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# Developments in the Properties and Applications of Lycasin® and Sorbitol

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## *ABSTRACT*

*Particular properties of Lycasin® and sorbitol may be exploited in the manufacture of a range of confectionery products. This presents the food technologist with the opportunity to move away from the limitations imposed by the carbohydrate components of conventional products. The different chemical properties of the polyhydric alcohols, when compared with 'equivalent' carbohydrates, will dictate different handling and storage of the raw materials, together with changes in manufacturing techniques and the storage conditions of the final product. The advantages of Lycasin® and sorbitol in the dental caries context will also be discussed.*

## INTRODUCTION

The general technology involved in the use of hydrogenated glucose syrups in food, and their properties, has been discussed previously (Zimmermann, 1978; Leroy, 1979). At about this time, the particular grade of Lycasin® 80/55 emerged as the most satisfactory grade of hydrogenated glucose syrup for a number of reasons, which are discussed below. In the 10-year period from 1968 until 1978, development of the syrups had been a joint venture with the Swedish company Lyckeby, who originally proposed hydrogenated glucose syrups in 1963. In 1978, Roquette took over the existing patents together with responsibility for the future development of Lycasin® products.

TABLE 1
The Specification of Hydrogenated Glucose Syrup Lycasin® 80/55

| | |
|---|---|
| Description | A hydrogenated glucose syrup which is clear and colourless with a sweet taste |
| Dry substance (Karl Fischer) | 74–76% w/w |
| Refractive index at 20°C | 1·4762–1·4815 |
| Reducing sugars | 0·2% max. |
| *Approximate percentage composition of dry substance* | |
| D-Sorbitol | 7 |
| Hydrogenated disaccharides | 52 |
| Hydrogenated tri- to heptasaccharides | 23 |
| Hydrogenated higher polysaccharides | 18 |
| Hydrogenated polysaccharides with a degree of polymerisation greater than 20 | 3 max. |
| pH (40% solids solution on w/w basis) | 5–7 |
| Arsenic | 1 ppm max. |
| Iron | 1 ppm max. |
| Lead | 1 ppm max. |
| Nickel | 1 ppm max. |
| Chloride | 50 ppm max. |
| Sulphate | 100 ppm max. |
| Heavy Metals | 10 ppm max. |
| Sulphated Ash | 0·1% max. |

There have been a number of studies made on what may be termed the initial Lycasin®, the most notable being Lycasin® 80/33 or Swedish Lycasin® (Karle and Buttner, 1971; Frostell *et al.*, 1974). Some studies compared Lycasin® 80/55 with Lycasin® 80/33 (Frostell, 1977; Birkhed and Frostell, 1978; Frostell and Birkhed, 1978; Imfeld and Muhlemann, 1978). The overall conclusion to be drawn from these studies was that Lycasin® 80/55 gave an improved performance in the prevention of dental caries over Lycasin® 80/33 even when different methods and techniques were used, both with animals and human subjects.

More recent studies have concentrated on Lycasin® 80/55 or compared the cariogenicity of what have become known as the bulk sweeteners—hydrogenated glucose syrups, sorbitol, mannitol and xylitol—usually using sucrose as a positive control (for example, Gehring, 1979; Gehring, 1981; Wursch and Kroellreutter, 1982). Imfeld and Duhamel (1980) examined whole foods made with Lycasin® 80/55. In each of these studies. Lycasin® 80/55 was found to be non-cariogenic.

As a result of this development, hydrogenated glucose syrup Lycasin® 80/55 is now produced by Roquette to stringent specifications which govern its non-cariogenic and technological properties. Since Lycasin® 80/55 is now effectively the only Lycasin® syrup available on the UK market, Lycasin will denote hydrogenated glucose syrup Lycasin® 80/55 throughout this paper. The specification for Lycasin is shown in Table 1.

The main line of research and development of Lycasin has naturally been concentrated upon its non-cariogenic properties. However, for Lycasin to be of practical use in the manufacture of confectionery, we have had to pay attention to other properties of this syrup, such as viscosity, anti-crystallising power, average molecular weight, hygroscopicity, sweetness, reactivity (principally the lack of reducing ability) and the compatibility of Lycasin with flavouring. Other important considerations will also include its performance on storage and stability and ease of handling at a range of temperatures.

## THE PROPERTIES OF LYCASIN IN RELATION TO ITS COMPOSITION

The above-mentioned properties can best be discussed after a consideration of the manufacturing process and a description of the carbohydrate residues present. Figure 1 shows that glucose, maltose, maltotriose and polysaccharides may be hydrogenated to sorbitol, maltitol, maltotriitol and hydrogenated polysaccharides, respectively. However, in order to achieve the desired properties in a hydrogenated glucose syrup, the starting glucose syrup must have a closely-defined carbohydrate spectrum. The carbohydrate spectrum of a glucose syrup may be considered to show polysaccharides of given concentrations depending on their degree of polymerisation (DP); glucose will therefore have a DP of 1, maltose will be DP2, maltotriose will be DP3 and so on. When we tested for the cariogenicity of the original forms of Lycasin it was discovered that, unless the concentration of the DP20+ fraction was kept below 3%, the hydrogenated glucose syrup could be fermented by bacteria present at the surface of the tooth, and such a syrup was therefore cariogenic. The compositional fact is reflected in Schedule 1, Part 2 of the *Sweeteners in Food Regulations, 1983* where the specification for hydrogenated glucose syrup does limit the DP20+ content to not more than 3%, calculated on a dry weight basis.

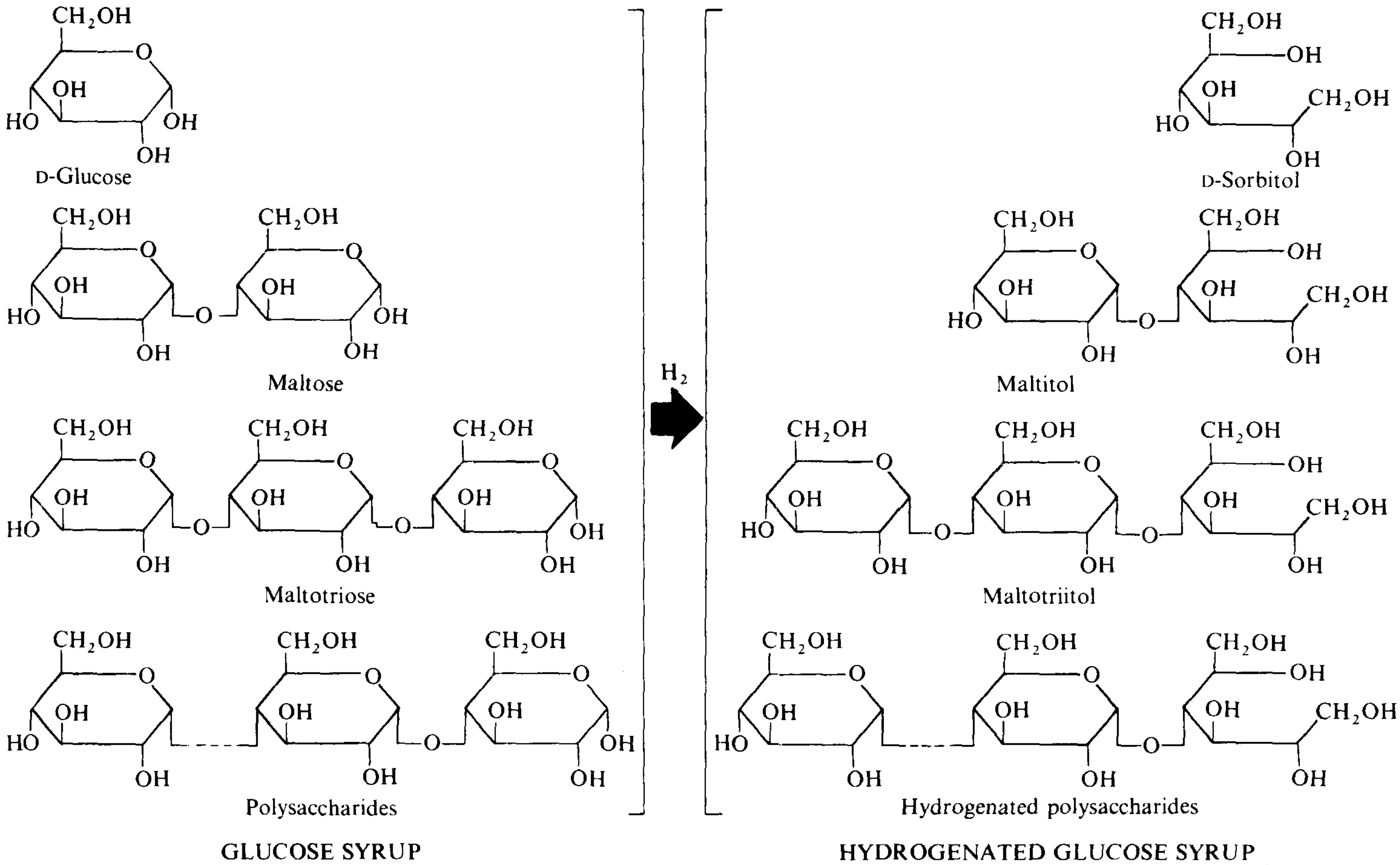

**Fig. 1.** The production of hydrogenated polysaccharides comprising a hydrogenated glucose syrup.

**TABLE 2**

A Comparison of the Sweetness of a Number of Carbohydrates and Polyols in 4% (w/v) Aqueous Solution at 20%

| | |
|---|---|
| Sucrose | 1 |
| Invert sugar | 1·1 |
| 37 DE Glucose syrup | 0·4 |
| 60 DE Glucose syrup | 0·6 |
| Dextrose monohydrate | 0·7 |
| Fructose | 1·3–1·7 |
| Meliose® 700 | 1 |
| Sorbitol | 0·7 |
| Mannitol | 0·5 |
| Lycasin® 80/33 | 0·4 |
| Lycasin® 80/55 | 0·75 |

The concentration of the other hydrogenated components of Lycasin was also determined for technological reasons; for example a concentration of approximately 52% maltitol ensures that Lycasin will have an adequate sweetness. For comparative purposes, Table 2 shows the perceived sweetness of a number of sweeteners; where sucrose is given a sweetness value of 1, Lycasin is approximately three quarters the sweetness of sucrose.

The presence of 23% hydrogenated trisaccharides to septasaccharides and 18% hydrogenated higher polysaccharides (DP3–DP7 and DP8+, respectively) ensures that Lycasin will have an appreciable viscosity. Again, for comparison, Fig. 2 gives the range of viscosities of solutions of various sweeteners at 70% dry substance and 25 °C. Under these conditions, Lycasin has the same viscosity as a 60 DE acid/enzyme glucose syrup. At 74% dry substance and 20 °C Lycasin has a viscosity of 2000 cPs. As a consequence of the hydrogenation process, Lycasin no longer contains free reducing sugars. This lack of reducing ability makes Lycasin very stable in comparison with glucose syrups. It is possible to heat Lycasin to 200 °C with no discolouration occurring either by caramelisation or Maillard reactions (when protein components of formulations are present). Thus, it is possible to make colourless, clear sweets at high temperatures without the usual regard given to the possible deterioration of the glucose syrups normally used in this application. Free sorbitol makes 7% of the dry weight of Lycasin. In addition, there is a further 35% of sorbitol present, bound to glucose or polysaccharide.

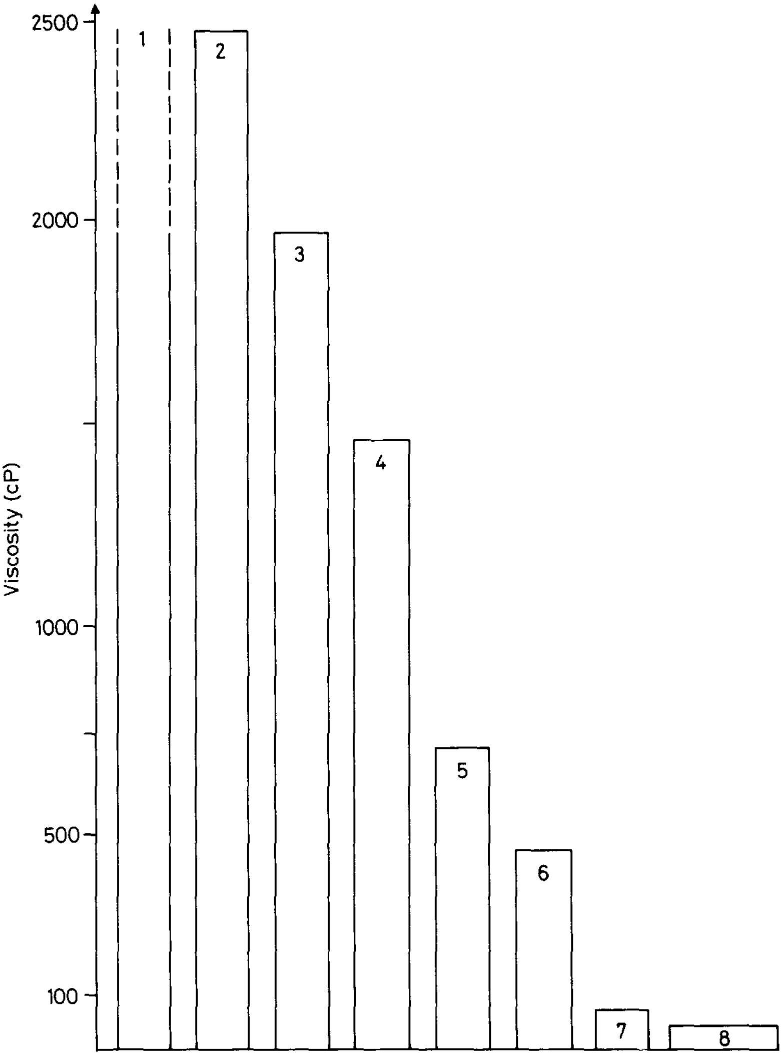

**Fig. 2.** A comparison of the viscosities of some carbohydrates and polyols at 70% (w/v) aqueous solution and 25 °C: 1, maltodextrins, Lycasin® 05/60 ($\eta > 15\,000$ cP); 2, 28 DE acid glucose syrup; 3, 38 DE acid glucose syrup, Lycasin® 80/33; 4, A/E 38 DE Roclys® glucose syrup; 5, E/E 47 DE 525 glucose syrup; 6, A/E 60 DE Flolys® glucose syrup, meliose—glucose syrup blends, Lycasin® 80/55; 7, E/E DE 4825 glucose syrup, sucrose, meliose, invert sugar, dextrose; 8, HFCS Meliose® 700, fructose, sorbitol.

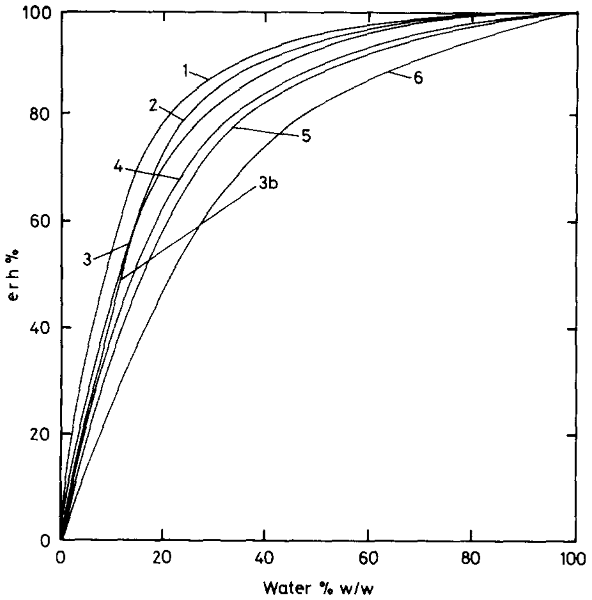

**Fig. 3.** A comparison of the humectancy of some carbohydrates and polyols at 20 °C: 1, 42 DE glucose; 2, 60 DE glucose Floyls®, Lycasin® 80/55; 3, sucrose; 3b, Meliose® 80/20C; 4, invert sugar, dextrose, fructose, Meliose® 700; 5, sorbitol, Neosorb® 70/70; 6, glycerol.

Sorbitol is a powerful humectant and therefore products made with Lycasin have a lower equilibrium relative humidity than that of standard confectionery made with sugar. Figure 3 illustrates the humectancy of Lycasin at 20 °C in comparison with other humectants and other components of carbohydrate confectionery, such as sucrose, invert sugar and a 42 DE glucose syrup.

As a result of the balance of the large and small molecules present in Lycasin, its average molecular weight may be evaluated at approximately 630. Figure 4 shows the influence of average molecular weight on the physical properties of solutions which need to be considered when developing formulations. It is possible, using this figure, to estimate any gross changes which would be expected when changing to Lycasin from a glucose syrup.

Finally, the spectrum of hydrogenated polysaccharides in Lycasin ensures that it cannot crystallise when the temperature is reduced or the solids content is raised. This property is particularly important in the

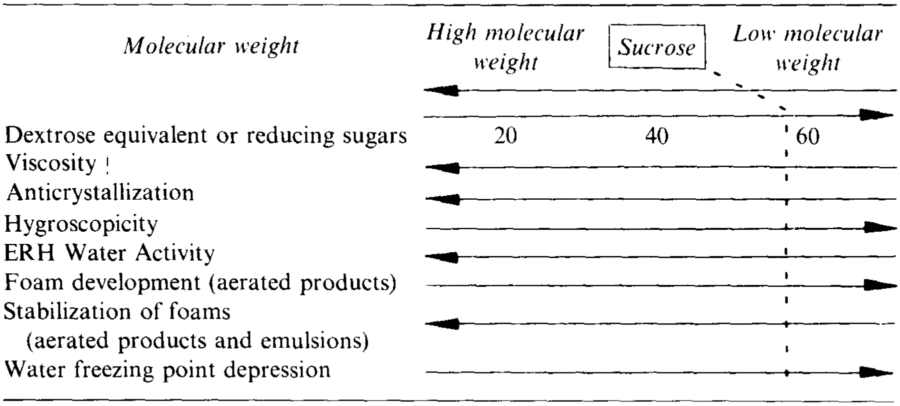

**Fig. 4.** Average molecular weight and its effect on some physical properties of solutions.

application of Lycasin in a 'doctor/sugar' role and also makes the production of hard boiled sweets particularly easy.

## STORAGE

As mentioned above, Lycasin will not crystallise and the limiting physical factor on storage will be its viscosity. An approximate viscosity of 18 000 cPs at 4 °C rapidly falls to 7600 cPs at 9 °C, to 2000 cPs at 20 °C and 1100 cPs at 30 °C. These values are all appreciably lower than the corresponding figures for a standard acid-converted 40 DE glucose syrup (79 % solids), permitting bulk storage of Lycasin at ambient temperatures. Given the higher solids content of Lycasin at 75 % solids (in comparison with liquid sucrose at approximately 65 % solids), in conjunction with its average molecular weight of 630, the microbiological stability of Lycasin on bulk storage is approximately equivalent to an acid-converted 42 DE glucose syrup at 80 % solids.

## DENTAL ASPECTS

Before describing the potential areas of use for Lycasin and sorbitol in essentially confectionery items, it is necessary briefly to describe what is meant by dental caries. Bacteria present in the mouth will metabolise carbohydrate and produce lactic acid which is excreted into the extracellular fluid. When these bacteria form a component of what is commonly known as the dental plaque, the lactic acid produced is in direct contact with, or at least in the micro-environment of, the tooth enamel. The mineral content of tooth enamel is calcium hydroxyapatite which, in common with other minerals, is subject to dissolution under certain conditions. In the dental situation it is commonly accepted that this process takes place at pH values below 5·7. The presence of lactic acid at the tooth surface will lower the pH sufficiently to allow demineralisation of the enamel to occur.

The demineralisation process may be seen as the formation of a white spot on the otherwise translucent tooth enamel. Recent studies have shown that this process is reversible in rats (Leach & Green, 1982; Leach *et al.*, 1983) and in human volunteers (Leach *et al.*, 1984). Remineralisation occurs when the pH of the tooth enamel micro-environment rises above 5·7. In Switzerland, the development of the Muhlemann test, where the pH of dental plaque is monitored *in vivo* using pH telemetry in human volunteers, has become the basis of legislation governing sugarless, non-cariogenic products (Imfeld, 1977). At Roquette a corresponding *in vitro* test has been developed where a sample of every batch of Lycasin made is incubated with the microorganisms and enzymes in pooled saliva samples. This test also provides a useful way of comparing different carbohydrates, hydrogenated glucose syrups and polyols. Figure 5 shows some of the results obtained. Under *in vivo* conditions the pH drop is very rapid, with pH values in the region of 4 being achieved within 30 s of a mouth rinse with a carbohydrate solution. The buffering and dilution effect of saliva will raise the pH of the dental plaque above 5·7, again in approximately 30 min. Both Lycasin and sorbitol do not cause this fall in pH below 5·7 and the products currently on sale in Switzerland containing Lycasin and sorbitol for the non-cariogenic market, naturally meet the requirements of the Swiss legislation mentioned above.

To date, the Ministry of Agriculture, Fisheries and Food (MAFF) has not produced proposals for testing for non-cariogenicity and it seems likely that a need would have to be demonstrated for non-cariogenic products before such legislation would be proposed. However, both MAFF and the Department of Health and Social Security have agreed the following form of words for the labelling of products made with Lycasin and/or sorbitol, which are designed to be non-cariogenic: 'the sweetener used in this product does not cause dental caries'. This does not infringe any existing or proposed labelling legislation relating to both food and medicines.

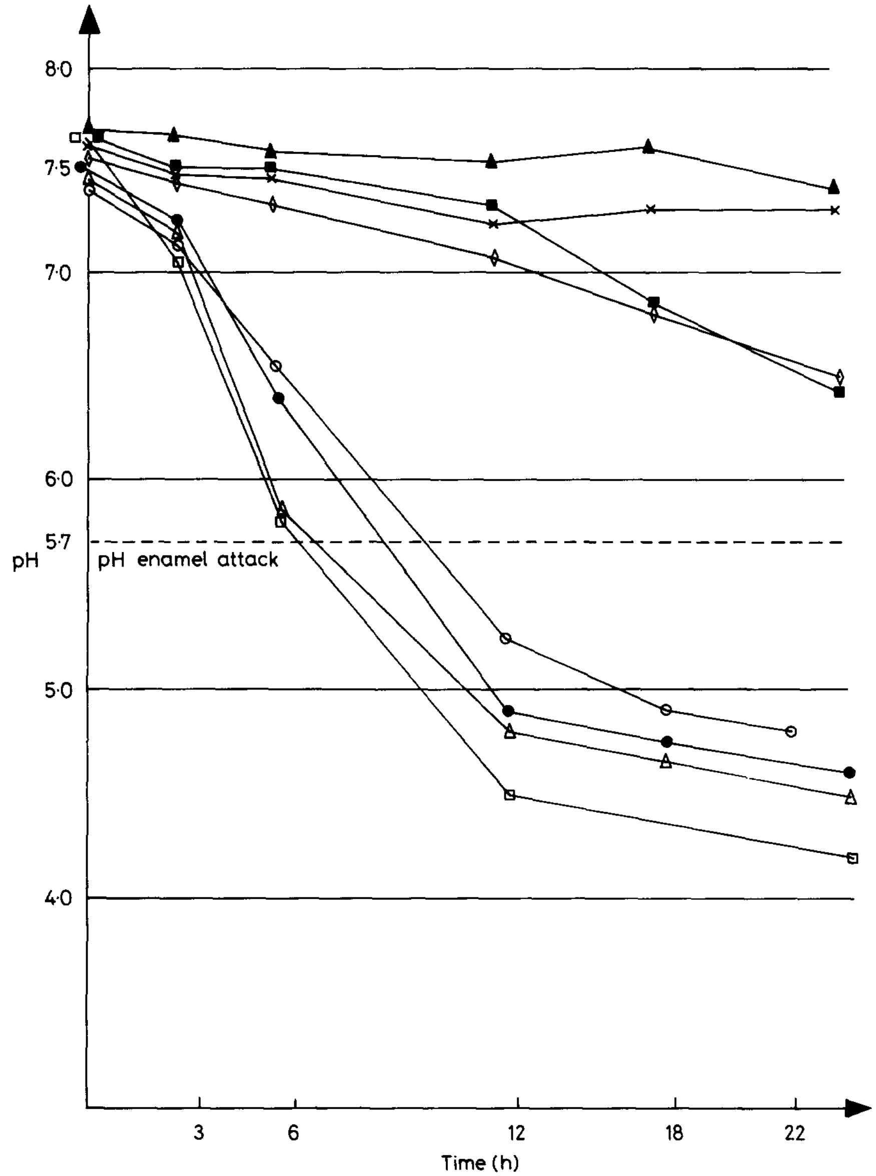

**Fig. 5.** An illustration of acid production by several fermentable carbohydrates using an *in vitro* test method. Polyols, including Lycasin®, are relatively non-fermentable: ▲, control; ×, mannitol; ◊, Lycasin® 80/55; ■, sorbitol; ○, lactose; ●, dextrose; △, glucose syrup; □, sucrose.

## DEVELOPMENTS IN CONFECTIONERY PRODUCTS

Classical carbohydrate-based confectionery technology is based on a crystallising component and an anti-crystalliser; these components usually being sucrose and a glucose syrup, respectively.

A convenient way to classify confectionery is to divide the products into four groups, depending on the proportions of the crystallising component and the anti-crystalliser present: crystallised products, e.g. hard coatings, tablets; partially crystallised products, e.g. chewy candies, chewing gums, fondants, soft coatings, fudges; vitreous products, e.g. hard boiled sweets, toffees; non-crystallised soft products, e.g. gums, jellies. In the same way, this classification may be applied to non-carbohydrate based confectionery, where sorbitol takes the place of sucrose as the crystallising component and Lycasin is the anti-crystalliser.

### Crystallised products

Hard panning is the process by which prepared centres are coated in crystalline material; the crystallising process is prompted by the evaporation of the coating syrup. Generally, layers of crystalline material are built up by numerous additions of the syrup, with the purposes of hard panning to improve the appearance of the confectionery and to prevent the core from exchanging moisture with the atmosphere. As is well known, the technique is as much an art as a technique, but there are several points which can be made when comparing sucrose and sorbitol used as an alternative in hard panning.

The solubility in aqueous solution of sorbitol and sucrose as a function of temperature is shown in Fig. 6. They have different solubility profiles, for example a 300 % solution of sorbitol is obtained at 35 °C, whereas the same solute concentration is achieved with sucrose at 65 °C. This difference is very important when the viscosity of the panning syrup is considered. To promote a quick and even coating of the cores, the viscosity of the syrup should be low; a useful figure is 200 cPs. This figure will obviously vary according to the size and shape of the cores. Figure 7 compares the viscosity of saturated solutions of sorbitol and sucrose, also as a function of temperature, and demonstrates that there is a minimum coating temperature for sucrose and, conversely, a maximum coating temperature when panning with sorbitol.

Using the general conditions shown in Table 3, it is possible to obtain a

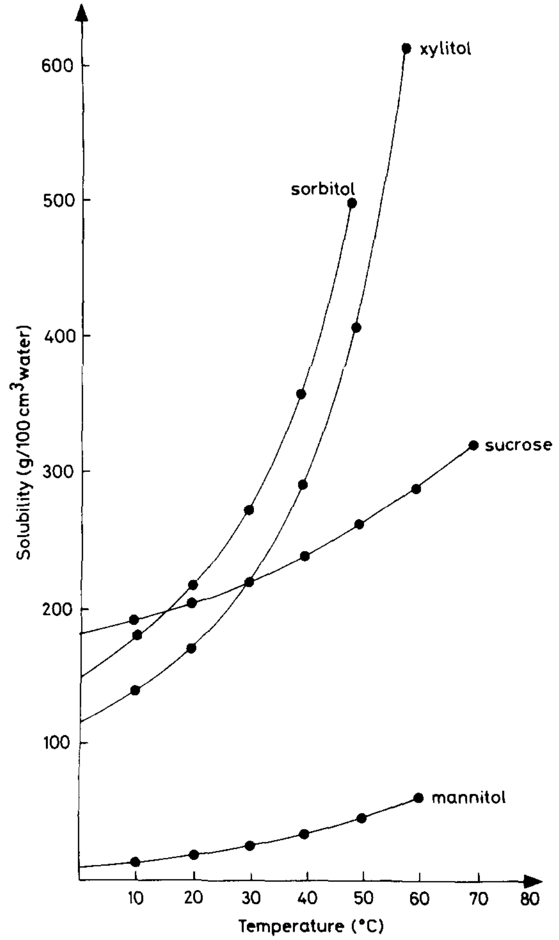

**Fig. 6.** The aqueous solubility of sorbitol, xylitol, mannitol and sucrose as a function of temperature.

TABLE 3
An Indication of the Conditions Necessary to Achieve Hard Panning with either Sorbitol or Sucrose

| | *Sucrose* | *Sorbitol* |
|---|---|---|
| Concentration of the syrup, % | 75-80 | 65-70 |
| Temperature of the bed of cores, °C | 55 | 30 |
| Temperature of the drying air, °C | 60-70 | 35-45 |

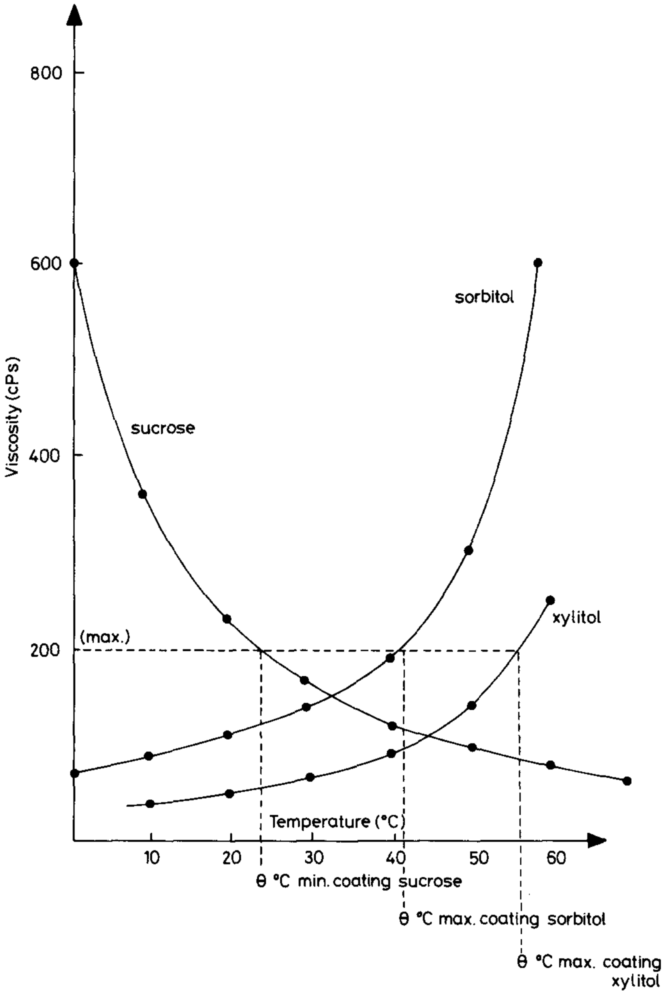

**Fig. 7.** The viscosity of saturated solutions of sorbitol, xylitol and sucrose as a function of temperature.

good hard coat of sorbitol which is not hygroscopic; the water activity value being approximately 0·74.

The trend in confectionery tablets seems to be towards production of smooth, hard and dense tablets. The crystalline structure of sorbitol permits the achievement of these properties very easily. We have developed a grade of sorbitol (Neosorb® powder DC)* especially suited

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* Lycasin and Neosorb are registered trade marks of Roquette Frères, F-59022, Lille Cedex, France.

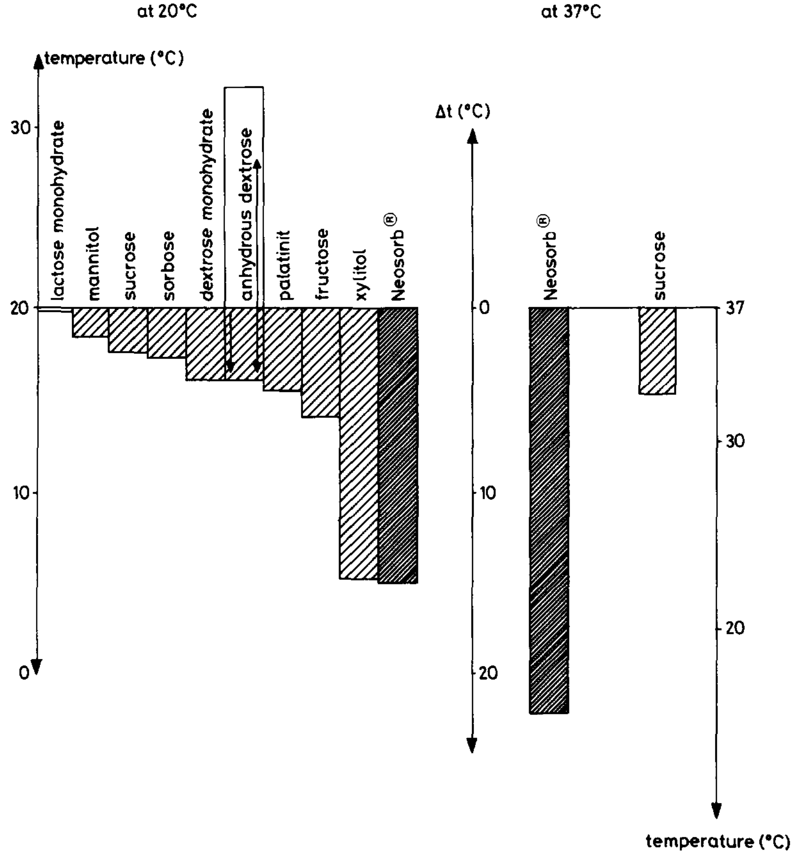

**Fig. 8.** A comparison of the endothermic reactions occurring when a quantity (150 g) of each substance is dissolved in water (50 ml), initially at either 20 or 37 °C.

for this application. One should bear in mind the flowability of the sorbitol powder to allow complete filling of the dies and also feeding of the powder through the hopper, etc. Magnesium stearate is usually used as the lubricant in direct compression tablets, and to achieve the above characteristics we have found a level of between 0·4 and 0·5 % to give the best results.

At this stage, it is appropriate to mention the so-called mouth cooling effect of sorbitol. Figure 8 compares several bulk sweeteners at 20 °C, and sorbitol with sucrose at 37 °C. The values shown were obtained when 150 g of each product were dissolved in 50 ml of water at the temperatures shown. The drop in temperature shown in this way takes into account the solubility of each of the products tested. Xylitol has the greatest negative heat of solution at $-34{\cdot}8\,\text{cal g}^{-1}$, but with a solubility of 256 g per 100 ml at 37 °C, the cooling effect is less than that given by sorbitol. The negative heat of solution of sorbitol is $-28\,\text{cal g}^{-1}$, owing to its higher solubility of 334 g per 100 ml at the same temperature. When mannitol is considered, with a solubility of approximately one tenth that of sorbitol at the same temperature, although the negative heat of solution for mannitol is $-30\,\text{cal g}^{-1}$, the cooling effect is very small.

## Partially crystallised products

These products depend on an equilibrium between the crystallising component (sorbitol) and the anti-crystalliser (Lycasin).

Lycasin serves a dual purpose in such products. The amount used gives the product both its plasticity and softness and also, as may be seen from the preceding sections, the composition of Lycasin determines the stability of the finished product and its shelf life. The benefits of using sorbitol and Lycasin in chewing gum have been discussed elsewhere (Whitmore, 1983), but in this application it is essential to achieve a good balance between the sorbitol, Lycasin and the insoluble gum base. In practice, we have found that a sorbitol/mannitol blend will make up the crystalline component and Lycasin at 80 % solids forms the liquid phase. It is difficult to estimate the final composition of the liquid phase in the final product, since a proportion of both the sorbitol and mannitol will dissolve in the available water. The use of Lycasin at a high solids content means that the water activity will not exceed 0·65 % and, therefore, little or no water loss will occur. Since Lycasin cannot crystallise, an undesirable hard chew, which did characterise early sugarless gums, will not result.

The water activity of Lycasin has been mentioned above on several occasions. The bulk storage of Lycasin at 75 % solids presents little microbiological problems, chiefly since its water activity is 0·78. Table 4 shows the water activity of some commercially-available syrups at 20 °C. Moulds and bacteria do not develop if the water activity is less than 0·8 and 0·9, respectively. Osmophilic yeasts do develop, however, at water activities down to 0·6.

## Vitreous products

Conventional carbohydrate-based high boilings contain sucrose and a proportion of glucose syrups to prevent graining. The equivalent non-cariogenic product is made entirely from Lycasin. The non-browning

TABLE 4
The Water Activity[a] of some Commercially-available Syrups at 20 °C

| *Syrup* | *Dry substance* | $a_w$ |
|---|---|---|
| Standard 42 DE glucose syrup | 75 | 0·81 |
| | 80 | 0·77 |
| | 85 | 0·70 |
| Acid/enzyme converted 60 DE glucose syrup flolys® | 75 | 0·78 |
| | 80 | 0·71 |
| | 85 | 0·64 |
| Glucose syrup 74/904 | 74 | 0·72 |
| Melrose® 700 | 70 | 0·76 |
| 85/20 F | 85 | 0·63 |
| 80/20 C | 80 | 0·71 |
| 80/27 C | 80 | 0·70 |
| 72/32 C | 72 | 0·77 |
| 72/20 F | 72 | 0·78 |
| Fructose syrup | 70 | 0·75 |
| Sorbitol® syrup | 70 | 0·73 |
| Lycasin® 80/55 | 75 | 0·78 |
| Liquid sucrose | 67 | 0·85 |

[a] Figures are given for guidance only and are not specifications.

characteristics of Lycasin are an advantage in the manufacture of this type of confectionery, but care should be taken to prevent charring of Lycasin during the heating process.

It is necessary to achieve a residual moisture content of less than 0·5 %, instead of the usual 2 %–3 % in conventional carbohydrate-based sweets. Very good results have been achieved using temperatures in the region of 175 °C, together with a vacuum of about 250 mm Hg applied for approximately 2 min towards the end of the cooking period. Equally good results have been achieved using higher temperatures when heating Lycasin in open pans.

These high temperatures are required to achieve the low residual moisture content, to prevent the finished sweets from the phenomenon of 'cold flow' during storage. It is also preferable to wrap the finished sweets while they are still warm. The wrapper should present an efficient barrier to moisture penetration when Lycasin high boilings are made. The reason

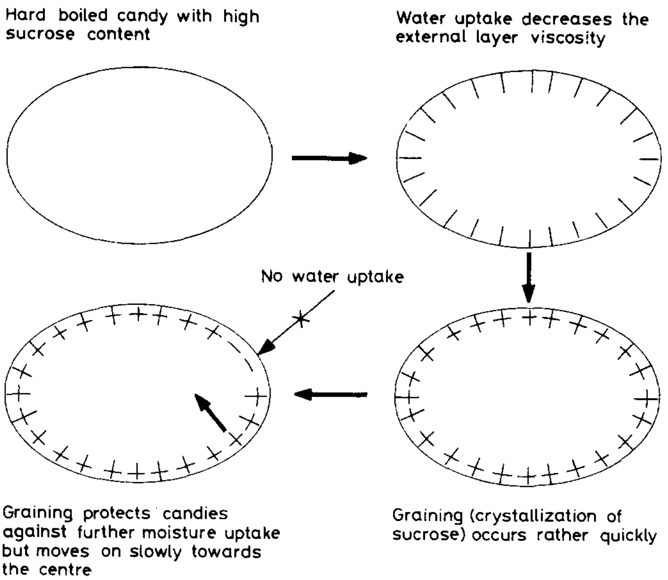

**Fig. 9.** The development of graining by a conventional sucrose/glucose syrup high boiling.

for this is best illustrated by reference to conventional carbohydrate-based high boiling. Figure 9 illustrates the water present at the surface of a conventional high sucrose hard boiled sweet will decrease the viscosity of the outer layer of the sweet and graining, i.e. crystallisation of sucrose at the surface, will occur. This graining will prevent further water uptake. Lycasin cannot crystallise and, therefore, water present at the surface of a Lycasin high-boiling will make the surface of the sweet sticky.

## Non-crystallised and soft products

In this category, the texture of the gums and jellies is given by agents such as gum arabic, gelatin and pectin. In order to obtain a good set, the absence of long chain polysaccharides is desirable. We have found that Lycasin will make very good wine gums and soft jellies (both with gelatin and gum arabic), and gelatin jellies and soft gums (with high-methoxypectin and carragheenan, together with sorbitol powder).

Recipes for each of the above confections in each of the classifications are available from Roquette (UK) Ltd.

## OTHER APPLICATIONS

### Low-alcohol beer

The alcohol level of a beer depends upon the proportion of fermentable sugars in the wort when it is fermented and also the rate at which these sugars are metabolised. There are several ways to reduce the alcohol level, apart from ultra-filtration or reverse osmosis, some of which are mentioned below.

(1) The alcohol may be evaporated, but this process has two main drawbacks: first, the extra stage involved and the expense of the energy expended; secondly, this process results in a poor-tasting beer, thought to be brought about by an imbalance of volatile aromatic substances caused by the evaporation process.
(2) The production of fermentable sugars may be inhibited, and enzyme activity replaced by a mixture of amylolytic enzymes, chosen for their ability to limit the production of simple sugars.
(3) There is the possibility of stopping hydrolysis completely before its normal finishing point.
(4) The addition of glucose syrups or maltodextrins containing only small amounts of simple fermentable sugars will dilute the wort before fermentation, and thus limit alcohol production.
(5) Fermentation may be stopped by a sudden complete cooling, so that only some of the sugars have been metabolised to alcohol. One drawback of this process might be the possibility of further fermentation taking place at a later stage.
(6) Some progress has been made by replacing a proportion of the malt with sorbitol. The results to date, however, are not totally satisfactory, mainly because of the sugary taste of the beer which can result.

With the drawbacks of the six above-mentioned methods in mind, some hydrogenated glucose syrups have been developed which have been found to give satisfactory results, with composition as follows (on a dry weight basis):

DP 1 between 0·1 and 35% (preferably between 0·1 and 20%)
DP 2 between 0·1 and 45% (preferably between 0·1 and 42%)

DP greater than 20, less than 45% (preferably less than 40% and, best of all, less than 30%)
DP 3–DP 20, to make up to 100%

The low-alcohol beer produced with a hydrogenated glucose syrup conforming to the above composition will have between 0·1 and 2% by weight of hydrogenated polysaccharides present. The hydrogenated glucose syrup is added late in the fermentation operation or, better still, before or during the sterilisation treatment of the wort. The quantity added should correspond to the 0·1–2% figure mentioned above. Further aspects of this application are discussed in Roquette Frères patent application No. 83 07922, *Beer Without Alcohol*, 11 May, 1983.

## Peanut based snacks

We have examined the use of sorbitol solutions (both crystallising and non-crystallising grades), maltodextrins, dried glucose syrups, high maltose glucose syrups and dextrose both to protect and coat the peanuts. Only the results relating to sorbitol syrups will be discussed here, and

TABLE 5
The Use of a Sorbitol (Neosorb®) Solution to Protect Peanuts During the Roasting Operation

| *Immersion conditions* | *Mixture* | *MS* (%) | *Number of cracked peanuts* | *Rate of breakage* (%) |
|---|---|---|---|---|
| Cold peanuts | Control | | 36 | 90 |
| | Neosorb 70/70 | 70 | 0 | 0 |
| | Neosorb 70/02 | 70 | 0 | 0 |
| | MD05 | 50 | 38 | 95 |
| | MD63 | 50 | 37 | 92·5 |
| | Glucose 525 75<br>Dextrose 25 | 70 | 36 | 90 |
| | | 28 | 36 | 90 |
| | MD63 | 70 | 33 | 82·5 |
| | Dextrose 40<br>Sucrose 60 | 70 | 29 | 72·5 |
| Hot peanuts | MD05 | 50 | 10 | 25 |
| | MD63 | 50 | 22 | 55 |
| | Dextrose | 50 | 8 | 20 |
| | Neosorb 70/70 | 70 | 4 | 10 |

these relate only to the protection application, i.e. the protection of the original form of the peanut in order to preserve this shape during the later stages of manufacture, roasting and coating.

Whole peeled peanuts were roasted at 250 °C for approximately 10 min. Either hot or cold peanuts were immersed in the sorbitol or carbohydrate syrups for 10–15 s. The temperature of the immersion bath was 25 °C. The peanuts were dried and any excess syrup eliminated using a jet of cold compressed air. The peanuts were roasted for a second time at 250 °C for 3–5 min.

Table 5 gives the results achieved and illustrates dramatically that non-crystallising sorbitol solution at 70 % dry substance (Neosorb 70/70; D-sorbitol present at about 50 % dry substance) or crystallising sorbitol solution also at 70 % dry substance (Neosorb 70/02; D-sorbitol present at about 70 %) will prevent peanuts from cracking if they are immersed in the sorbitol syrup after cooling. If the peanuts are immersed when hot, the best protection performance is given by non-crystallising solution (Neosorb 70/70).

## CONCLUSIONS

This work has demonstrated that it is possible to develop a large range of confectionery products based on Lycasin and sorbitol. Sucrose and glucose syrups may be replaced by sorbitol and Lycasin, respectively, to produce a range of non-cariogenic confectionery. The situation has been exploited in Switzerland where such confectionery holds a considerable share of the market. There remains a great deal of work to be done not only on the technological side but also in connection with the marketing of non-carbohydrate confectionery. The recent release on the UK market of both pharmaceutical and confectionery items made with Lycasin is very encouraging, and it is hoped that the progress made to date will continue and allow the confectionery industry to offer products which consumers have previously been unable to enjoy.

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