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LEARNING ABOUT HONEY THROUGH FRUCTOSE

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One of the two main sugars in honey—glucose—has been used commercially for many years, especially as a component of drinks, sweets, etc., that are sold as easily digested and quick energy sources. The other sugar—fructose—has been produced in commercial quantities only in the past decade or so, by the application of large-scale ion-exchange techniques to the hydrolysis of various carbohydrates. Finland has been one of the most active countries in the new fructose industry, spare capacity being used in the sugar (sucrose) refining plants of the Finnish Sugar Co. Ltd. and Xyrofin Ltd. The glucose and fructose produced by inversion, dissolved in water, are chromatographically separated by means of specially made columns filled with calcium polystyrene sulphonate ion-exchange resins. The Finnish Sugar Co. has been able to develop a method for crystallizing fructose directly from a solution in water, and this process has substantially reduced production costs[12].

The properties of glucose that contribute to characteristics of honey have been familiar for many years, but fructose has not been available in large quantities for testing until recently. In 1981, during a visit to Finland, I was able to learn about the research work done there by Dr. L. Hyvönen and her colleagues. This enables us to begin to get a proper understanding of the characteristics of honey that are due to its fructose content. They include some of the most valued and most acclaimed properties of honey.

Granulation of honey

Fructose is the most water-soluble of all the sugars. At 25°C a saturated solution contains 81% fructose; for glucose the figure is 51% and for sucrose 67%[3]. This high solubility makes fructose difficult to crystallize, and although the glucose-to-water ratio in honey is currently used as an indicator of its granulating tendency[13], we should bear in mind the significance of a high fructose content in preventing granulation. All honeys contain more fructose than glucose, with a few exceptions—which granulate very rapidly indeed—such as rape (*Brassica napus*) and dandelion (*Taraxacum officinale*). Non-granulating honeys contain much more fructose than glucose, for instance tupelo (*Nyssa ogeche*) 67% more, sourwood (*Oxydendron arboreum*) 62% more, and acacia (*Robina pseudoacacia*) 45% more.

In addition to the high solubility of fructose in water, a solution containing more than 60% fructose can contain much more glucose in solution than a more dilute fructose solution can[9, 13].

Hygroscopicity of honey

Fructose is quite hygroscopic. At room temperature there is a rapid rise in its rate of absorption of water from the air when the relative humidity reaches about 60%. Foods containing fructose must therefore be packed to exclude air, or they will absorb water from it. Neither glucose nor sucrose is hygroscopic in the same way, and it is likely that honey owes its hygroscopicity entirely to its fructose content. Experiments with the use of fructose in baking show that its hygroscopic nature preserves the moisture of foods such as cakes and breads. This same valued property of honey may thus also be ascribed to the fructose in it.

Effects of heat on honey

When an acid solution of sucrose, glucose or fructose in water is heated, HMF (hydroxymethylfurfal) may be formed. Fructose is, however, much more sensitive than glucose to the reaction that produces HMF[7]. One might expect, therefore, that high HMF values would be found more often in processed (heated) honeys that have a high fructose content than in others.

Fructose also has a stronger reaction than glucose with amino acids at high temperatures[7]. During the baking of breads and cakes, therefore, fructose browns more intensely than glucose or sucrose, in lower concentrations of amino acids and at an earlier stage of the baking[5, 6]. Tests showed that a properly baked fructose cake was always darker than a similar sucrose cake. Also, at the same baking temperatures, a fructose cake needed to be removed from the oven earlier, or it would burn. Readers experienced in baking with honey will recognize these characteristics. The use of fructose as a sweetening agent in bakery products results in a crust browning such as has been associated with honey[11] for many years.

The high chemical reactivity of fructose is probably the reason for the instability of colour, and for colour faults, in some fruit and berry products. Similar problems have been encountered with honey.

Sweetness

The sweetness to man of a solution of any sugar depends on its concentration, other components of the mixture tasted (for instance other sugars, and any acids), and the temperature.

In Finnish tests[4] the sweetness of 5%, 10% and 20% sucrose solutions at room temperature were taken as standard (100); the relative sweetness of sucrose at different temperatures then varied between 90 and 110, that of glucose between 58 and 87 (it was relatively sweeter at high concentrations, but varied little with temperature), and that of fructose between 87 and 114. Low concentrations of fructose (5%) at low temperatures (5°, 22°C) showed the greatest enhancement of sweetness compared with sucrose.

Hyvonen's thesis 'Varying relative sweetness' (1980), from which much of the information on fructose is quoted, gives three sets of estimates for the sweetness of fructose at different temperatures, relative to a 5% solution of sucrose (taken as 100). They can be combined as follows, the number in brackets showing whether 1, 2 or 3 figures were used:

5°	18°	22°	25°	37°	40°	50°	60°
143	129	125	125	100	103	88	80
(3)	(1)	(1)	(1)	(1)	(2)	(1)	(2)

On balance, therefore, one would expect honey also to be relatively sweeter at low concentrations, and when taken cold or at room temperature, than when taken in hot

food or drinks. The presence of acid further enhanced the sweetness of fructose at low temperatures, and reduced it at high temperatures. A synergistic effect of about 20% to 30% has been found in the sweetness of glucose-fructose mixtures; effects with other mixtures of sugars are less marked.

These facts help to account for the sweetness of honey, and the extra sweetness of high-fructose honeys, and they suggest that honey should be relatively sweeter in cold than in hot drinks. Further studies on honey would seem useful, now that the contributions to sweetness of its component sugars are more fully understood.

High fructose syrups

Products that contain both glucose and fructose have come on to the market in the past decade or so, and are relevant to the beekeeping industry in two ways. First, the enzymatic inversion of relatively cheap carbohydrates such as starch from corn (maize) may show a rather similar sugar spectrum to honey, in which sucrose is inverted by the honeybee enzyme invertase. As illegal adulterants of honey, these compounds have been very difficult to detect in honey[1, 14]. But as commercial syrups for feeding to bees, they can serve a useful purpose.

The products are described as 'high fructose' substances, although this is a misnomer since the fructose content is often not more than half the total sugars. One sample of 'high fructose isomerose' contained 39·9% glucose and an estimated 25·2% fructose, with 29·6% water[10]. Packs and bulk supplies of these syrups, which the bees do not have to invert before storing in the combs (as they do sucrose syrup), are on sale in many countries. Some are marketed under trade names that may be as emotive as those used for cosmetics and some health foods: Apifonda, Stimulapi, Apirève, Nektarin, and so on.

Conclusions

Honey scientists may well now be able to use the research work done on fructose to enrich our knowledge of honey. And the beekeeping industry in different countries needs to be aware of the development work on fructose for another reason: honey should be a candidate for some of the applications already found for fructose, which would therefore be worth investigating. Publications 2 and 8 listed below cover many subjects, including dietetic advantages and disadvantages of fructose in relation to other sugars, which are not discussed here. Finally, the distinction between the sugar fructose and so-called 'high fructose' syrups—both now commercially produced—should be understood by all concerned.

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