DYNAMICS OF SUGARS COMPOSITION IN BERRIES

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Abstract. The major sugars in six cultivars grown in Latvia are analysed. The content of glucose, fructose and sucrose in strawberry, blackcurrant and redcurrant berries was determined by applying the method of high performance liquid chromatography (HPLC). By using the obtained calibration curves, concentrations of diverse sugars were found in the analyzed samples. Fructose or fruit-sugar, the same as glucose, is mainly the source of energy in the human body though it is decomposed faster and easier than glucose. In all the researched berry cultivars, the amount of fructose was the largest, particularly in blackcurrants. Six strawberry, black- and redcurrant cultivars were evaluated as raw materials for industrial production. The investigation involved chemical and sensory analyses of fresh berries. The results indicate that pH and sugars of fresh berries influence their quality. Furthermore, high level of sugar adversely affects taste stability. Taste degradation in berries is parallel to flavour deterioration. It is concluded that the main emphasis should be given to the properties of fresh berries.
Key words: berries, glucose, fructose, sucrose, potential of hydrogen.

Introduction

In order to optimize humans' health and decrease emergence of diseases caused by food, new food-related strategies are necessary, which are connected with a link between nutrition and metabolism. American and British researchers consider that if fruits and vegetables prevail in the diet, possibility to fall ill with cardiovascular diseases is reduced for 40%. In Latvia's climatic conditions research will enable to use local fruit and berry production more extensively and comprehensively. Their use in nutrition will eliminate seasonal nature and imbalance. In order to improve continuous supply of Latvian inhabitants with locally produced good quality products of fruits and berries, it is necessary to carry out their complex study, including also study of chemical content (Petrova et al., 2005).

In botany, a berry is a simple fruit having seeds and pulp produced from a single ovary; the ovary can be inferior or superior. The garden strawberry is a common plant of the genus *Fragaria* which is cultivated worldwide for its fruit, the (common) strawberry (Moore and Ballington, 1990). The fruit is highly appreciated not only for its characteristic aroma but also for its bright red colour, and it is consumed in large quantities - either fresh, or in prepared foods such as preserves, fruit juice, pies, ice creams, milk shake, etc. Artificial strawberry aroma is also widely used in all sorts of industrialized food products (Skrede, 1982).

Blackcurrant and redcurrant berries are of raw material importance for human alimentary (Laugale, 2007). Aroma, color and ascorbic acid content are the most important quality parameters of these berries (Laugale and Bite, 2008). Together these fruits account for more than 90% of soft fruit production for the industry (Brennan, 1990). During the process of ripening enzymes in berries react with their substrates: starch is decomposed to glucose which partly isomerizes as fructose. From the viewpoint of physiological effect, the most important biologically active substances are carbohydrates, organic acids, vitamins, mineral substances, fibre, etc. Carbohydrates are a component of every live cell. They are the main component of plant dry matter (50-80%). In food carbohydrates are the source of energy.

Carbohydrates are the major source of fuel for the body and individual cells. They are composed of carbon, hydrogen and oxygen.

Physical state of food products often is compared with physical-chemical characteristics of pure water, although water quality of different solutions and products is quite variable and depends on the impact of dissolved substances to transition of water phases.

Those carbohydrates come from the plant-based foods that you eat. You can either use carbohydrates right away for your energy needs or your body can convert them into fat to use later. There are three types of carbohydrates: sugars, starches, fibre (Moore and Ballington, 1990).

The body begins the process of breaking carbohydrates down into their individual monosaccharides almost before we start to eat them.

High sugar fruits are still low in calories and very high in nutrition. They don't need to be avoided, unless you are in the initial stages of a low carbohydrate diet.

The major sugars are identified as glucose, fructose and sucrose. All three increased during ripening; sucrose was found to be in the greatest concentration throughout, with fructose the predominant reducing sugar. Acidity loss was shown by decreasing titratable acidity and increasing pH values (Viljakainen et al., 2002).

Under the influence of fructose, activity of enzymes necessary for metabolism of carbohydrates is increased. In the human body, fructose is able to change into glycogen without the involvement of hormone insulin contrary to glucose, for the use of which insulin is necessary. These properties of fructose are important in the case of some diets when fructose is more recommendable than glucose.

By carrying out comparative researches with different kinds of carbohydrates in nutrition it is ascertained that fructose more than other carbohydrates increases fat content in blood and liver.

Enlarged amount of sucrose in nutrition increases fat and cholesterol content in blood more than respective amount of glucose; from all types of carbohydrates, the compound carbohydrate – starch - has the least impact on fat content in blood. It is considered that unfavourable impact of sucrose on fat metabolism mainly depends on fructose, which sucrose molecule contains, as well as it is connected with relatively fast absorption of sucrose from small intestines.

The aim of the research is related to usage of fresh berries in further heat treatment.

Materials and Methods

Experiments were carried out at the laboratories of the Faculty of Food Technology by using berry cultivars available for consumption. The following cultivars were used in the research: strawberries 'Polka' and 'Honeoye', currants 'Red Lake' and 'Primus', blackcurrants 'Silmu' and 'Titania'. The content of glucose, fructose and sucrose in strawberry, blackcurrant and redcurrant berries was determined by applying the method of high performance liquid chromatography (HPLC). The method is based on the fact that the chromatographic separation of glucose, fructose and sucrose is based on their delayed time differences (Kūka, 2008), which enables to carry out quality and quantity analysis of the sample. Liquid chromatography is a method of separating and analyzing mixtures of substances in which the mobile phase is a liquid. By the method of liquid chromatography it is possible to separate fixed and thermally non-persistent substances. In the liquid chromatography, separation of substances takes place in a constant temperature which most often is close to room temperature. In the liquid chromatography, the mixture to be separated is forced through columns and the mobile phase is let in. By injecting the sample in the HPLC, with the mobile phase it flows to the column. In order to guarantee high efficiency, correct injection of the sample, its quantity and volume have essential importance. After the extraction of carbohydrates they are determined by using refraction detector which monitors composition of elution flown out of the column. The signal coming from the detector is electronic; therefore it can be processed by using electronic data processing systems. For determination of carbohydrates in berries, light refraction coefficient detector is used. It is all-purpose and can be used in cases when the substance does not absorb UV radiation, for example, in determination of carbohydrates. The pikes are identified according to the time of a particular carbohydrate flowing out from the chromatography column. Composition of carbohydrates is calculated by using standard method according to the pike square (Kūka, 2008).

Fundamentals of the standard method are construction of calibration curve by using sugar standard-solutions of diverse concentrations. By using the obtained calibration curves, concentrations of diverse sugars are found in the analyzed sample. Using potentialities promoted by Shimadzu LC-20 Prominence with light refraction coefficient detector of the RID-10A brand liquid chromatography software, analyses of the obtained results of the calibration curve and the analyzed sample is carried out automatically.

The research was made according to the standard method.

The reagents used: glucose, fructose, maltose, sucrose, acetonitrile and deionised water.

Preparation of the basic solution – weighed out 2±0.0002 g of fructose, glucose, maltose and sucrose in 10 ml volumetric flasks, filled with deionised water up to the mark and mixed thoroughly (concentration of the obtained mass was 0.2 g mL^{-1}).

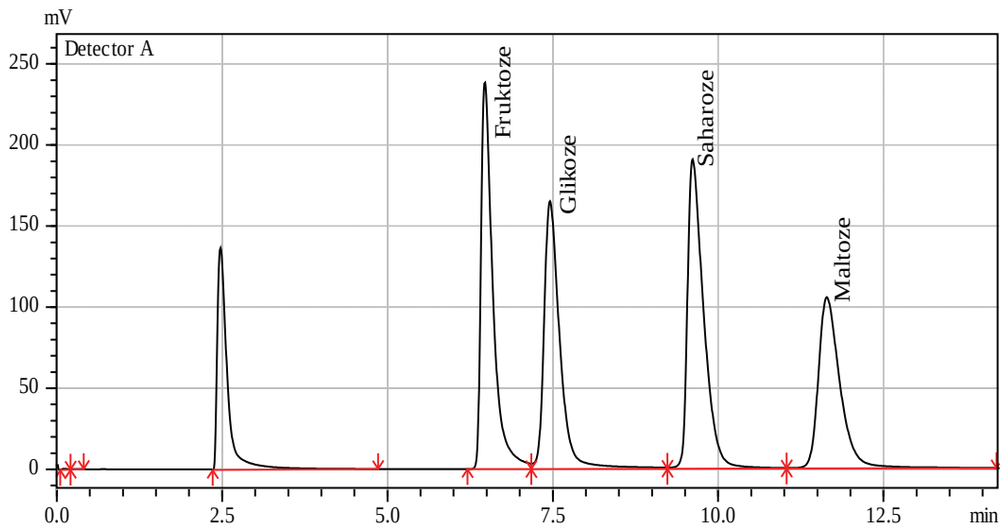


Figure 1. Standard-curve of carbohydrates for carrying out chromatography analysis.

Parameters of the method:

- column: amino column (- NH_2);
- isocratic regime;
- temperature of the column and detector: 25 °C;
- mobile phase: acetonitrile/water (80:20 V/V);
- capacity of the injection sample: 10 µl;
- total time of the analysis (glucose, fructose, sucrose, maltose): up to 30 minutes;
- rate of the flow: 1.3 mL min^{-1}.

Liquid chromatography of the carbohydrate calibration:

the chromatography data processing system fixes the composition of glucose, fructose, sucrose, maltose in berry by comparing the berry chromatography with the chromatography of sugar standard-solution mentioned above.

Composition of carbohydrates in the analyzed samples was calculated in the form of percentage expression. The following formula was used in calculations:

$$W\,\% = \frac{CxV}{m} \times 100, \qquad (1)$$

where

C – concentration read, g L^{-1};

V – capacity of the extraction solution (total), L;

m – weighed mass, g

Results and Discussion

Consumers try to choose as fresh and good looking products as possible and products that are familiar and known to be safe. The consumer has the right to obtain safe food. The strawberry, a fruit that features a fragrantly sweet flavour, is the most popular type of berry fruit in the world (Lefever et al., 2004). While there are more than 600 cultivars of strawberries that differ in flavour, size and texture, one can usually identify a strawberry by its red flesh that has yellow seeds piercing its surface, and the small, regal, green leafy cap and stem that adorn its crown (Petrova et al., 2005). In addition to strawberries that are cultivated, there are also varieties that grow wild. These are much smaller in size, but feature a more intense flavour (Deuel, 1996). The fruit of the blackcurrant (scientific name *Ribes nigrum* has an extraordinary high vitamin C content (302% of the Daily Value per 100 g), good level of potassium, phosphorus, iron and vitamin B5, as well as broad range of other essential nutrients (Kampuse et al., 2002). Other phytochemicals in the fruit (polyphenols/anthocyanins) have been demonstrated in laboratory experiments with potential to inhibit inflammation mechanisms suspected to be at the origin of heart disease, cancer, microbial infections or neurological disorders like Alzheimer's disease. Blackcurrant seed oil is also rich in many nutrients, especially in vitamin E and several unsaturated fatty acids including alpha-linolenic acid and gamma-linolenic acid. European raw blackcurrants content: carbohydrates – 15.4 g, sugar – 7.9 (Laugale, 2007). The researched cultivars were characterised by productivity and self-fruitfulness. Clusters were short; berries were very large and large, average levelled by size, did not fall; tearing of berries was dry; taste was good – sour-sweet. Redcurrants are for culinary use: juice, jellies and purees. Cultivars are selected for the clarity of juice, size of berry and productivity. The sector of soft fruits and cherries for processing faced a difficult 2004 year with low producer prices for several products (in particular blackcurrants, strawberries and sour cherries) in several Member States. Low prices affected also several products in 2005 (in particular strawberries and blackcurrants).

The largest dry matter part of blackcurrant and redcurrant chemical composition is made by carbohydrates, which are there in the form of sugars, and they make approximately equal proportions in these berries (Kampuse et al., 2002). Sugars are the most important energy and flavour substances of many berries and fruits. Energy value of berries and fruits depends on the quantity of sugars, but flavour – on the quantity and also on the composition of sugars (Laugale and Bite, 2008).

When analyzing berry samples we found out that the most significant carbohydrates are glucose and fructose.

Fructose is a simple sugar (monosaccharide) found in many foods. It is also one of the three most important blood sugars, the other two being glucose.

Glucose is a simple carbohydrate, or *sugar*. It is very important because cells in an organism use it to provide energy. Its chemical formula is $C_6H_{12}O_6$. This means it has 6 carbon atoms, 12 hydrogen atoms, and 6 oxygen atoms bonded together.

Glucose and fructose composition of berries depends on the ripeness stage of berries. If the berries are in full- ripeness, then glucose and fructose composition is higher. In unripe berries carbohydrates are mainly found in the form of starch, which by the increasing ripeness transform into glucose, fructose and sucrose.

The most significant carbohydrates of berries included in this experiment are shown in Fig. 2.

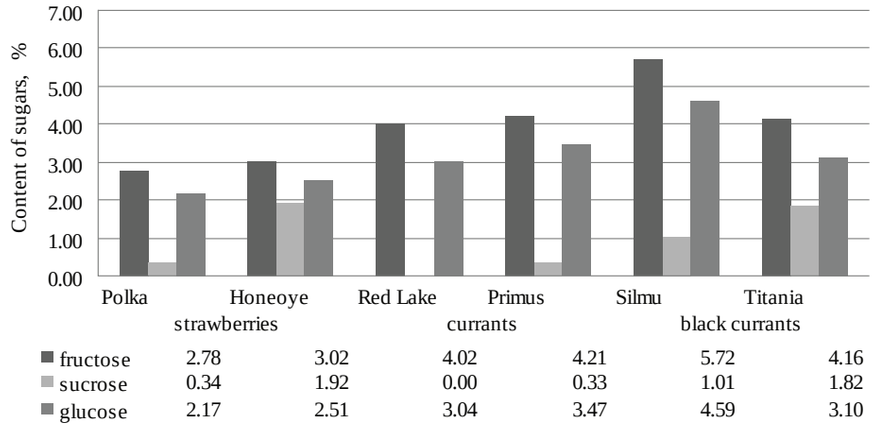


Figure 2. Composition of sugars in berries.

The results illustrated in figure 2 confirm that amount of carbohydrates in berries fluctuates from 0.00 to 5.72%. The results also show that the variety of berries influences the amount of sugars found in berries. It is particularly typical between the strawberry cultivars 'Polka' and 'Honeoye' and blackcurrants cultivars 'Silmu' and 'Titania'. The dynamics of sugars in berries shown in figure 2 indicates that the most important carbohydrates of berries are glucose and fructose. The amount of fructose in researched strawberry, blackcurrant and red currant cultivars was the highest. Fructose is the sweetest of the carbohydrates. It means that blackcurrants were the sweetest of all the researched berries. In its turn amount of sucrose was the lowest in all the researched cultivars of berries. By comparing kinds of berries we found out that in red currants the amount of sucrose was the lowest, and in currant cultivar 'Red Lake' there was no sucrose at all. It proves that the results of the research confirm to the data mentioned in the scientific literature (Brennan, 1990).

In strawberries, blackcurrants and redcurrants monosaccharides glucose and fructose were found more than sucrose and these monosaccharides in all these berries were approximately in equal proportions. Disaccharide sucrose was found in very little amounts. The least amount of monosaccharides was found in redcurrants, compared to blackcurrants. In some cultivars they are not found at all (Kampuse et al., 2002). According to different data of scientific literature, quantity of sugars in blackcurrants is different. According to the data of Western scientific literature, the content of sugars in fresh blackcurrants is 6.3%, but according to the data of Russian scientific literature – 7.3-12.0% (Laugale, 2007).

The medium of food products influences possibilities of different chemical reaction processes. Results of the research of pH of berries confirm the presence of acids. Potential of hydrogen (pH) is a scale of acidity from 0 to 14, which shows how acidic or alkaline a substance is. The lower the pH, the more acidic is the solution. The higher the pH, the more alkaline the solution. The prevailing acidity of fresh berries ranges from pH 3 to 5. Acidity decreases during ripening when organic acids are used in the synthesis of sugars (Viljakainen et al., 2002). The researched pH of strawberry, blackcurrant and redcurrant medium is shown in the figure 3.

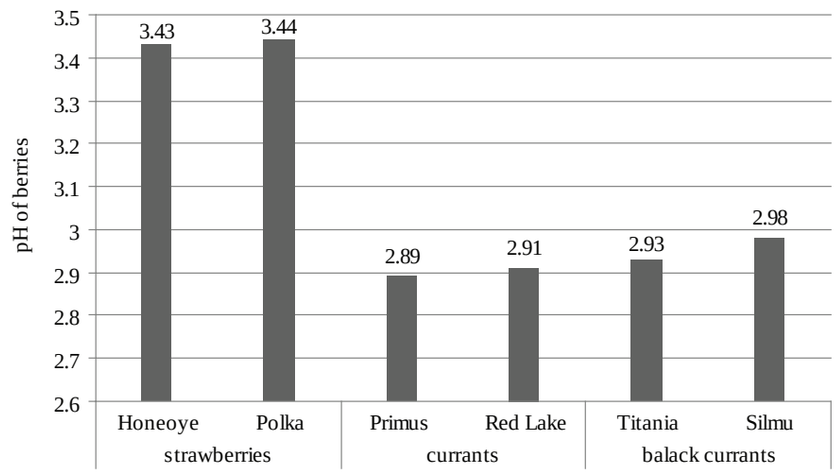


Figure 3. pH concentration in berries.

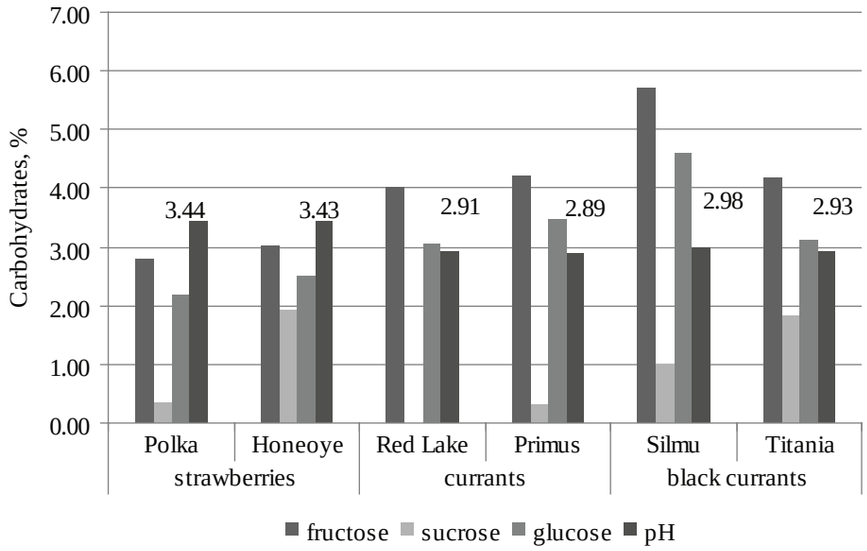


Figure 4. Comparison of pH and sugars in berries.

The results indicate that pH of analyzed berry samples ranges from 2.89 to 3.44. The increased acidity facilitates decomposition of carbohydrates present in berries. Taste of berries is influenced by pH, it states whether the berries are sour. pH is a value depending on temperature a lot, therefore with temperature changes also pH amount cahanges. If we compare types and cultivars of berries it can be concluded that there are no essential differences.

Increased acidity facilitates decomposition of carbohydrates in berries (glucose, sucrose and fructose). Taste of berries depends on pH. The characteristic sour taste of berries is formed by organic acids. The sour taste depends on the quality and quantity composition of organic acids - they in certain proportions, together with sugars and flavourings, determine sensory properties and quality of berries. Citric acid is found most in redcurrants and blackcurrants, which is confirmed also by diverse sources of scientific literature (Viljakainen et al., 2002). Besides, in blackcurrants are found also malic acid and a bit of oxalic acid. In redcurrants, malic acid is found in very negligible quantities and oxalic acid practically is not found at all. Historical information and facts about consumption of sweet products prove that people have always enjoyed sweet taste. Enjoying sweet taste is hereditary to people.

When analyzing pH concentration among types and cultivars of berries shown in figure 3, it can be concluded that pH found in strawberries is the highest. Taste of berries depends on pH. It indicates that there is more soury medium in researched cultivars ‘Polka’ and ‘Honey’ than in blackcurrants and redcurrants. Comparison of pH and sugars in berries is shown in figure 4.

The major sugars are identified as glucose, fructose and sucrose. All three increase during ripening; sucrose is found to be in the greatest concentration throughout, with fructose the predominant reducing sugar. Acidity loss is shown by decreasing titratable acidity and increasing pH values.

Berries are also analyzed for pH. Data are presented both on a concentration basis (mg/g of fresh weight) and on a per berry basis (mg/ berry).

The sugars and organic acids present in the pulp at various stages of ripeness are analysed by HPLC. Ripening is associated with a loss in firmness, peel chlorophyll and pulp acidity, with increasing soluble solids and total sugars.

Carbohydrates in foods that are digested and absorbed in the small intestine provide energy to body tissues mainly in the form of glucose and, to some extent, fructose. Fruits and berries are the principal sources of major dietary antioxidants, and there is now compelling evidence to support the assertion that beneficial effects result from consuming larger amounts of these foods.

Conclusions

1. The largest dry matter part of strawberry, currant and blackcurrant chemical composition is made by carbohydrates, which are found there in the form of sugars – fructose, glucose, and a bit of sucrose.
2. In all the researched berry cultivars the mount of fructose was the largest, particularly in blackcurrants, but the amount of sucrose was the least; in the redcurrant cultivar ‘Red Lake’ it was not found at all.
3. Taste of berries depends on quality and quantity composition of organic acids, they in certain proportions together with sugars and flavourings influence sensory properties and quality of berries.
4. When anallyzing pH concentration in different types and cultivars of berries, pH level found in strawberries was the highest.

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