UNIVERSITY OF MANITOBA

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RELATIONSHIPS OF SUGARS TO COLOUR OF PROCESSED POTATOES

Introduction

The acceptability of potatoes for processing as french fries or chips is largely dependent on the colour of the end product. Colour is directly related to the quantity of sugars in the tuber. The quantity and composition of sugars in tubers is dependent on cultivar, stage of maturity, occurrence of stress, and handling and storage management practices. Regulation of sugar levels in tubers by proper production and storage management practices is essential to ensure acceptable processing quality.

Sugars and fry colour

Sucrose is the transport form of sugar from leaves to tubers and is the major free sugar in immature potato tubers. Hydrolysis or breakdown of sucrose in harvested tubers results in the production of the reducing sugars, glucose and fructose (Figure 1a). The colour of fried processed potatoes is directly related to the concentration of glucose and fructose in the tuber. Frying at high temperature causes a non-enzymic browning reaction, known as the Maillard reaction, between the reducing sugars and amino acids in the tuber (Figure 1b).

Excessive browning and development of off-flavours due to high reducing sugar content results in unacceptable product. Sucrose is a non-reducing sugar and contributes little to fry colour.

Sugar changes during growth

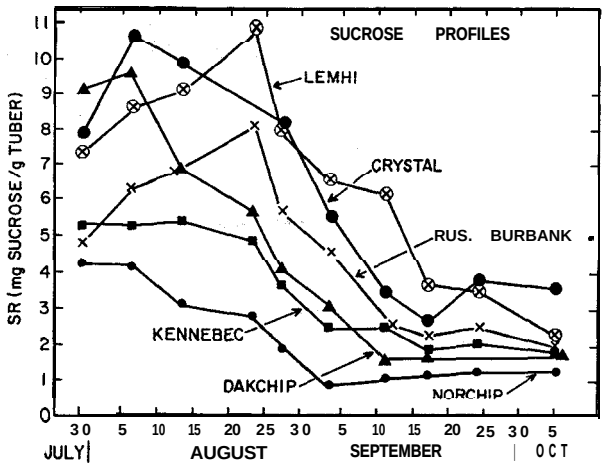
Sucrose and glucose contents are high during tuber bulking. Fructose however is generally present in very low concentrations in the field. As the tubers size and the crop matures, sucrose and glucose decrease to a low level. The amount of sugar in mature tubers varies between cultivars (Figure 2). When the tuber has attained this low sugar level, often referred to as 'chemical maturity', dry matter accumulation is at a maximum and the crop is generally ready for harvest. The sucrose content, therefore, is a good measure of crop maturity. In most potato cultivars, tubers with less than about 2.8 milligrams sucrose per gram (mg/g) fresh weight are considered chemically mature. These tubers should have acceptable processing quality out of long term storage.

Figure 1. Breakdown of sucrose in potato tubers and development of colour after frying.

(a) Sucrose $\xrightarrow{\text{Hydrolysis}}$ Glucose + fructose (Reducing sugars)

(b) Reducing sugars + amino acids $\xrightarrow[\text{Temperature}]{\text{High}}$ Browning

Figure 2. Sucrose profiles of six potatoe cultivars during growth (From Sowokinos and Preston, Minnesota Ag. Expt. Station Bull. 596-1988).



Sucrose transported to the tuber from the leaves is utilized in various ways in the tuber (Figure 3). In actively growing tubers, a protein inhibitor prevents the enzyme invertase from hydrolyzing sucrose to reducing sugars. Once harvested, invertase is activated and results in accumulation of reducing sugars.

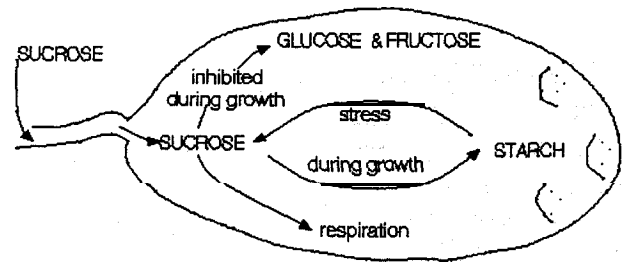
Sugar changes in storage

If sucrose is low in tubers at harvest, the concentration of all sugars remains low in healthy tubers under good storage management. However, tubers harvested with sucrose greater than 1.5 will accumulate reducing sugars in storage. The higher the sucrose at harvest, the greater the reducing sugar accumulation.

In storage, sucrose concentration is not a good measure of fry colour of Russet Burbank and Shepody potatoes as sucrose itself does not contribute directly to darkening. The best indicator of fry colour in storage is therefore the concentration of reducing sugars.

Changes in sugars can be used as an indicator of stress in tubers. Stresses such as low temperature, low oxygen, or physical damage will usually increase sugars. This can be a useful tool to monitor storage management practices.

Figure 3. Fate of sugars in potato tubers.



Estimating fry colour from glucose

The reducing sugars glucose and fructose are both present during storage with the concentration of glucose generally higher than that of fructose. Measurement of glucose alone will give a good estimate of the colour of french fries. The relationship between fry colour and glucose concentration in Russet Burbank potatoes is shown in Figure 4.

Measuring sugars

Various instruments are available for measuring sugars however many are inappropriate for use on farms. The cost of a Yellow Springs Instrument (YSI) industrial analyzer to measure sugars could be justified if analyzing a large number of samples. Glucose enzymatic test strips are less precise but provide an estimate of glucose content and, in addition to being easy to use, are inexpensive.

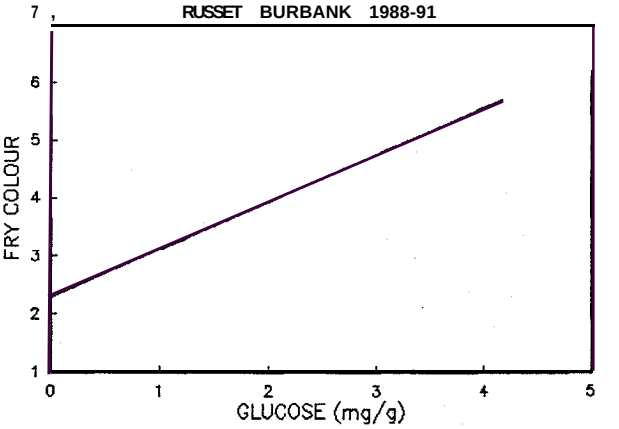
A colour reaction between glucose in the tuber and a dye in the strip results in a colour change from which glucose concentration is determined.

Tes-Tape, a product of Eli Lilly Canada Inc. used by diabetics to measure glucose in urine, provides an approximation of glucose in juice of potato tubers.

Safe levels of sugars

Sucrose at harvest Russet Burbank harvested with sucrose less than 4.1 mg/g or Shepody harvested with sucrose less than 2.8 mg/g and preconditioned for 14 days at 15°C (59°F) before storage at 8°C (46° F) should produce fries during long term storage which will meet processor specifications for maximum bonus payment for colour (0 on USDA scale, Table 1). However, this would be the maximum tolerable level of sucrose and it is preferable to harvest tubers with as low sucrose as possible.

Figure 4. Relationship between french fry colour and glucose concentration (Refer to Table 1 for colour scale).



Glucose in storage Russet Burbank with a glucose less than 2.1 mg/g or Shepody with a glucose less than 1.8 mg/g will produce french fries which should meet processor specifications for maximum bonus payment for colour. However, lower glucose levels are recommended.

Table 1. Relationships of french fry colour scales used in Manitoba.

USDA colour chart	000	00	0	1	2	3	4
University of Manitoba	1	2	3	4	5	6	7
Carnation Foods Co. Ltd.			0	1	2	3	4
McCain Foods Ltd.			1	2	3	4	5

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