The science breaker

**Explore the best sugar factory: the fruit**

Authors: Elsa Desnoues, Michel Génard, Bénédicte Quilot-Turion, Valentina Baldazzi

Everyone knows that eating fruit is important for good health, they are full of vitamins and essential elements. However, what boosts consumption is the fact that they are delicious. The taste of a fruit is mainly determined by its sugar and acid composition. Indeed, fruit contains several sugars with different properties. For example, in peach there are four different sugars: sucrose, which is the most abundant at maturity, then glucose and fructose and finally sorbitol. These sugars have different sweetness, in fact fructose has a sweetening power twice that of sucrose. But some people have fructose intolerance. Understanding the mechanisms responsible for the synthesis and accumulation of different sugars will make it possible to select fruit that meet very specific criteria to increase fruit consumption.

Sucrose and sorbitol are produced in the leaves through photosynthesis and are transported to the fruit via sap. Inside a fruit, cell enzymes (miniature protein machines that speed up biochemical reactions) break down part of sucrose and sorbitol into fructose and glucose. These sugars are then either stored in the cell vacuole, which gives the good sweet taste of fruit, or degraded by other enzymes in the cytoplasm to provide energy or synthesize structural compounds for the cell.

In today's peaches, fructose and glucose concentrations are equivalent. However, some wild peaches, or peaches used as ornament, possess fruit with a very low concentration of fructose compared to glucose. This natural feature makes it possible to investigate the mechanisms linked to the accumulation of fructose in peach fruit.

At first, we postulated that a difference in enzyme activities could be at the origin of the low fructose content observed in wild peaches. We characterized the activity of all the enzymes involved in sugar metabolism in more than 100 peach varieties, with both standard and low-fructose fruit1. Surprisingly, no difference was found according to the fructose type.

To better investigate the biological mechanisms behind sugar accumulation in peach fruit, we decided to develop a mathematical model of sugar metabolism during fruit growth.

A model is a simplified representation of a (biological) system that includes the essential features without the burden of unnecessary details. A model, indeed, cannot prove if a given mechanisms is at work or not in a given situation but it can demonstrate whether the proposed mechanism is sufficient to produce an observed phenomenon.

Our model represents the action of the different enzymes that synthetize or degrade sugar molecules as well as the action of transporter proteins that carry them through the cell vacuole’s membrane. Such an internal transport may have important consequences on the final fruit taste because it allows the storage of sugars in the vacuole and thus prevents them from being degraded by the enzymes of the cytosol.

The model made it possible to simulate the sugar composition in peach fruit and it allowed to test functional hypotheses to understand why certain peaches have less fructose than glucose. Low fructose concentrations measured in some wild peaches may result from lower synthesis or higher degradation of fructose than glucose, or from a very low storage capacity of fructose in the vacuole.

The model revealed that the best way to simulate a low fructose to glucose ratio in a peach fruit is to increase the specificity for fructose of a particular enzyme, called fructokinase, that degrade fructose in cell cytosol. This characteristic is called the affinity of an enzyme and, unfortunately, is difficult to measure experimentally. By modifying the fructokinase affinity, fruit having a standard fructose content could be virtually transformed into low-fructose fruit, and conversely.

From a fundamental science perspective, the model allowed the identification of a candidate mechanism to explain the difference in concentration between fructose and glucose observed in wild peaches. Although further laboratory studies are needed to validate model’s findings, the development of a mathematical model of fruit sugar metabolism can substantially improve our understanding of the control of fruit sweetness. When combined with genetic approaches, the application of the model to a large number of peach varieties will help to identify genomic regions linked to variations in fruit sugar composition. In a world characterized by an increased attention to individual’s health and liking, this can considerably speed up the selection of new varieties that better meet consumer’s expectations.

1: **Desnoues E, Gibon Y, Baldazzi V, Signoret V, Génard M, Quilot-Turion B** (2014) Profiling sugar metabolism during fruit development in a peach progeny with different fructose-to-glucose ratios. *BMC Plant Biology* 14, 336. DOI: https://doi.org/10.1186/s12870-014-0336-