SPECIAL ROLE OF SUGARS IN AGRICULTURE AND SOME POSSIBILITIES OF DETERMINATIONS IN VEGETABLES AND FRUITS - PREPARING AND TEST OF TOMATO FRUIT

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Abstract: *Farmers are required to keep many standards on food safety, and maintain the land in good agricultural and environmental condition. The demand for analysis of the sugar content is widely and consistently high, because of its importance as an enjoyment value and energy content of different food products. The aim of the study was to provide a brief overview of the possibilities of sugar analysis in fruits and vegetables. We made a short analysis of the preparation method used in our experiments, and followed the stability of the measured value of the sugar content in the filtered samples.*

Key words*: sugar, horticulture, tomato, sugar analysis, refraction*

INTRODUCTION

The European Union's Agricultural Fund for Rural Development (EAFRD) is on strengthening the EU's agriculture and agro-food sectors, as well as to the sustainable development of rural economy. Rural development is the 2nd pillar of the Common Agricultural Policy (CAP) of the European Union. Rural development programmes are aiming at farm modernisation and innovation. Modernization of the horticultural growing and the high quality products of vegetables and fruits are also supported. EU actively supports the fruit and vegetable sector to become a more competitive and market-oriented sector, increased use of eco-friendly cultivation, and greater consumption of fruit and vegetables by the population. Hungary is a rural country with about 66% of its area classified as rural. The southern part of the Great Hungarian Plain is the largest horticultural area of the country. Our research group has made many experiments testing the quality of large scale of horticultural products in nutrient supply studies for long [3, 6, 12]. These experiments help to make eco-friendly, sustainable cultivation and to grow high quality products. Our accredited laboratory helps in controlling the composition and quality of the soil, irrigation water and the large variety of the horticultural plant products, mainly vegetables and fruits, and different plant parts as well. Sugar content is one of the most important components of the enjoyment value of the different food products and also important in the characterization of the energy content of a given food, feedstock or product as well [8, 10]. Sugar content may be influenced many ways during growing [2, 9].

Determination of sugar content in food and raw materials is not a simple task usually. The reason of it is that natural sugars are always a mixture of different saccharides in our foods. Generally, a main sugar component is present, which is dominant in the particular fruit or vegetable, but it is accompanied by several other sugars. Among the sugars there is a very large variety of isomers, which often differ from each other only in their spatial structure. This is true even if only series of D configurations – has been developed in evolution and widespread - are considered. In many cases, considering the general enjoyment value originated from sugars, methodical procedures do not seek full and detailed component analysis. The methods are based on a variety of technics, we return to this, later in this paper.

The situation is complicated rather, - demonstrating the significance of the task - by the fact that a variety of scales and evaluations are used to express or estimate sugar content. Some of these are related to very simple procedures that have been used for a long time. Specially known, special area of the analysis is the sugar industry and the winery. ICUMSA (International Commission for Uniform Methods of Sugar Analysis) is a standardizer organization, established at the end of the 19th century [13]. Interestingly, ICUMSA consists of national committees of major importing and exporting countries and has given voting rights on the basis of the quantity of sugar imported and exported in the previous two years. In the ICUMSA Methodological Manual, detailed descriptions of scales and sugar analysis are found, primarily for the examination of raw sugar, sugar beet and white sugar [7].

The most important units and analytical methods used to characterize the sugar content

The determination of the sugar content of different sweet solutions and extracts has traditionally derived from measurement of one of the two major physical parameters, the density and the refractive index. These options are derived on the base that the main part of the dry matter is the mixture of different sugar components. These features are easily measurable, the devices are readily available, and their great advantage is that they are portable and can be easily used in field conditions. Let's take a look at some of the options:

The Brix degree or sugar degree (labeled °Bx) is the standard unit of the sugar content of the solutions. It is conventionally used since the 19th century. It got its name from a German scholar, Adolf Ferdinand Wenceslaus Brix (1798-1870). Brix degree (°Bx) indicates the ratio of sugar to water in the solution, for example 10 Brix degrees means 10 grams of sucrose sugar content in 100 g solution (and 90 grams of water). Usually, °Brix is also called Brix%. As the result is temperature-dependent, 20 or 25 °C is the benchmark for the measurement at present. Thus, the scale expresses the percentage of sucrose content, and the unit of measurement is widely used today in the food and sugar industries. Similarly, the two other scales referred to a temperature of 17.5 ° C: *Balling degree* (°Bg, °Blg) and *Plato degree* (^{o}P), the latter being used the most in the brewing industry. The three scales are often used interchangeably, as the differences are negligible. Defining method of the values of the scales previously was based on measuring density, and more recently it is based on refractive index measurement [17].

Perhaps, the most commonly used way of determination of the sugar content in Hungary is the *Baumé degree* (B°, Bé°). It is named after Antoine Baumé, a French pharmacist, and it is suitable for measuring the density of various liquids. The use of it first spread in France and Spain. It is mainly used to measure the sugar content of wine grapes and other fruit juices, but is also used in beer production. The curiosity of this device is that it has two separate scales to measure the densities of denser or thinner liquids than that of water.

In the present practice, the density measurement is replaced by the measurement of the refractive index when determining the sugar content. Refractometers are usually smaller in size, less fragile, more robust in design, more portable accurate. Thus, winemakers, gardeners, spirit drink makers or beekeepers can make their measurements quickly and cheaply.

The refractometer follows the refraction of light in a given fluid. The refractive index depends on the type of liquid, concentration and temperature. The refractive index of the solution is proportional to the water soluble solids content, and the water-insoluble components cannot be measured in this way. The design of the refractometers may be different. In a classic case, a few drops of fluid should be applied to the prism during the measurement and then with closed with a matt roof. In the built-in optical telescope and turning to a light source, you can easily read the measured value from a scale with numbers.

Most of the water-soluble dry matter is made up of sugar components in fruits, so although other chemical compounds can be measured, it is most commonly used to determine the sugar content of aqueous solutions. Universal refractometers with a Brix scale allow you to measure the sugar content of your choice in different fruit juices, wines, vegetable juices and concentrates, or even in condensed milk. These Brix ranges are generally between 0-20 ^{o}Bx [1] and can be used with accuracy of 0.1%, but different refractometers for the Brix range also exist.

Modern digital refractometers have automatic temperature compensation for 25 ^{o}C. The measurement technique and temperature compensation method is based on the ICUMSA method. The result is calculated on the Brix or RI (refractive index) scale, after accurate determination of the refractive index of the liquid. The light from the LED light passes through the prism in contact with the sample, and breaks on the sample. By reaching a critical incision angle, the light no longer passes through the sample, but reflects on it and is sensed by the sensor. The device determines the critical angle (refractive index) and calculates the Brix value based on the refractive index. The device also indicates the temperature in usual.

Quantitative determination of the sugar content can be done by chemical methods as well, e.g. according to Schoorl's method. In this indirect determination, a reddish copper (I) oxide is separated from the copper ammonium complex (Fehling reagent) on the effect of the reducing sugars. The excess of copper is determined by iodometric titration. The result is given in the most dominant sugar component of the solution, using an experimental Schoorl table. During the measurement we must pay particular attention to the controlled conditions and reaction time. In the determination of non-reducing sugar components (mainly sucrose), acidic hydrolysis must be performed beforehand [3, 6].

Precise qualitative and quantitative determinations of the different carbohydrate components in the sample require high level instrumentation. Detailed measurements can be performed by different chromatographic methods in general. The studies are extremely important in food, nutrition and health science researches, but the cost of materials and equipments is naturally higher several orders of magnitude [5, 16]. The development of chromatographic methods (HPLC, GC-MS, TLC, ILC, etc.) is still ongoing.

In our present study, we investigated the sugar content of raw, freshly picked tomato fruits by refractometric method. In our work, we were looking for whether or not the sugar content changed in the tomato filtrate - obtained after processing, - during a few days of storage.

MATERIALS AND METHODS

Our tomato cultivation experiment was carried out at the Faculty of Horticulture and Rural Development at the University of John von Neumann, in spring of 2017. In the greenhouse of the faculty we tested tomato test plants in hydroculture. Tomatoes were a continuous growing variety Soliance F1. During the experiment, plant conditioning treatment was performed between April and June 2017, on average every two weeks, altogether 6 times. The detailed description of the experimental conditions is not relevant for the present study, because we are on focusing on the storage conditions.

The matured berries were collected in 10 days on the average. In this paper we examined the fruits collected on 28 July 2017. A total of 13 groups were set up depending on the crop enhancement material treatments, in two repetitions.

Tomato analysis was carried out in the Soil and Plant Testing Laboratory of the faculty. From 2009 we have continuously tested soil, leaf and horticultural product samples in the accredited Soil and Plant Testing Laboratory of the Faculty of Horticulture and Rural Development (University of John von Neumann, formerly Pallasz Athéné and Kecskemét College). The preparation of tomato berries was done in the same way in each group. The berries were thoroughly washed, chopped and homogenized in a rotary blender. Four groups of berries were cultivated in one group. The raw tomato paste was filtered on a filter paper. The sugar content of the filtrate was measured on a digital refractometer HI96801 (Hanna Instruments). The measuring range of the device is 0-85% Brix (0.1% resolution with automatic temperature compensation between 10-40 ^{o}C). Required sample quantity: 100-200 µl per measurement.

The calibration was performed with a 5 m/m% sucrose solution and the accuracy of the device was checked with 5 m/m% glucose solution as well.

Sample processing was performed on the day of the collection. The measurement was performed on the same day (Measurement 1), and the filtrate was stored at 7-8 ^{o}C thereafter. Brix measurements in the samples were repeated after 1, 2 and 5 days storage time in each groups (Measurement 2, 3, 4). We did not use any preservatives during the storage period. The results were averaged and standard deviation was also calculated on all measurement days.

Microsoft Office Excel program was used in the statistical tests and illustration of the results. Average levels, standard deviation and statistically significant differences were estimated. Essential deviations in measurements have been accepted in the 5% significance level.

RESEARCH RESULTS

The Brix values of the examined samples were measured on the day of processing and during storage (Figure 1). The mean values did not change on the first day of storage and then showed a slight upward trend.

Standard deviation seemed to be decreased first and then showed a slight increase. Brix% showed a slight upward trend from the second day after preparation but the difference was not significant (p> 0.0.5).

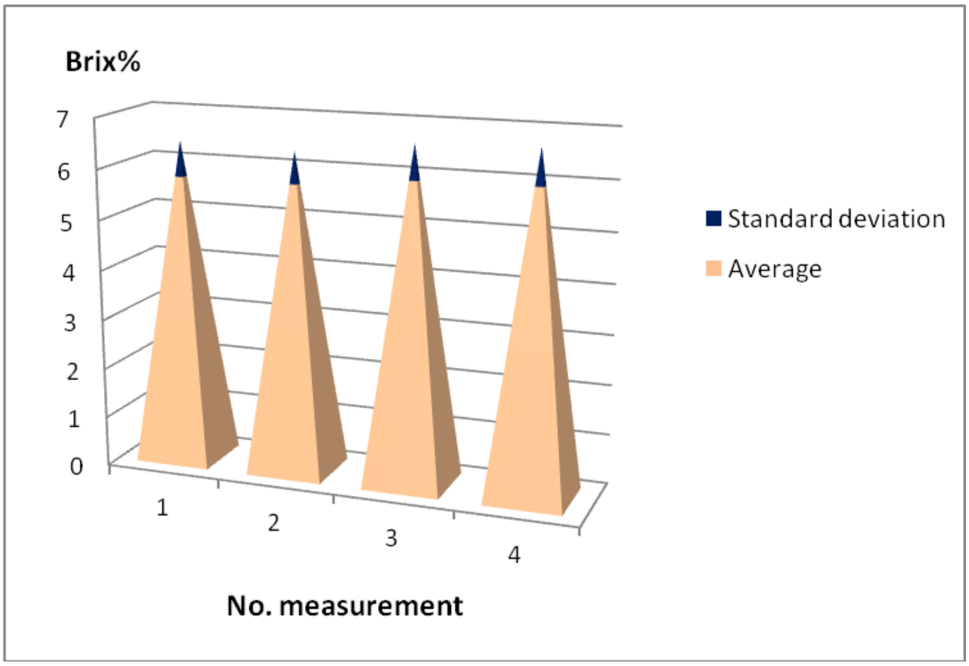

Figure 2. Average values and deviations of Brix% content of tomato berries

The trend changes are shown in Figure 1. Brix% seemed to be constant or increased slightly in some groups.

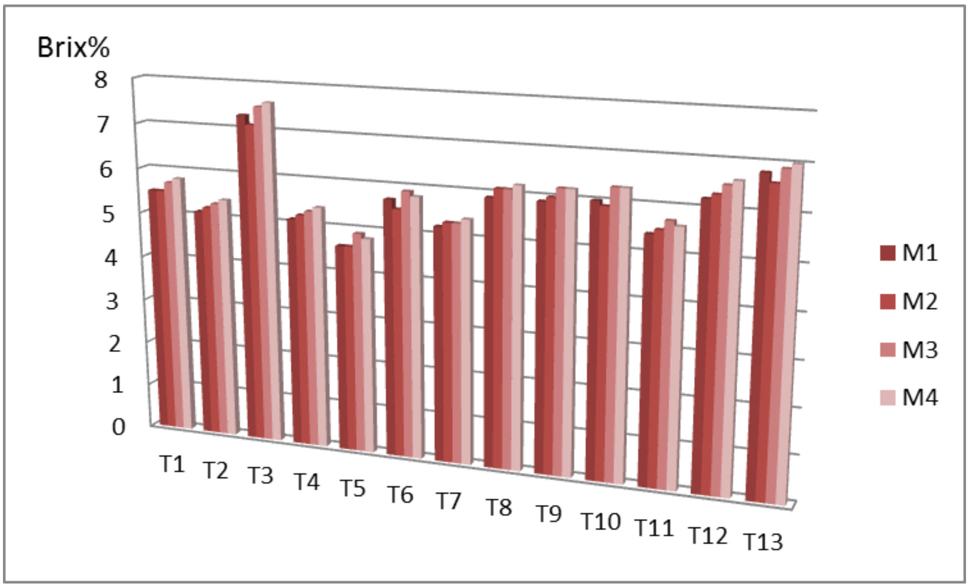

Figure 2. The change in Brix value during storage in the 13 sample groups (T1-T13) in the different measurement days (M1-M4)

Brix% showed a slight upward trend from the second day after preparation but the deviation was not significant (p>0.0.5). The trend changes are shown in *Figure 2*.

CONCLUSIONS

In the case of root vegetables (mainly potatoes and carrots) examination of the changes in the content of different nutrients during the storage period is rather wide in the scientific literature. However, there are fewer data exist regarding the changes in the content of them in the freshly consumed vegetables and fruits, and mainly, few data exists regarding the methodological problems and following the changes meanwhile. Some authors have investigated the effect of storage time, temperature and pressure on tomatoes [2, 14]. According to the results of the majority of the literature, the amount of six-carbon sugars (hexoses) in the potatoes and carrots during storage is slightly increased, while the amount of 12 carbon sucrose is slightly reduced. However, changes are often different among the varieties and may strongly depend on the temperature used. Tomato red-fruit sugars partly come from starch degradation. Physiological and metabolic alteration during storage showed that fructose levels were coincident with chilling tolerance in fruit [10].

In our previous study, six different types of tomatoes were studied during a 3-week storage period. Sugar content and acid / sugar ratio in tomato fruits changed depending on the variety. The latter ratio generally showed an upward trend [3].

In our present study, we had to get information on the results after a few days of storage of the freshly processed and filtered tomato fruit, the sugar content is appreciable or not, i.e. how fast the test is need to be performed. In our study, we assumed that the filtered tomato fluid, being removed from the natural skins and fibres, could change the sugar content faster, or start fermenting faster than the whole fruit. In mature crops, colorants with antioxidant properties (mainly lycopene) and other "preservative" agents are present, in a balanced ratio and equilibrium, developed harmoniously during evolutionary development.

Our results showed that the sugar content determined on the basis of the Brix value did not decrease in the filtered tomato in a few days of storage, presumably not degraded, did not start fermentation and even slightly upward tendency existed in the tested variety, but the difference was not significant. The Brix value of the analyzed Soliance F1 variety is moderate among the varieties [4]. The upward tendency is consistent with the scientific data described for several stored raw vegetables, probably due to a slight rise in the levels of hexoses [11, 15]. However, during the longer storage period, the standard deviation slightly increased. Sugar content decreased in some groups during longer storage, which may indicate the beginning and the different degrees of sugar degradation and fermentation processes. Detailed examination of this can be the subject of next studies, depending on the change in storage temperature and on the quality and dosage of the applied crop enhancement materials.

Via our investigations, we would like to point out that in many cases, it is important to carry out methodical investigations and to provide a precise description of the methodology of the scientific results. The results - as we have seen in several cases – may vary; the time intervals and environmental conditions of the measurements may also affect the results of sugar analysis. It cannot be ruled out that the small, tendentious methodical changes affect the degree of significance between the different treatment groups, by strengthening or covering the differences either. Keeping the same methodology is particularly important in the case of studies taking samples several times during a growing season or in the case of long-term, more year studies.

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