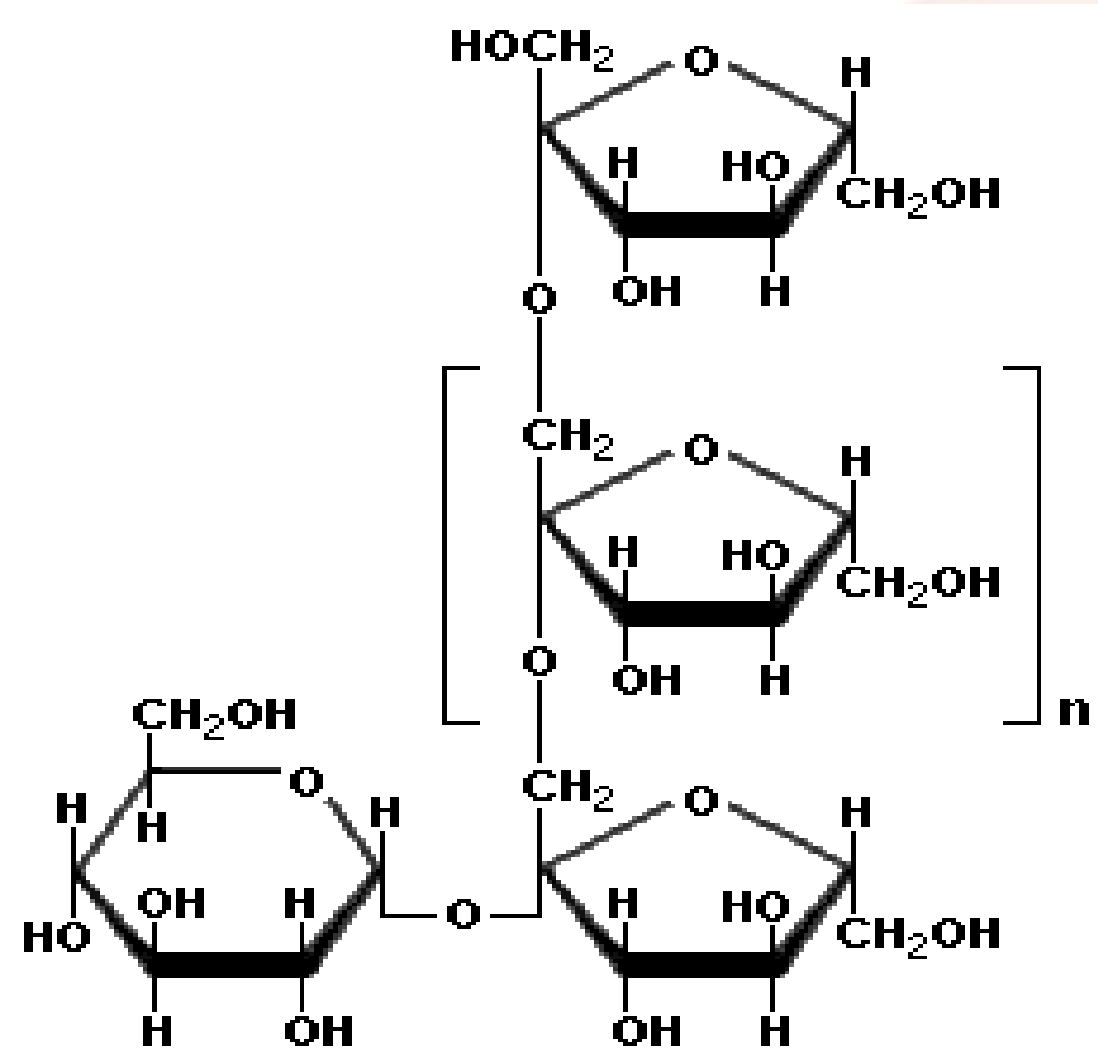




- Inulin is a reserve polymer in plants of the ***Asrerceae*** family.
- Sources include onions, garlic, banana and **chicory** roots.
- Production started early 1990s in Belgium and the Netherlands.







- A linear chain of fructose residues linked by  $\beta$ -(2-1) bonds and terminated by a glucose unit.
- Resist digestion => unabsorbed upper GIT  
- 2 Kcal/g

Inulin n=apprm 35

- Native / medium chain length as present in chicory has DP from 3 to 60 monosaccharide units with an average of about 10.

- In dairy and bakery products, beverages, low-fat spreads, ice cream and confectionary products
  - Physico-chemical properties are linked to DP.
    - Short chain fraction (oligofructose) more soluble & sweeter.
  - Acts as a prebiotic - is selectively fermented by beneficial flora, stimulates their growth, and reinforces its action against putrefactive microorganisms.
  - Inulin is well tolerated at doses lower than 20g/day, might cause flatulence at higher doses.

# *CASE STUDY*

**Applicability and suitability of different sweeteners and polysaccharides in chocolate manufacture**



- Given that all sucrose needs to be replaced, sugar-free products are most challenging to develop.
- Alternative sweeteners are successful if they match closely the taste quality of sucrose.
- Thus, they should have a clean taste, with a quick onset and minimum persistence.



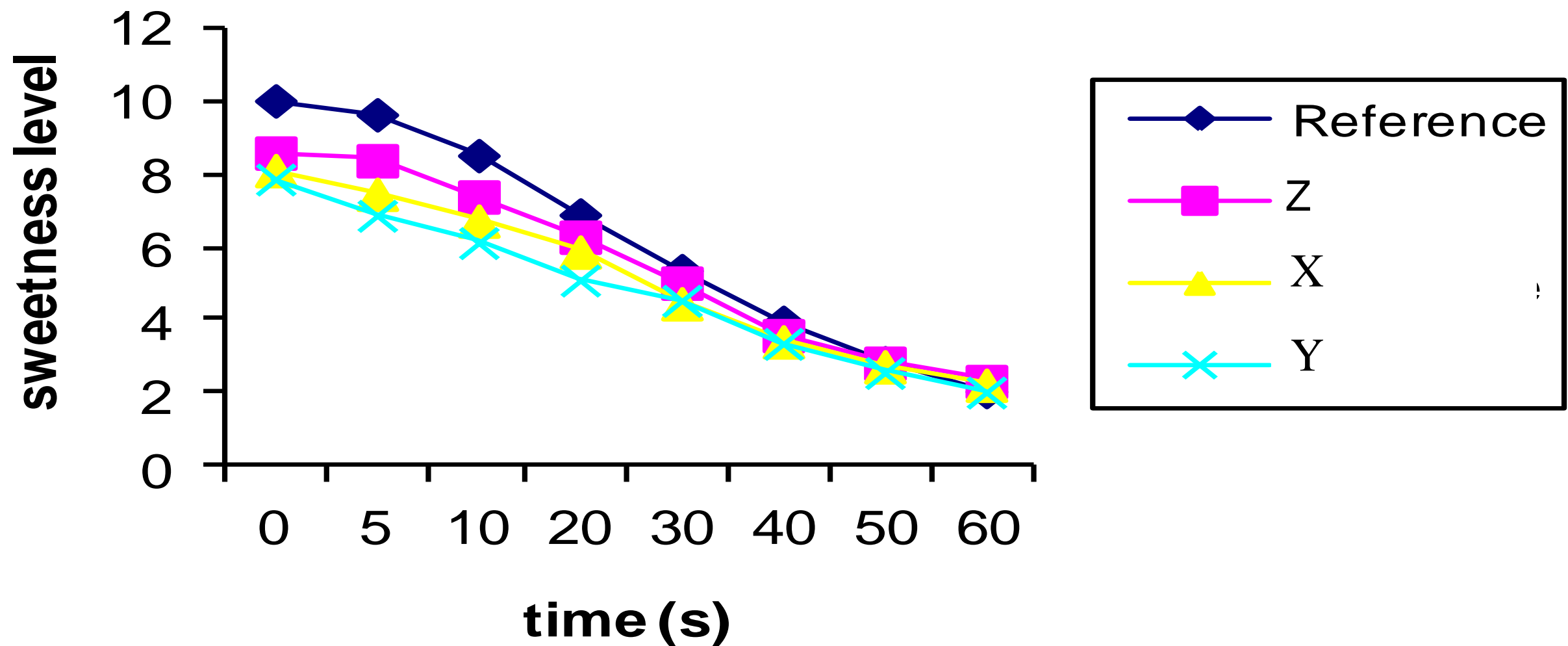
# Case study



## PRODUCTION OF A SUGAR-FREE CHOCOLATE WITH A NATURAL SWEETNESS

### WHAT ARE THE OPTIONS?

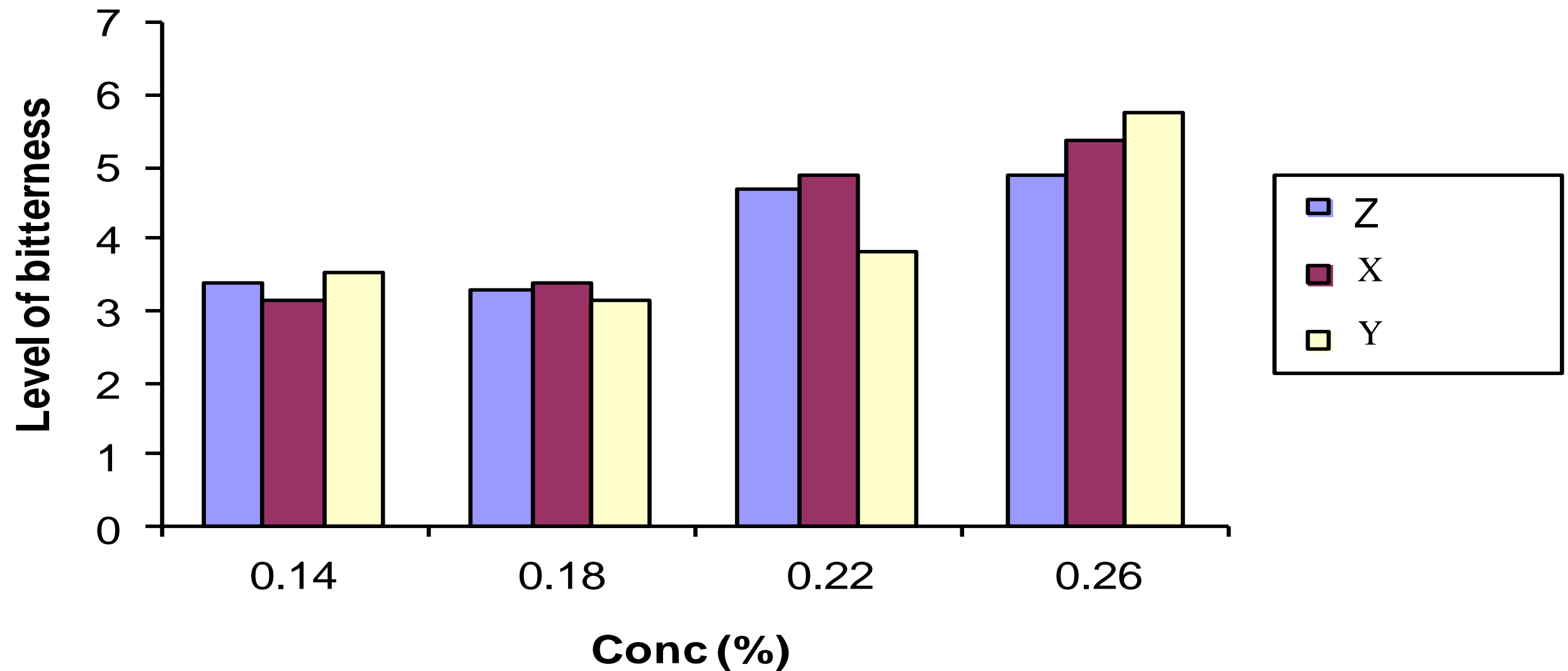
## Sweetness profile of stevia sweeteners



[0.14%w/w    0.18%w/w    0.22%w/w    0.26%w/w ]



## ■ Bitterness Levels



**Reference (0.006g/l quinine) = 2**

## Ingredient (%)

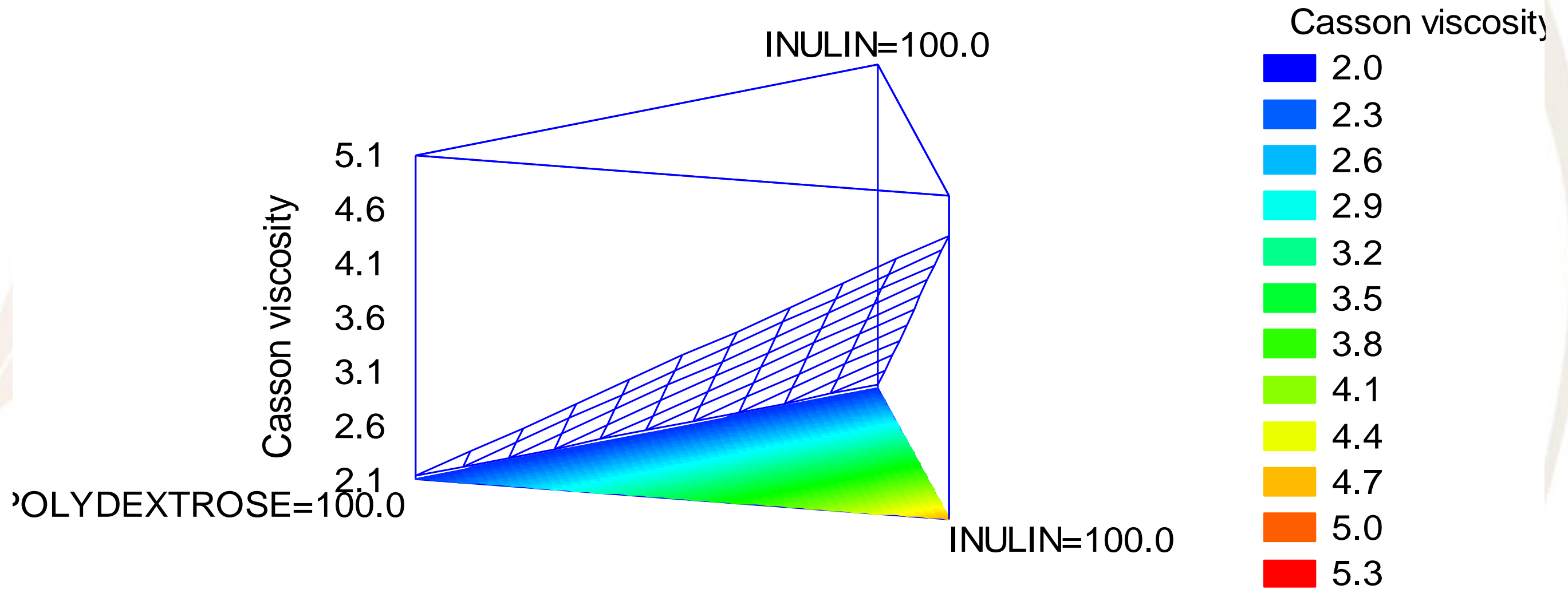
Treatment

CL	CB	Suc	Stevia	Lec	PD	IN
40	11.60	48	<->	0.4	*	*

CL = Cocoa Liquor    CB = Cocoa Butter    Suc = Sucrose    Lec = Lecithin

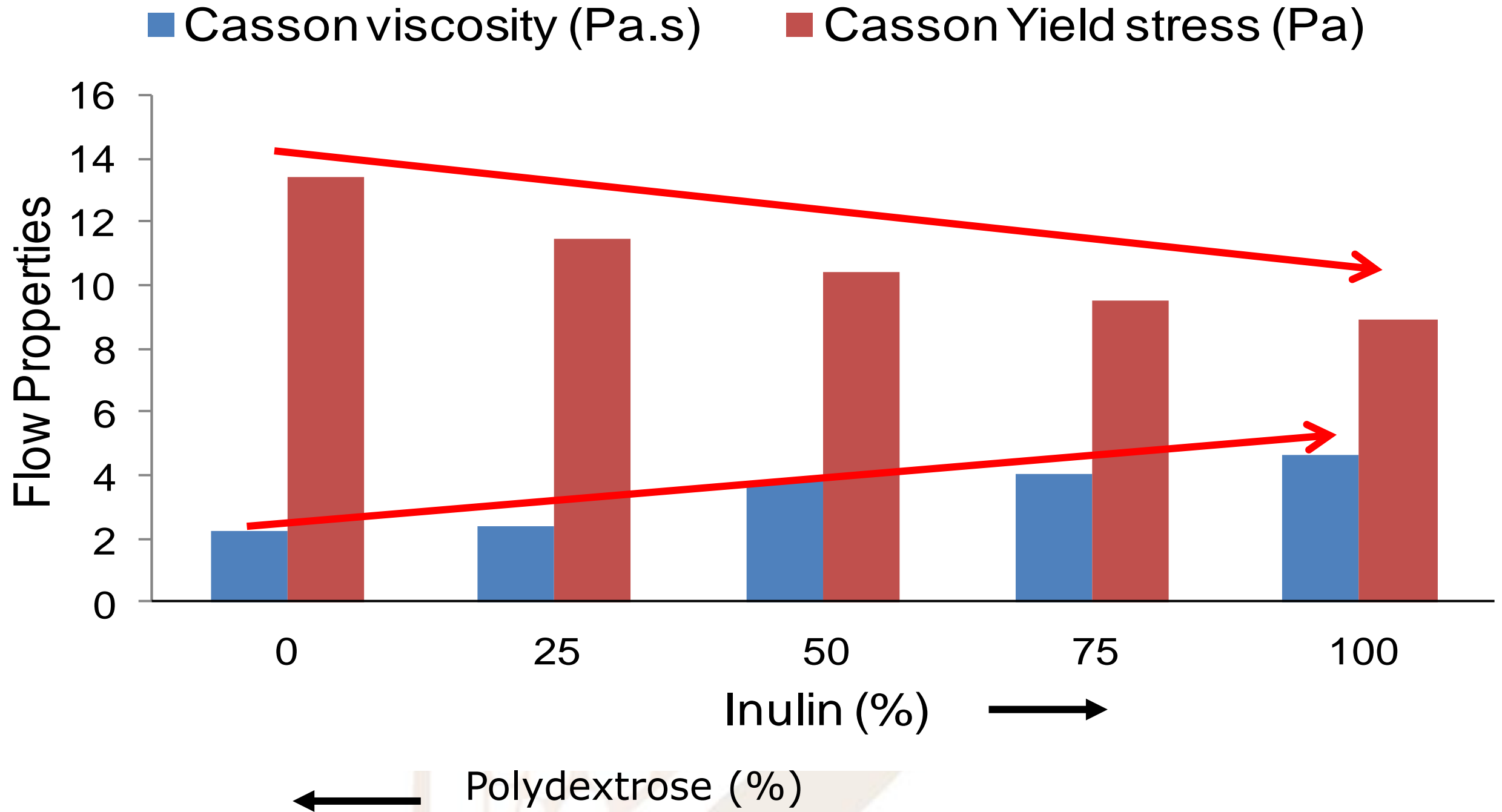
Polydextrose (%)	100	75	50	25	0
Inulin (%)	0	25	50	75	100

Response Surface Plots





# Results (rheological properties)



Knowledge of the compositional effects can help determine optimal combinations that will result in similar physico-chemical characteristics as the traditional chocolate



# Conclusions



- *Development of high-quality sugar-free chocolate requires the use of the most appropriate ingredients that could completely replace sugar without negatively affecting the rheological, physical and organoleptic properties.*
- *Sugar is not only added to promote sweetness in chocolates, but exerts many functional properties that make it useful as a bulking agent, texture modifier, mouth-feel modifier, flavour enhancer and preservative.*
- *Sucrose substitution by high-intensity sweeteners such as aspartame, sucralose, stevia, ..., in conjunction with bulking agents polydextrose, maltodextrin, inulin has great potential for the successful manufacture of sugar-free chocolate products with the appropriate desirable quality*
  - *appearance, texture, taste and flavour, very similar to that of their sugar counterparts.*



# *Thank You*

