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Confectionery Technology and the Pros and Cons of Using Non-sucrose Sweeteners

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ABSTRACT

One use for alternative sweeteners is to replace the more conventional sugars in existing products. Sucrose is the basic ingredient for traditional sugar confectionery, and the whole industry has been built around its physical and chemical properties. These combine with those of the other sugars used, particularly glucose syrups and invert sugar, to provide the essential features of sucrose-based confectionery. They would have to be matched by any other sweetener which was used to replace them. Consideration will be given to the properties of sucrose and glucose syrups, and they will be compared with those of some of the alternative sweeteners. The implications that any differences in properties have on the application of the new sweeteners in confectionery production will then be discussed.

INTRODUCTION

The availability of a range of new sweeteners presents the confectionery industry with the opportunity either to replace conventional sugars in existing products or to develop a new range of products.

The alternative sweeteners which are considered here are limited to those currently allowed for use in foods in the UK. They can be divided into two groups: bulk sweeteners, which are similar in sweetness to sucrose, and intense sweeteners, with a sweetness many times greater than

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that of sucrose. In traditional confectionery products, sucrose imparts both sweetness and bulk. Therefore, bulk sweeteners are of most interest as a replacement, although intense sweeteners can also be used in combination with bulking agents such as polydextrose.

Sucrose is the basic ingredient for traditional sugar confectionery and the industry has evolved around its physical and chemical properties. These properties give sucrose-based confectionery their essential features and they would need to be matched by any replacement material.

USE OF SUCROSE IN TRADITIONAL CONFECTIONERY PRODUCTS

Traditional confectionery products have a high ratio of sugars to water; their solids contents are sufficiently high to inhibit microbiological activity. Normally, any syrup phase in a confectionery product is above 76 % solids, and at this solids level the products would have a shelf-life of up to 1 year. Sucrose forms a 66 % solution at ambient temperature (20 °C) but its solubility increases with temperature; at 85 °C it is 80 % soluble. Dissolving sugar in water raises the boiling point. For example, a 90 % sucrose solution boils at 123 °C and a 97 % solution at 150 °C. It is important to note that in the manufacture of confectionery the boiling point of a sweet is used as a measure of its solids content. The amount of

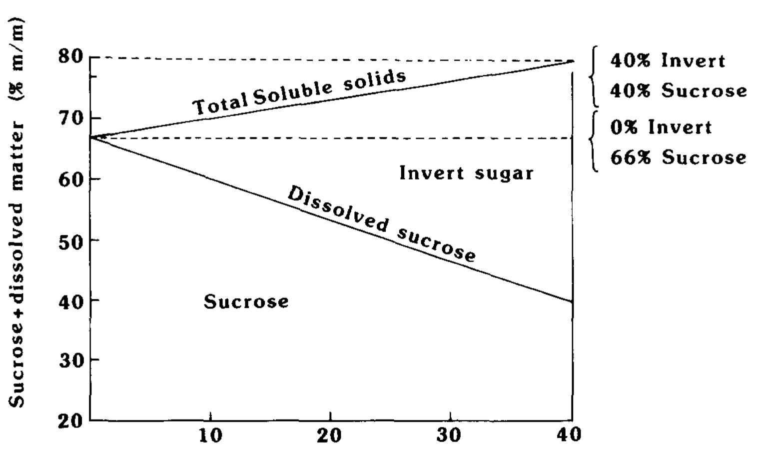

Fig. 1. Effect of glucose syrup and/or invert sugar on the solubility of sucrose.

moisture which remains in the sweet controls its hardness, stability and shelf-life.

At 20 °C, sucrose will only form a 66 % solution, but as can be seen in Fig. 1 the effect of the presence of other sugars is to modify the solubility of sucrose. Glucose syrup and invert sugar, which are the other sugars used in traditional confectionery, both lower the amount of sucrose which remains in solution whilst increasing the total amount of sugars (sucrose and glucose syrup solids) in solution. This means that syrups can be produced which are greater in solids than the 76 % necessary to ensure microbiological stability. It also means that the presence of another sugar can be used to prevent or control the crystallization of sucrose. Control and prevention of sucrose crystallization is helped by the ease with which supersaturated solutions of sucrose can be formed. Figure 2 shows the zones of saturation for sucrose and how these vary with solids content and temperature. Also shown are the degrees of saturation, defined as:

$$\frac{\text{Weight of sugar in a given weight of water}}{\text{Weight of sugar in the same weight of water in a saturated solution}}$$

Four zones of saturation can be recognised although the boundaries are indistinct:

(1) saturated, 1 or less. Crystals do not form or grow;
(2) metastable zone, 1–1·25 saturation. Crystals will grow but only if present in the solution;
(3) intermediate zone, 1·25–1·4 saturation. Crystals will grow and new crystals will form in the presence of these crystals;
(4) labile zone, 1·4 and over saturation. Crystals form spontaneously without other crystals being present.

The effects of this are two-fold: (i) the sucrose molecule is large and relatively complex and needs to orientate itself before it can nucleate; (ii) if the amount of sucrose which can be dissolved at a particular high temperature is comparable with the amount present in a solution boiling at the same temperature, the degree of supersaturation is low.

These factors all combine to allow the formation of supersaturated solutions of sugars at high temperatures. If these are cooled rapidly they form a glass, but if they are cooled slowly and are agitated they crystallize. Two basic confectionery products result: a high-boiled sweet (glass) and a fondant (crystal in a syrup phase), respectively. In a fondant, to obtain an acceptable texture, a precise balance is required between crystal size,

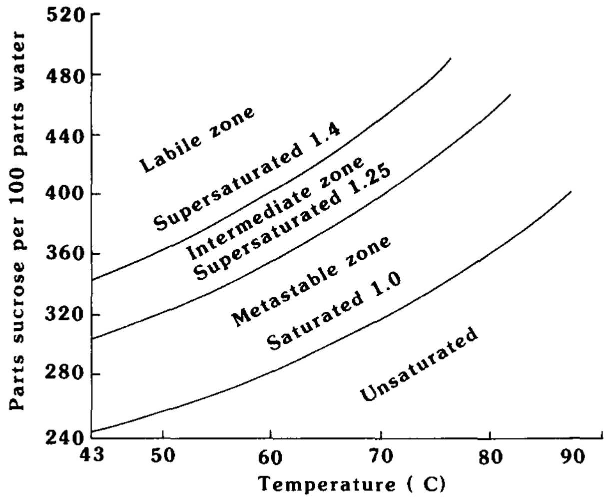

Fig. 2. Zones of saturation for sucrose.

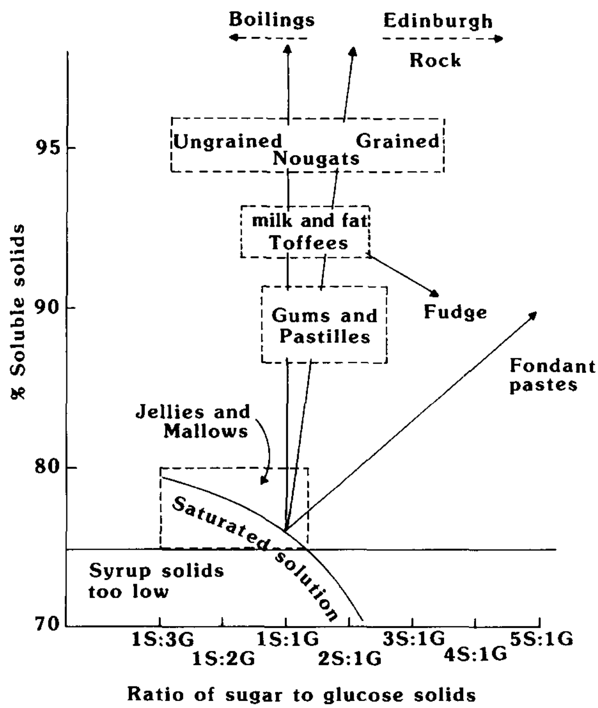

Fig. 3. Confectionery compositions.

crystal shape and the relative quantities of syrup to crystal phases. This balance depends on the solubility of sucrose, its crystal morphology, its viscosity, the moisture content and the quantity of glucose syrup present. Here the glucose syrup controls the amount of crystallization which occurs. In a boiled sweet a higher proportion of glucose syrup and a lower moisture content is used. In this case, the glucose syrup is used to prevent crystallization.

Other confectionery products also rely on the balance of sucrose to glucose syrup, the properties of sucrose and moisture content to provide their stability and texture, although this is influenced by the presence of other ingredients, e.g. fats, proteins and gelling agents. Figure 3 shows the sucrose and glucose syrup compositions and moisture contents of a range of confectionery products, and illustrates the versatility that sucrose allows in their formulation.

COMPARISON OF THE PROPERTIES OF SUCROSE AND GLUCOSE SYRUP WITH THOSE OF NON-SUCROSE SWEETENERS

By comparing the properties of the bulk sweeteners with those of sucrose and glucose syrup, it is possible to form some conclusion as to their probable performance in confectionery products. Table 1 presents some of the more important properties of the alternative sweeteners together with those of sucrose and glucose syrup.

SOLUBILITY

Isomalt and mannitol are of low solubility and this limits the amount which could be used in confectionery. Sorbitol and xylitol are of sufficiently high solubility to be used in greater amounts. Hydrogenated glucose syrup (Lycasin), which is non-crystallizing and of high viscosity, would inhibit the crystallization of other sugars, thus making it suitable as a replacement for glucose syrup in conventional confectionery products.

SWEETNESS

Only xylitol has a similar sweetness to that of sucrose. The remaining bulk sweeteners are all less sweet. The lack of sweetness could be overcome by

TABLE 1
Comparison of Alternative Sweeteners with Sucrose and Glucose Syrup

Sweetener	*Relative sweetness*	*Solubility (%)*	*Molecular weight*	*Boiling point of 75% solution (°C)*
Conventional sugars				
Sucrose	1·0	66	342	107
Glucose syrup 42DE	0·3	Supplied as a syrup (82% solids)	340	106
Bulk sweeteners				
Hydrogenated glucose syrup/ Lycasin	0·75	Syrup (75% solids)	340+	Not known
Isomalt	0·5	28	368	Not known
Sorbitol	0·5	75	182	111
Xylitol	1·0	63	152	112
Mannitol	0·6	18	182	Not known
Intense sweeteners				
Saccharin (Na)	300	45	205	N/A
Acesulfame-K	130	31	201	N/A
Aspartame	200	38	294	N/A
Bulking agent				
Polydextrose	—	Syrup (70% solids)	~1 600	Not known

incorporation of an intense sweetener. The use of aspartame for this purpose, however, is limited by its instability at the high heat/low pH conditions found in many confectionery products, and saccharin has a bitter aftertaste. Lack of sweetness could be used to advantage in allowing greater flavour and for savoury products.

MOLECULAR WEIGHT

Table 1 shows that there are differences between the molecular weights of the various sweeteners and that of sucrose. Apart from isomalt, which has a higher molecular weight, and Lycasin, which has a similar molecular weight, the molecular weights of the bulk sweeteners are all lower than that of sucrose. The significance of these differences to the confectioner is: (i) at the same solids content a syrup of a lower molecular weight sweetener such as xylitol will have a lower relative vapour pressure. The product will thus adsorb water more rapidly from the atmosphere and this will require sophisticated packaging; (ii) sweeteners with different molecular weights will have different boiling point elevations. It can be seen from the table that both sorbitol and xylitol, which are lower in molecular weight, require higher boiling temperatures to reach the same solids level. This will necessitate longer cooking times and more energy usage. Although no information is available on the boiling point elevations of Lycasin, isomalt or mannitol, these can be assumed to be in line with their molecular weights.

MAILLARD REACTION

None of the new sweeteners contains free aldehyde groups. This means that they cannot take part in the Maillard browning reaction. Therefore, a toffee made from them would lack colour and flavour.

WORK AT THE LEATHERHEAD FOOD RESEARCH ASSOCIATION

Work has been carried out at Leatherhead on the utilization of alternative sweeteners to sucrose in confectionery products. A summary of the results is shown in Table 2, which gives details of the effects of alternative sweeteners in various confectionery products. These results indicate that, using existing alternative sweeteners, it is not possible to reproduce, exactly, existing confectionery products. Some stable products can be made, but they are different from existing products, and to the majority of consumers they will be regarded as inferior; moreover, they will be more expensive. In addition, processing is more complicated, and will probably need different plants. Elevated boiling temperatures require more energy usage, and increased hygroscopicity requires improved packaging. However, if claims can be made for these products on health grounds as diabetic products, there will be a market for them.

This brief summary is sufficient to indicate that no one of the alternative sweeteners has all the properties of sucrose, although in some individual aspects there are similarities. It is unlikely, therefore, that any one sweetener could be used to replace sucrose. A combination of more

TABLE 2
Summary of Work on Alternative Sweeteners

	Sorbitol/mannitol	*Xylitol*	*Hydrogenated glucose syrup (Lycasin)*	*Polydextrose*
Chocolate	Used for diabetic chocolate; lacks sweetness but can be boosted with other sweeteners; noticeable cooling effect in chocolate; hygroscopic—care must be used in manufacture to ensure no moisture ingress; must be kept below 43 °C	Same sweetness as sucrose Maximum temperature 54 °C	Supplied as a syrup; cannot be used in chocolate	Acceptable but has no sweetness Requires an intense sweetener
Boiled sweets	Will produce a transparent, apparently glassy product, but which is in fact crystalline; manufactured by seeding a cooled 97% solids syrup with finely powdered sorbitol; best results achieved with a mixture of sorbitol and mannitol; requires high boiling temperature	Does not form a glass and, unlike sorbitol, will not produce a transparent crystalline glassy product on seeding	Forms a glass which is tough and does not dissolve readily; poor flavour carrier	Forms a glass but is tough and does not dissolve readily; poor flavour carrier; requires high boiling temperature; very high viscosity boiling

Fondant	Produces a crystal phase when used by itself, but imparts a very waxy texture	Produces a good crystal phase Best results achieved using either sorbitol or fructose/thin boiling starch as the syrup phase	No crystal phase; might be used to provide a syrup phase with xylitol as the crystal phase	Creams made with a mixture of polydextrose and dextrose monohydrate; texture not as plastic as sucrose-based fondants
Gelatine jelly	Will form a gel but texture is very short	Gelatine gel formed at 60 % total solids containing 6 % gelatine deposited in chocolate shells	Not investigated	
Agar	Did not form a gel at 78 % solids	Not investigated	Did not form a gel at 78 % solids	Not investigated
Pectin	Pectin jellies made with sorbitol tend to crystallise to form hard transparent products	Forms a gel if fructose is also present	Acceptable	Acceptable; some forms of polydextrose have a high buffering capacity and the amount of acid required for pH adjustments is unacceptably high
Toffee	Not investigated	Tends to crystallise; does not brown; can be used for fudge if fructose is added	Acceptable if fructose also present to promote Maillard reaction	Gives a satisfactory texture but added sweetener is required

than one might be more beneficial, but to achieve this will require a knowledge of how the properties of the sweeteners interact (information which the confectioner already has and uses for glucose syrup and sucrose). Such information is not available; suppliers only give the properties of their own sweeteners. Products containing combinations of sweeteners can only be made on a trial and error basis with no guidelines for their stability.

The real potential in regard to the new sweeteners, however, lies not in using them to replace sucrose in existing products but in utilizing those properties which are different from those of sucrose to produce new products.