Understanding the impact of repeated consumption using temporal sequential profiling

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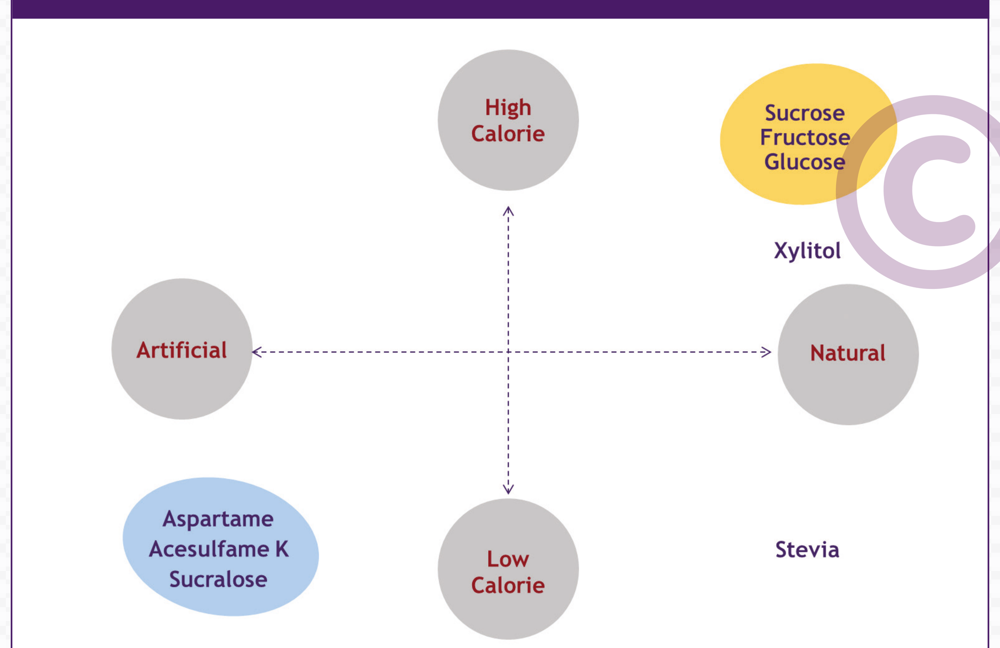
Introduction

Obesity and diabetes have become global health problems. This has led food and beverage manufacturers to investigate ingredient alternatives that reduce the calorific content of products, whilst having minimal impact on sensory characteristics.

Consumers are also demanding natural and healthy sweetening alternatives, and though there are a range of natural sugars available, these are highly calorific (Fig 1). High intensity sweeteners, which offer a low calorie alternative to sugar, have been in use for many years; however, the majority of these are artificial and linked to other health concerns, which limit consumer acceptance.

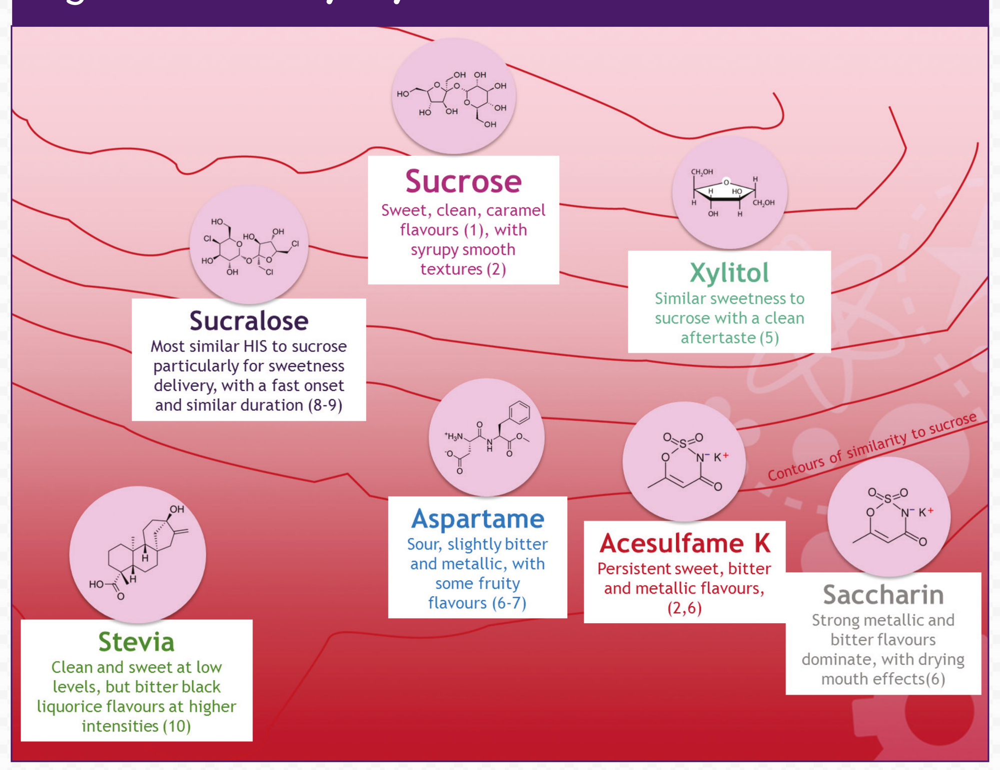
Figure 1 **Sweetening agents**



Currently, two natural options offer fewer calories than sugar: Xylitol has 30% fewer calories than sugar, and Stevia is a promising very low calorie alternative [1-2].

The sensory characteristics of sweeteners have been widely studied, with some sweetening agents more sensorially similar to sucrose, the ideal sweetening agent, whilst others including Stevia, are further away (Fig 2). However, all previous research investigating these characteristics has been conducted using descriptive analysis and single sip methods, which are different to consumers' typical consumption of larger volumes of sweetened products.

Figure 2 **Sensory 'lay of the land'**



Objectives

This study investigated the effect higher volumes and repeated consumption have on the sensory profile of a range of sweetening agents and sugar, and to determine the ideal high intensity sweetener to replace sucrose.

Method

Three sugars and five sweeteners all of which are commonly used in a wide range of food and drink products [3-8] were selected for this study (Table 3).

Table 3 **Selected sugar and sweetener solutions**

Sugar	Concentration (%)	Uses
Sucrose	2.0	Universal sweetening agent - sugar used in jams, sauces, drinks and sweets
Fructose	1.3	Originating from fruit, veg & honey, used in soft-drinks and in many foods as High Fructose Corn Syrup
Glucose	2.9	Used in sweets, condiments and beverages

Sweetener	Concentration (%)	Uses
Xylitol	2.50	Because of "tooth-friendly" health benefits, bulk sweetener used in toothpastes and dental care
Acesulfame K	0.01	Used in baking, carbonated drinks, protein shakes, chewable medicines
Sucralose	0.003	Table-top sweetener, used in sweets, cereal bars, soft drinks
Aspartame	0.01	Used in soft drinks, breath mints, cereals, frozen desserts, gelatine desserts, juices, medications
Stevia	0.01	Natural sweetener originating from plant leaves, used in more and more products including yogurts & soft drinks

Equi-sweet solutions of all sweetening agents were developed and refined by the MMR UK sensory panel, ahead of sequential profiling which was adapted and used for this study to assess the effect of repeated consumption [9].

The sequential profiling method involved panelists drinking 8 x 15ml of a sweetened solution and rating attributes immediately after consumption, then twice more after 45 seconds and 90 seconds for after-effects. No palate cleansing was conducted between each 15ml drink and all panelists consumed 120ml of each sweetened solution. The attributes assessed in this study were selected from literature and refined by the MMR sensory panel, and included nine flavor and mouthfeel attributes (Table 4).

Table 4 **Defined sensory attributes**

Sweet (F)	Icing Sugar (F)
Bitter (F)	Chalky (Mf)
Metallic (F)	Drying (Mf)
Salty (F)	Cooling (Mf)
Liquorice (F)	

Findings

Figure 5 shows the sensory space of the sugars and sweeteners with each of the sweetening agents mapped at two consumption points: after the initial 15ml drink and after the full 120ml volume.

Figure 5 **PCA map showing differentiating attributes**

Sucrose does not change significantly over repeat consumption, whereas Fructose becomes sweeter and more drying. Glucose changes the most out of the sugars, developing more icing sugar and chalkiness.

Of the sweeteners, Xylitol, Acesulfame K and Sucralose do not change significantly overall during repeat consumption, whilst Aspartame becomes significantly more metallic and Stevia increases in both bitter and metallic notes.

Comparing sequential profiles directly helps to determine the most suitable sweetener to replace Sucrose. Figure 6a shows the sequential profile for Sucrose with very few off-flavours, although drying builds up very slightly.

A high intensity sweetener which provides a similar clean taste, with minimal off-notes is Acesulfame K (Fig. 6b). Apart from some very slight chalkiness, Acesulfame K has the same attributes as Sucrose and builds up slightly in drying. However, it also builds up in bitterness over repeat consumption.

Alternatively, Sucralose (Fig. 6c) offers a profile which doesn't change over repeat consumption, with no attributes significantly increasing over the 120ml consumption. However, it does have off flavours with distinct metallic, bitter and slight liquorice notes.

The sequential profile of Stevia (Fig. 6d) is also different to sucrose, with a stronger consistent liquorice flavour, and metallic and bitter notes which increase significantly over the 120ml consumption volume.

Fig. 6 **Sequential profiles of Sucrose, Acesulfame K, Sucralose and Stevia**

Conclusion

This study found repeat consumption influences the sensory characteristics of sugars and sweeteners, but the extent of change depends on the sweetening agent.

Repeat consumption profiling has highlighted a range of attributes, including bitter and metallic, which increase in some sweetening agents as additional volumes are consumed. This further emphasises the role of repeat consumption methods, which are more representative of consumer product use than typical sip tests, and which should be part of tests performed on sweetened products during development work. Further assessments into the repeat consumption of high intensity sweeteners at higher concentrations and in complex products would further help to understand the off-notes found in this study, and determine whether any synergistic effects may occur.

Selecting the ideal replacement for Sucrose is not a simple task. Whilst the cleanest taste is offered by Acesulfame K, a build up in bitterness means this sweetener worsens over repeat consumption. Sucralose elicits more off-notes throughout consumption and these don't build up or worsen, therefore effective masking could make this option suitable. The natural sweetener Stevia is currently embraced by many food manufacturers as a viable sweetening option, but repeat consumption as conducted in this study has highlighted that masking and reducing the build-up of multiple off-notes may be necessary to replace Sucrose.

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