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# USE OF SUGAR CONTENT ANALYSIS FOR THE ESTIMATION OF BERRY JUICE AUTHENTICITY

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Sucrose, glucose and fructose contents in juices of three varieties of: strawberry (Senga, Ducat, Marmolada), raspberry (Beskid, Canby, Malling Seedling), black currant (Ben Lomond, Titania, Ojebyn) and red currant (Rondom, Jonker, Holenderska) were determined in this study. Furthermore, the juices were analysed for glucose:fructose ratios. Examinations were performed in three consecutive years: 1998, 1999 and 2000 with enzymatic methods. The achieved sugar contents and sugar ratios were compared with standard values specified in Code of Practice.

Deviations from ranges in sugar contents established in the Code of Practice were found and changes of these ranges were proposed. On the basis of sucrose, glucose and fructose contents as well as the glucose:fructose ratio it cannot be judged whether the examined berry juice is authentic or adulterated with other berry juice.

## INTRODUCTION

Examinations conducted by specialized laboratories all over the world as well as in our country indicated that a part of juices available on the market are not authentic. Usually juices are adulterated by the addition of water, sugars, acids, synthetic taste and aromatic substances, dyes, extracts of peels and foots. Furthermore, expensive juices can be adulterated by cheap juices.

The basic detection method for adulterations of fruit juices is a comparative analysis of their chemical composition with standard values, *e.g.* those specified in the Code of Practice. The Code of Practice was elaborated by the Association of the Industry of Juices and Nectars from Fruits and Vegetables of the European Union (AIJN) – an organization which is engaged in standardization of the quality rules and authenticity estimation of fruit juices. The Code of Practice publishes absolute quality requirements (*e.g.* density, contents of heavy metals) and tolerance concentrations of different components, *e.g.* saccharides in authentic fruit juices [Czapski & Tyma, 1996; Martinek, 1998; Neuhäuser, 2000; Niewiarowicz, 2000; Obiedziński, 1998; Płocharski, 2000; Stój *et al.*, 2001; Targoński, 2000].

In the majority of native fruit juices, the content of saccharides is limited only to glucose, fructose and sucrose. Contents of these sugars as well as glucose:fructose ratios are different for different juices, hence they can be the indicators of their authenticity. These parameters are compared with standards, *e.g.* those specified in the Code of Practice. Deviations from accepted norms are the indicators of non-declared juice addition.

Strawberry juices have been reported to contain from trace concentrations to 38.7 g/L of sucrose, from 11.8 g/L to 45.2 g/L of glucose and from 13.5 g/l to 41.4 g/L of fructose [Durst *et al.*, 1995; Kallio *et al.*, 2000; Lundahl *et al.*, 1989; Spanos & Wrolstad, 1987]. According to the Code of Practice, however, strawberry juices should contain maximally 10 g/L of sucrose, 15–35 g/L of glucose and 18-40 g/L of fructose. Raspberry juices have been shown not to contain or to contain maximally 13.233 g/L of sucrose, as well as to contain from 0.405 g/L to 34.870 g/L of glucose and from 6.391 g/L to 37.9 g/L of fructose [Durst *et al.*, 1995; Kallio *et al.*, 2000; Lundahl *et al.*, 1989; Spanos & Wrolstad, 1987]. The Code of Practice does not permit the presence of sucrose in raspberry juices, permits 15–38 g/L of glucose and 18–45 g/L of fructose. Standard values in black currant juices are: 0 g/L of sucrose, 23–50 g/L of glucose and 30–65 g/L of fructose.

Contents of particular sugars in berry juices have mainly been determined with the use of liquid chromatography [Boccorh *et al.*, 1998; Corradini *et al.*, 1995; Durst *et al.*, 1995; Lundahl *et al.*, 1989; Spanos & Wrolstad, 1987], gas chromatography [Kallio *et al.*, 2000; Prodolliet & Hischenhuber, 1998; Wang *et al.*, 1997], and enzymatic methods [Plowman, 1991]. In comparison with chromatographic methods, the saccharide analysis using enzymatic methods is relatively easy. The advantage of enzymatic methods is their specificity, which results from the capability of enzymes to specifically catalyze the metabolism of individual juice components. They are characterized with high sensitivity and repeatability, are work- and time-saving and enable avoiding the use of complicated and expensive apparatus [Boehringer Mannheim; Henniger, 1990].

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Contents of sucrose, glucose and fructose in authentic juices of three strawberry, raspberry, black currant and red currant varieties were determined in this study. Furthermore, the juices were analysed for glucose:fructose ratios. The achieved contents of sugars and ratios of sugars were compared with standard values specified in the Code of Practice [1996] and changes in the ranges of these parameter in the Code of Practice were proposed. The aim of present research was to search for the answer whether the determination of sugar contents can be used for the estimation of local berry juices adulterations. Examinations were performed in three consecutive years: 1998, 1999 and 2000. Use was made of the enzymatic methods recommended in the Code of Practice.

## MATERIAL AND METHODS

Four berry species were collected in 1998, 1999 and 2000. Strawberries (*Fragaria ananassa*) of Senga, Ducat and Marmolada cv. originated from the plantation in Zemborzyce. Raspberries (*Rubus idaeus*) of Beskid, Canby and Malling Seedling cv. as well as black currants (*Ribes nigrum*) of Ben Lomond, Titania and Ojebyn cv. were from The Experimental Farm in Felin. Red currants (Ribes rubrum) of Rondom and Holenderska cv. were collected in a garden in Klementowice and Jonker cv. was collected in Góra Puławska.

Berry fruits were stored in a refrigerator at -28°C. Juices were made from fruits defrosted at ambient temperature in a juice extractor Zelmer 277.8 and then centrifuged in an MPW 365 centrifuge for 15 min at 4°C and 11 000 rpm.

Prior to sugar determinations, samples of juices were neutralized with NaOH solution and adjusted to pH of about 8, diluted with redistilled water, decolourized with PVPP (polyvinylpolypyrrolidone) and filtered. Determinations of sucrose, glucose and fructose were performed using the enzymatic method according to Boehringer Mannheim in two replications. Enzymatic kit No 716260 of the above-mentioned company was used in the study.

After completing the enzymatic reactions, the absorbance of solutions was measured at a wavelength 340 nm using a UV-VIS Unicam 5625 spectrophotometer. Contents of sugars were calculated according to the following equation:

$$c = \frac{V \times MW}{\varepsilon \times d \times v \times 1000} \times \Delta A \times r$$

where: c – saccharide content (g/L); V – final volume (mL); v – sample volume (mL); MW – molecular weight of saccharide (g/mol); d – light path (cm); $\varepsilon$ – extinction coefficient of NADH – at 340 nm = 6.3; $\Delta A$ – absorbance difference; r – dilution factor

Determination results were analysed statistically using the Tuckey's test at a significance level of $\alpha$=0.05.

## RESULTS AND DISCUSSION

Contents of sucrose in berry juices were shown in Table 1.

Strawberry juices made of each strawberry variety and in the consecutive years of harvest contained sucrose at concentrations from 0.08 g/L in strawberry juice of Marmolada cv. in 1999 to 12.55 g/L in juice of Ducat cv. in 1998. Juice of Ducat cv. had significantly higher average content of sucrose (5.01 g/L) in comparison with that of sucrose in juice of Senga cv. (1.75 g/L) and Marmolada cv. (0.96 g/L). Kallio *et al.* [2000] determined saccharide contents with the use of gas chromatography method in strawberry juices of Senga, Jonsok, Korona, Polka, Honeoye and Bounty cv. Likewise in the present paper, the authors found the presence of sucrose in all the examined juices, but at considerably higher concentrations. Juice of Senga PP cv. in 1997 contained the lowest – 9.0 g/L, and juice of Korona cv. in 1997 – the highest level of sucrose – 38.7 g/L. In the present examinations, sucrose contents in strawberry juices of Senga cv. in 1998, 1999 and 2000 accounted for 4.60 g/L, 0.33 g/L and 0.33 g/L, respectively. According to Kallio *et al.* [2000], juices of Senga PP and Senga VP cv. in 1997 contained 9.0 g/L and 21.0 g/L of sucrose, respectively, in 1998 – 17.8 g/L and 13.0 g/L of sucrose, respectively. Sucrose contents in juices of Senga E and Senga SW cv. in 1997 were 29.4 g/L and 29.2 g/L, respectively, and in 1998 – 24.9 g/L and 35.2 g/L, respectively. However, Lundahl *et al.* [1989]

TABLE 1. Contents of sucrose in berry juices in 1998, 1999, 2000.

| Type of juice | Fruit variety | Sucrose (g/L) | | | |
|---|---|---|---|---|---|
| | | Year of fruit harvest | | | Average |
| | | 1998 | 1999 | 2000 | |
| Strawberry juice | Senga | 4.60 | 0.33 | 0.33 | $1.75^{A} \pm 2.47$ |
| | Ducat | 12.55 | 0.25 | 2.22 | $5.01^{B} \pm 6.61$ |
| | Marmolada | 0.82 | 0.08 | 1.97 | $0.96^{A} \pm 0.95$ |
| Raspberry juice | Beskid | 0 | 5.33 | 10.42 | $5.25^{B} \pm 5.21$ |
| | Canby | 0 | 0.25 | 6.65 | $2.30^{A} \pm 3.77$ |
| | Malling Seedling | 1.15 | 0.16 | 4.19 | $1.83^{A} \pm 2.10$ |
| Black currant juice | Ben Lomond | 15.84 | 1.89 | 7.30 | $8.34^{C} \pm 7.03$ |
| | Titania | 0.16 | 4.68 | 15.02 | $6.62^{BC} \pm 7.62$ |
| | Ojebyn | 1.23 | 7.14 | 15.84 | $8.07^{C} \pm 7.35$ |
| Red currant juice | Rondom | 0.08 | 0 | 0.25 | $0.11^{A} \pm 0.13$ |
| | Jonker | 0 | 0 | 2.38 | $0.79^{A} \pm 1.37$ |
| | Holenderska | 0 | 1.23 | 0.58 | $0.60^{A} \pm 0.62$ |

A, B – values in the columns with different letters are significantly different at $\alpha$=0.05

observed only the trace concentrations of sucrose in juices made of different strawberry varieties. According to the Code of Practice, the highest content of sucrose in authentic strawberry juice, determined with the enzymatic method, should account for 10 g/L and only in rare cases can exceed this value. Deviations from the standard were found in juice of Ducat cv. in 1998 – in which the content of sucrose was 12.55 g/L. Therefore, in present paper, sucrose concentrations achieved in strawberry juices, meet recommendations of the Code of Practice. However, it is suggested that the highest tolerance content of sucrose in strawberry juice be increased by *ca.*3 g/L.

Durst *et al.* [1995] examined sucrose contents with the liquid chromatography in raspberry juices of Willamette, Meeker, Heritage, Golden, Chilcotin and Skeena cv. originated from North America as well as of Veten, Norna, Malling Seedling and Malling Promise cv. from Poland. Juices of Malling Seedling cv. did not contain sucrose, as opposed to raspberry juices of the same raspberry variety examined in our study, in which sucrose contents ranged from 0.16 g/L in 1999 to 4.19 g/L in 2000. Durst *et al.* [1995] did not find the presence of sucrose also in juices of Veten, Norna, Malling Promise, Golden cv., in six of twenty one juices of Willamette cv. and in six of eight juices of Meeker cv. Spanos and Wrolstad [1987] determined sucrose concentrations with the liquid chromatography in raspberry juices. Raspberry juices of Meeker and Willamette cv. originated from Oregon and juices of Meeker (Washington) and Marcy cv. (New Zealand) did not contain sucrose, either. Likewise in our examinations, juices of Beskid and Canby cv. in 1998 did not contain sucrose. According to Durst *et al.* [1995], the highest level of sucrose was found in juice No 18 of Willamette cv. (13.233 g/L), according to Spanos and Wrolstad [1987] – juice of Skeena cv. (9.1 g/L), and in our examinations – juice of Beskid cv. in 2000 (10.42 g/L). The average content of sucrose in raspberry juice of Beskid cv. was significantly higher (5.25 g/L) than the average contents of sucrose in juices of Canby (2.30 g/L) and Malling Seedling cv. (1.83 g/L). The absence or low concentrations of sucrose in raspberry juices examined by Durst *et al.* [1995] as well as by Spanos and Wrolstad [1987] might result from its hydrolysis during the preparation of juices, due to pasteurization and concentration of juices at high temperatures, which then were diluted and analysed for sucrose content. According to the Code of Practice, commercial raspberry juices contain no sucrose. It is proposed that the Code of Practice allows the presence of sucrose in authentic raspberry juice at a concentration of *ca.* 11 g/L.

According to the Code of Practice, black currant juice should not contain sucrose. Only in some cases, immediately after the preparation of juice, the presence of sucrose at concentrations from 1 to 3 g/L is observed. However, black currant juice examined by us, contained from 0.16 g/L of sucrose in juice of Titania cv. in 1998 to 15.84 g/L of this saccharide in juices of Ben Lomond in 1998 and Ojebyn cv. in 2000. Therefore the introduction of the highest content of sucrose in black currant juice at a level of *ca.* 16 g/L should be considered.

Sucrose contents in red currant juices in particular years were different, *i.e.* they ranged from 0.08 g/L in juice of Rondom cv. in 1998 to 2.38 g/L in juice of Joker cv. in 2000. Some red currant juices did not contain sucrose: juice of Rondom cv. in 1999, juices of Jonker cv. in 1998 and in 1999 as well as juice of Holenderska cv. in 1998. The Code of Practice does not define the contents of sucrose, glucose and fructose as well as a glucose:fructose ratio in red currant juice. Therefore, it is necessary to complete the Code of Practice of the above-mentioned parameters which are used for the estimation of red currant juice authenticity.

Contents of glucose in berry juices were shown in Table 2.

Contents of glucose in strawberry juices were from 18.18 g/L in juice of Ducat cv. in 1999 to 35.21 g/L in juice of Marmolada cv. in 1998. The average glucose content of 1998, 1999, 2000 in strawberry juice of Marmolada cv. was significantly higher (26.01 g/L) than the average glucose contents in juices of Senga (19.68 g/L) and Ducat cv. (19.15 g/L). Kallio *et al.* [2000] determined higher concentrations of glucose in juices of different strawberry varieties – from 18.9 g/L in juice of Senga VP cv. in 1998 to 45.2 g/L in juice of Polka cv. in 1997. In our examinations in 1998, 1999 and 2000 juices of Senga cv. contained 19.57 g/L, 18.70 g/L and 20.77 g/L of glucose, respectively. In juices of

TABLE 2. Contents of glucose in berry juices in 1998, 1999, 2000.

| Type of juice | Fruit variety | Glucose (g/L) | | | |
|---|---|---|---|---|---|
| | | Year of fruit harvest | | | Average |
| | | 1998 | 1999 | 2000 | |
| Strawberry juice | Senga | 19.57 | 18.70 | 20.77 | $19.68^{A} \pm 1.04$ |
| | Ducat | 19.10 | 18.18 | 20.17 | $19.15^{A} \pm 1.00$ |
| | Marmolada | 35.21 | 18.22 | 24.61 | $26.01^{B} \pm 8.58$ |
| Raspberry juice | Beskid | 23.76 | 21.46 | 17.75 | $20.99^{A} \pm 3.03$ |
| | Canby | 25.49 | 21.59 | 26.64 | $24.57^{B} \pm 2.65$ |
| | Malling Seedling | 19.48 | 20.47 | 17.75 | $19.23^{A} \pm 1.38$ |
| Black currant juice | Ben Lomond | 31.84 | 20.90 | 37.83 | $30.19^{CD} \pm 8.58$ |
| | Titania | 39.53 | 32.82 | 49.36 | $40.57^{F} \pm 8.32$ |
| | Ojebyn | 40.87 | 29.71 | 39.64 | $36.74^{E} \pm 6.12$ |
| Red currant juice | Rondom | 36.76 | 29.19 | 33.90 | $33.28^{D} \pm 3.82$ |
| | Jonker | 37.02 | 22.46 | 30.36 | $29.95^{C} \pm 7.29$ |
| | Holenderska | 46.57 | 27.55 | 37.14 | $37.09^{E} \pm 9.51$ |

A, B – values in the columns with different letters are significantly different at $\alpha = 0.05$

Senga cv. Kallio *et al.* [2000] found from 18.9 g/L to 32.2 g/L of glucose. Then, Lundahl *et al.* [1989] achieved a considerably lower concentration of glucose in strawberry juice – 11.8 g/L. According to the Code of Practice, the concentration of glucose in authentic strawberry juice, determined using the enzymatic method, ranges from 15 to 35 g/L. Strawberry juices examined in the present paper met the requirements of the Code of Practice referring to glucose concentration.

Contents of glucose in raspberry juices ranged from 17.75 g/L in juices of Beskid and Malling Seedling cv. in 2000 to 26.64 g/L in juice of Canby cv. in 2000. Raspberry juice of Canby cv. significantly differed reffering to glucose content (24.57 g/L) from juices of Beskid (20.99 g/L) and Malling Seedling cv. (19.23 g/L). Other authors reported on more differentiated concentrations of glucose in raspberry juices. Durst *et al.* [1995] determined from 0.405 g/L of glucose in juice of Meeker cv. to 34.870 g/L of this saccharide in juice of Golden cv., whereas Spanos and Wrolstad [1987] found from 18.0 g/L of glucose in juice of Marcy cv. (New Zealand) to 34.4 g/L of this saccharide in juice of Meeker cv. (Washington). In our examinations, the concentrations of glucose in juices of different raspberry varieties met recommendations proposed in the Code of Practice (15–38 g/L).

According to the Code of Practice, the content of glucose in authentic black currant juice ranges from 23 to 50 g/L. Black currant juices contained from 20.90 g/L of glucose in juice of Ben Lomond cv. in 1999 (9.1 % less glucose than the lowest content) to 49.36 g/L of this saccharide in juice of Titania cv. in 2000. Differences between average contents of glucose in black currant juices of Ben Lomond (30.19 g/L), Ojebyn (36.74 g/L) and Titania cv. (40.57 g/L) were confirmed statistically. Therefore, it is suggested that the lowest content of glucose in black currant juice proposed by the Code of Practice be decreased to *ca.* 20 g/L.

Also glucose levels in juices of different red currant varieties significantly differed from the average glucose concentrations. The highest level of glucose was found in juice of Holenderska cv. (37.09 g/L), lower in juice of Rondom cv. (33.28 g/L), and the lowest in juice of Jonker cv. (29.95 g/L). The contents of glucose in red currant juices in particular years ranged from 22.46 g/L in juice of Joker cv. in 1999 to 46.57 g/L in juice of Holenderska cv. in 1998.

Contents of fructose in berry juices were shown in Table 3.

Contents of fructose in strawberry juices ranged from 18.61 g/L in juice of Ducat cv. in 1999 to 36.63 g/L in juice of Marmolada cv. in 1998. The average content of fructose in strawberry juice of Senga cv. was 20.41 g/L, in juice of Ducat cv. – 20.99 g/L and in juice of Marmolada cv. – 27.54 g/L. From the statistical point of view, fructose concentration in juice of Marmolada cv. significantly differed from that in juices of other strawberry varieties. Kallio *et al.* [2000] found from 21.4 g/L of fructose in juice of Honeoye cv. in 1998 to 41.4 g/L of this saccharide in juice of Polka cv. in 1997. In our examinations, concentrations of fructose in strawberry juices of Senga cv. accounted for: 19.47 g/L in 1998, 19,69 g/L in 1999 and 22.08 g/L in 2000. Kallio *et al.* [2000] found similar concentrations of fructose in juices of Senga VP cv. in 1997 and in 1998 – 22.8 g/l and 21.6 g/l of fructose, respectively, and in juice of Senga E cv. in 1998 – 22.6 g/l of fructose. Other juices contained more fructose – from 25.3 g/L in juice of Senga SW cv. in 1997 to 32.5 g/L in juice of Senga SW cv. in 1998. However, Lundahl *et al.* [1989] determined less fructose in strawberry juice – 13.5 g/L. According to the Code of Practice, authentic strawberry juice should contain 18–40 g/L of fructose, determined using the enzymatic method. In the present examinations, none of the strawberry juices exceeded the established standard values.

In the present examinations of raspberry juices, the content of fructose ranged from 21.34 g/L in juice of Malling Seedling cv. in 2000 to 30.60 g/L in juice of Canby cv. in 2000. The average content of fructose in raspberry juice of Canby cv. was significantly higher (28.51 g/L) than the average contents of fructose in juices of Beskid (24.28 g/L) and Malling Seedling cv. (22.44 g/L). Other authors found greater ranges of fructose concentrations in raspberry juices. Durst *et al.* [1995] reported on fructose content ranging from 6.391 g/L in juice of Meeker cv. to 37.047 g/L in juice of Heritage cv., whereas Spanos and Wrolstad [1987] found from 24.1 g/L of fructose in juice of Marcy cv. (New Zealand) to 37.9 g/L in juice of Meeker cv. (Washington).

TABLE 3. Contents of fructose in berry juices in 1998, 1999, 2000.

| Type of juice | Fruit variety | Fructose (g/L) | | | |
|---|---|---|---|---|---|
| | | Year of fruit harvest | | | Average |
| | | 1998 | 1999 | 2000 | |
| Strawberry juice | Senga | 19.47 | 19.69 | 22.08 | $20.41^{A} \pm 1.45$ |
| | Ducat | 23.16 | 18.61 | 21.21 | $20.99^{AB} \pm 2.28$ |
| | Marmolada | 36.63 | 20.00 | 25.99 | $27.54^{CD} \pm 8.42$ |
| Raspberry juice | Beskid | 29.76 | 21.52 | 21.56 | $24.28^{BC} \pm 4.75$ |
| | Canby | 30.24 | 24.69 | 30.60 | $28.51^{DE} \pm 3.31$ |
| | Malling Seedling | 22.90 | 23.08 | 21.34 | $22.44^{AB} \pm 0.96$ |
| Black currant juice | Ben Lomond | 41.28 | 26.60 | 44.30 | $37.39^{G} \pm 9.47$ |
| | Titania | 49.88 | 39.82 | 58.51 | $49.40^{I} \pm 9.35$ |
| | Ojebyn | 47.14 | 34.43 | 46.99 | $42.85^{H} \pm 7.30$ |
| Red currant juice | Rondom | 30.07 | 31.12 | 36.69 | $32.63^{F} \pm 3.56$ |
| | Jonker | 39.45 | 25.39 | 30.99 | $31.94^{EF} \pm 7.08$ |
| | Holenderska | 55.44 | 33.43 | 44.03 | $44.30^{H} \pm 11.01$ |

A, B – values in the columns with different letters are significantly different at $\alpha = 0.05$

In our examinations, the concentrations of fructose in juices of different raspberry varieties agreed with those proposed in the Code of Practice (18-45 g/L).

Of the black currant juices, the lowest level of fructose was found in juice of Ben Lomond cv. in 1999 – 26.60 g/L (by 11.3% less than the permissible lowest content amounting to 30–65 g/L) and the highest level in juice of Titania cv. in 2000 – 58.51 g/L. In juices of different black currant varieties, significant differences were observed between the average contents of fructose. The highest level of fructose was recorded in juice of Titania cv. (49.40 g/L), lower – in juice of Ojebyn cv. (42.85 g/L), and the lowest – in juice of Ben Lomond cv. (37.39 g/L). Therefore, it is necessary to decrease the lowest content of fructose in black currant juice proposed in the Code of Practice to *ca.* 26 g/L.

In particular years of study, fructose concentrations in red currant juices ranged from 25.39 g/L in juice of Jonker cv. in 1999 to 55.44 g/L in juice of Holenderska cv. in 1998. From the statistical point of view, the average content of fructose in juice of Holenderska cv. (44.30 g/L) was significantly higher in comparison to the average contents of fructose in juices of Rondom (32.63 g/L) and Jonker cv. (31.94 g/L).

Glucose:fructose ratios in berry juices calculated on the base of glucose and fructose contents were shown in Table 4.

The glucose:fructose ratios in strawberry juices were from 0.83 in juice of Ducat cv. in 1998 to 1.02 in juice of Senga cv. in the same year. According to Kallio *et al.* [2000], the glucose:fructose ratio in juice of Senga VP cv. in 1997 accounted for 0.95, just as much as in our examinations in juice of Senga cv. in 1999. In other juices, however, the glucose:fructose ratios ranged from 0.88 in juice of Senga VP cv. in 1998 to 1.11 in juice of Senga SW cv. in 1997. According to Lundahl *et al.* [1989], the glucose:fructose ratio in strawberry juice was 0.87. According to the Code of Practice, the glucose:fructose ratio in strawberry juice should range from 0.75 to 1.0. This value in juice of Senga cv. in 1998 was 1.02 (exceeding by 2% the highest tolerance value), which is within the determination error limits.

The glucose:fructose ratios in raspberry juices ranged from 0.80 in juice of Beskid cv. in 1998 to 1.00 in juice of the same raspberry variety in 1999. Other authors also calculated approximate glucose:fructose ratios in raspberry juices. According to Durst *et al.* [1995], the glucose:fructose ratio was the lowest in juice of Norna cv. – 0.76, and the highest – in juice of Malling Seedling cv. – 1.03. Ratios of the two sugars were from 0.75 in juice of Marcy cv. (New Zealand) to 0.91 in juice of Meeker cv. (Washington) [Spanos & Wrolstad, 1987]. The glucose:fructose ratios ranged from 0.70 in raspberries of Haida cv. to 0.85 in raspberries of Skeena cv. [Plowman, 1991]. In our examinations, the ratio of the two saccharides in juice of Beskid cv. in 1999 was 1.00, thus it exceeded the standard range amounting to 0.6–0.95 (by 5.3%). The standard range was exceeded to a little extent, within determination error limits, and it is not suggested to change the glucose:fructose ratio in raspberry juice established in the Code of Practice.

Of the black currant juices, the lowest glucose:fructose ratio was found for juice of Ben Lomond cv. in 1998 – 0.77 and the highest – juice of Ojebyn cv. in the same year – 0.87. The average ratio of the examined monosaccharides in black currant juices was significantly higher in juice of Ojebyn cv. (0.86) in comparison to the average ratio of sugars in juice of Ben Lomond cv. (0.81). All black currant juices had the glucose:fructose ratio like that stated in the Code of Practice (0.6–0.9).

In particular years of study the glucose:fructose ratios in red currant juices ranged from 0.83 in juice of Holenderska cv. in 1999 to 1.22 in juice of Rondom cv. in 1998. A statistical analysis confirmed significant differences between the average glucose:fructose ratios in juices of three red currant varieties. In juice of Rondom cv., the ratio accounted for 1.03, in juice of Jonker cv. – for 0.93, and in juice of Holenderska cv. – for 0.84.

Results of our examinations indicated that particular saccharides (sucrose, glucose and fructose) were at similar ranges of concentrations in strawberry, raspberry, black currant and red currant juices. Individual berry juices also demonstrated similar glucose:fructose ratios. Therefore on the basis of saccharide content analysis, it cannot be concluded whether the examined berry juice does not contain the addition of other berry juice.

TABLE 4. Glucose:fructose ratios in berry juices in 1998, 1999, 2000.

| Type of juice | Fruit variety | Glucose: fructose ratios | | | |
|---|---|---|---|---|---|
| | | Year of fruit harvest | | | Average |
| | | 1998 | 1999 | 2000 | |
| Strawberry juice | Senga | 1.02 | 0.95 | 0.94 | $0.97^{E}$ |
| | Ducat | 0.83 | 0.98 | 0.96 | $0.92^{DE}$ |
| | Marmolada | 0.97 | 0.92 | 0.95 | $0.94^{E}$ |
| Raspberry juice | Beskid | 0.80 | 1.00 | 0.82 | $0.87^{CD}$ |
| | Canby | 0.85 | 0.88 | 0.88 | $0.86^{BC}$ |
| | Malling Seedling | 0.85 | 0.89 | 0.83 | $0.85^{ABC}$ |
| Black currant juice | Ben Lomond | 0.77 | 0.79 | 0.86 | $0.81^{A}$ |
| | Titania | 0.80 | 0.83 | 0.85 | $0.82^{AB}$ |
| | Ojebyn | 0.87 | 0.86 | 0.85 | $0.86^{BC}$ |
| Red currant juice | Rondom | 1.22 | 0.94 | 0.93 | $1.03^{F}$ |
| | Jonker | 0.94 | 0.89 | 0.98 | $0.93^{E}$ |
| | Holenderska | 0.85 | 0.83 | 0.85 | $0.84^{ABC}$ |

A, B – values in the columns with different letters are significantly different at $\alpha = 0.05$

The high variability of determined sucrose, glucose and fructose contents in juices made of the same berry species was due to differences in variety, stage of ripeness and climatic conditions. The high variability of determination results limits the usefulness of the present method for the examination of juice authenticity.

## CONCLUSIONS

1. It is necessary to complete the Code of Practice with the permissible contents of sucrose, glucose and fructose, as well as a glucose:fructose ratio in red currant juice.

2. Deviations from ranges of sugar contents accepted in the Code of Practice were found. Sucrose was determined in raspberry juice at a concentration of 10.42 g/L and in black currant juice at a concentration of 15.84 g/L, while according to the Code of Practice, there is no sucrose in these juices. These results pointed to the need of corrections in the Code of Practice.

3. On the basis of sucrose, glucose and fructose contents, as well as a glucose:fructose ratio, it cannot be stated whether the examined berry juice is authentic or adulterated with other berry juice.

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# ZASTOSOWANIE ANALIZY CUKRÓW DO OCENY AUTENTYCZNOŚCI SOKÓW Z OWOCÓW JAGODOWYCH

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W niniejszej pracy oznaczono zawartość sacharozy, glukozy i fruktozy w sokach otrzymanych z trzech odmian truskawek (Senga, Ducat, Marmolada), malin (Beskid, Canby, Malling Seedling), czarnych porzeczek (Ben Lomond, Titania, Ojebyn) i czerwonych porzeczek (Rondom, Jonker, Holenderska). Ponadto ustalono stosunki zawartości glukozy do zawartości fruktozy w tych sokach. Badania wykonano w trzech kolejnych latach: 1998, 1999 i 2000, przy wykorzystaniu metod enzymatycznych. Porównano otrzymane zawartości cukrów oraz stosunki cukrów z wartościami standardowymi zawartymi w Kodeksie Praktyki.

Stwierdzono odstępstwa od zakresów zawartości cukrów przyjętych w Kodeksie Praktyki i zaproponowano zmiany tych zakresów. Na podstawie zawartości sacharozy, glukozy i fruktozy oraz stosunku zawartości glukozy do zawartości fruktozy nie można stwierdzić czy badany sok z owoców jagodowych jest autentyczny, czy zafałszowany innym sokiem z owoców jagodowych.