Chaenomeles japonica, *Cornus mas*, *Morus nigra* fruits characteristics and their processing potential

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Abstract The aim of this study was to determine the suitability of Japanese quince (*Chaenomeles japonica*), cornelian cherry (*Cornus mas*) and black mulberry (*Morus nigra*) fruits as raw materials for processing. All analyzed fruits were characterized by high antioxidant activity and total phenolic content. Fruits of Japanese quince and cornelian cherry had also high acidity. Products such as fruit wines and liquors were prepared from the tested fruits. In respect of soluble solid content and reducing sugars content the obtained wine should be classified as dry wines. All analyzed liquors were characterized by similar alcohol content and the soluble solid content. Moreover, liquors made from Japanese quince and cornelian cherry were characterized by high total acidity and antioxidant capacity. The results of sensory analysis showed high commercial potential of the examined fruits.

Keywords Japanese quince · Cornelian cherry · Black mulberry · Wines · Liquors · Pro-healthy properties

Introduction

The most popular fruits such as apples, plums, grapes, cherries, apricots, oranges, grapefruits, and banana are commonly used for processing of fruits (fruit industry). Strong competition and consumers' expectations force producers of fruit products to create new products with high sensory

attractiveness and health promoting properties. Producers often use less known, exotic fruits, whereas there can be found, in Poland, many underestimated species of fruit. They usually grow wild or are planted for decorative purposes. Some of them were used in the past for juices, liquors and other products. Nowadays a growth of interest in these species can be observed, especially because of their health-promoting characteristics connected with high contents of vitamins and antioxidant components. Among others, Japanese quince, cornelian cherry and black mulberry can be named in this group (Sokół-Łętowska et al. 2009).

Japanese quince (*Chaenomeles japonica* L.) belongs to the *Rosaceae* family, subfamily *Pomoideae*. It is resistant to low temperatures, and survives well during a short vegetation period. Fruits are small, apple-shaped, about 4 cm in diameter, with a weight below 50 g, and develop yellow-green to dark yellow color with red spots (Rumpunen 2002). The characteristic, attractive aroma, as well as high contents of organic acids and fiber, together with high polyphenol and vitamin C content, creates a strong potential base for Japanese quince as raw material for processing. In Japanese quince fruit there are also present components connected to citrus aroma (Burmistrov 1994; Rumpunen 2002). Jordan et al. (2003) detected and identified 60 volatile compounds in 33 genotypes of Japanese quince. These compounds included 13 terpenic hydrocarbons, 14 alcohols, 5 ketones, 14 aldehydes and 14 esters (Jordan et al. 2003). A method for obtaining Japanese quince juice and its potential use for ice cream, lemonade, jam, curd and yoghurt production was described by Hellin et al. (2003).

Cornelian cherry (*Cornus mas* L.) belongs to *Cornaceae* family. It grows as a tree or bush, mainly growing wild or in gardens (Yilmaz et al. 2008). In controlled plantations it is grown mainly in Turkey and can achieve yields from 20 to 25 t/ha (Demir and Kalyoncu 2003). The fruit of the

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cornelian cherry is juicy, with an astringent-acid taste. The most popular varieties have olive shape fruits, dark red, but there can also be found fruit with pear or bottle shape and pink or yellow color (Gasik and Mitek 2008; Yilmaz et al. 2008). These are characterized by sweet-acid taste and specific aroma (Burmistrov 1994; Demir and Kalyoncu 2003). The astringency, being a distinctive characteristic of cornelian cherry fruit taste, is present due to high content of tannins—up to 2.5 g/100 g of fruit. The high content of organic acid, vitamin C and first of all anthocyanins of high antioxidant potential in connection with characteristic aroma and attractive red-ruby color states for great potential of cornelian cherry as raw material for the food industry (Gasik and Mitek 2008).

Black mulberry (*Morus nigra* L.) is a tree of the *Moraceae* family. There are known at least 24 species of black mulberry and more than 100 varieties. Black mulberry trees grow in tropical and subtropical climates but they are readily adaptable to other conditions, even subarctic. The black mulberry fruits are like small blackberries in shape, but they are softer. They can reach up to 2.5 cm in length and 1–1.5 cm in diameter. The black mulberry fruits are insipid in taste, which can be surely ascribed to small amounts of organic acids present (Ercisli and Orhan 2007).

The aim of the study was to assess the technological suitability of Japanese quince (*Chaenomeles japonica* L.), cornelian cherry (*Cornus mas* L.) and black mulberry (*Morus nigra* L.) for the fruit processing industry. During experiments, there were produced products of the examined fruits in laboratory conditions (wines, liquors). The chemical composition, content of polyphenols and antioxidant activity of fruits and obtained products were assessed. The sensory attractiveness of obtained products was also scored.

Materials and methods

The experimental materials were fruits of Japanese quince (*Chaenomeles japonica* L.), Cornelian cherry (*Cornus mas* L.) and Black mulberry (*Morus nigra* L.) purchased at a local market. The fruits were stored at -80°C and sampled for experiments.

Wines

Wines were produced in laboratory conditions.

The Japanese quince and cornelian cherry were chunked and pureed with pectinolytic enzymes (Pektopol, Jasło, Poland; 1 mL/5 kg, for 24 h). All fruits were pressed with a vertical basket press. The fruit musts of Japanese quince and cornelian cherry were diluted with water to obtain 9 g/L of acidity. The must of black mulberry was acidified with citric

acid to 4 g/L. All musts were sweetened to 21 % of extract and inoculated with yeast at 0.5 g level (calculated as dry weight content). For the inoculation of musts *Saccharomyces cerevisiae* (Steinberg variety for quince, Bingen variety for cornelian cherry and black mulberry) originating from the Pure Culture Collection of the Fermentation Technology and Technical Microbiology Department at the University of Agriculture in Krakow were used. Then the alcohol fermentation was performed (temp. $20\pm 2^{\circ}\text{C}$, 25 days). After the fermentation, the young wine was separated from the sediments and left for seasoning (8 months, $10\pm 1^{\circ}\text{C}$ in thermostatic cabinet).

Liquors

Japanese quince fruits, after washing, were stoned and broken up, and then were macerated with 40 % ethanol solution (1 kg with 1 L, 20°C , 6 weeks). Then the tincture was decanted, fruits had sugar (saccharose, 0.5 kg) poured on and were left to dissolve, then spilt once again with the first decanted tincture and left for 6 weeks. After that time the liquor was filtered and used for experiments.

The cornelian cherry fruits were spilt with 60 % ethanol solution (1 L for 1 kg) and left for 6 weeks (temp. 20°C). Then the treatment as for obtaining Japanese quince liquor was used.

The liquor of black mulberry was prepared in the same way as for cornelian cherry but without breaking of fruits.

All the products were prepared in three repetitions.

Estimation of dry weight of fruits

Dry weight was estimated by the drying method and results were expressed in %.

Estimation of extract of raw fruit

Homogenates were prepared (homogenizer Ultra Turrax T 25 basic, IKA®, Staufen, Germany; 5 min, 22,000 rpm) of 40 g of stoned fruits and 160 mL of distilled water. Then 100 g of homogenates was sampled, boiled for 5 min, and cooled. Then, distilled water was added up to 100 g and filtered. The extract was measured with Abbe's refractometer [%].

Estimation of total acidity of raw fruits

From the above prepared homogenates (40 g of stoned fruits and 160 mL of distilled water; homogenizer Ultra Turrax T 25 basic; 5 min; 22,000 rpm) 25 g was weighed and 100 mL of distilled water was added, then boiled. After cooling, the solution was filtered and a sample of 50 mL was taken. Then it was titrated with 0.01 M NaOH solution to pH=8.1. The result was expressed as g/100 g of malic acid.

Estimation of fermenting sugar content in fruits and glycerol and residual sugar in wines

The fresh fruit sample in the amount of 10.0 g was triturated in a mortar, resuspended in 50 mL of water and centrifuged (15 min, $1,745\times g$, 20 °C). The wines were only centrifuged. The measurements were performed with a liquid chromatograph (HPLC, Dionex USA). The samples were eluted isocratically at 85 °C from the ion exchange column (Bio-Rad Aminex HPX 87C, 300×7.8 mm) with mobile phase flow at 0.6 mL/min. As an eluent deionised water was used. Before each analysis, samples were dissolved (1:100) and filtered with ϕ 0.44 μ m pore filters. The injection volume was 20 μ L. The chromatography peaks were identified by comparison of particular retention times with external standards. The qualitative and quantitative calculations were performed with Chromeleon 6.80 software.

Titrateable acidity, volatile acidity, alcohol concentration and extract contents in wines and liquors

Titrateable acidity, volatile acidity, alcohol concentration and extract contents in wines and liquors were determined according to the International Organization of Vine and Wine (OIV) Compendium of International Methods of Wine and Must Analysis (2006) (OIV 2006).

Volatile compounds analysis of wines (GC-SPME)

Two milliliters of each wine sample was transferred to a 15 mL amber vial having a screw cap (Supelco) with a magnetic stirrer and 1 g of NaCl, then 2 μ L of internal standard (4-methyl-2-pentanol) was added. For sampling, fiber (PDMS, 100 μ m) was inserted into the headspace under magnetic stirring (300 rpm) for 35 min at 40 °C. Subsequently, the SPME device (Supelco Inc., Bellefonte, PA, USA) was introduced in the injector port for chromatographic analysis and was left in the inlet for 2 min.

The GC-SPME analysis was performed on a Hewlett Packard 5890 Series II chromatograph system. The tested components were separated on a HP-INNOVAX capillary column (cross-linked polyethylene glycol stationary phase; $30\text{ m}\times 0.53$ mm ID with 1.0 μ m film thickness). The detector and injector temperature was 250 °C, and the column was heated using the following temperature program: 35 °C for five minutes at an increment of 5 °C/min to 110 °C, then 40 °C/min to 220 °C and maintaining a constant temperature for three minutes. The carrier gas was helium at 20.0 mL/min flow. Hydrogen flow rate was 33.0 mL/min, and that of air was 400 mL/min.

The qualitative and quantitative identification of volatile substances (acetaldehyde, 3-hydroxy-2-butanone, acetone, amyl alcohols, butanol, 2,3-butanedione, ethyl acetate, ethyl

butyrate, ethyl isovalerate, hexanol, isobutanol, methanol, pentanol, propanol, 1,3-propanediol, 2-phenylethanol) was based on the comparison of retention times and peak surface area read from sample and standard chromatograms.

Antioxidant activity assay

Antioxidant activity was determined according to Tarko et al. (2009). ABTS radical was generated in the chemical reaction between the 7 mM diammonium salt of the 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic) acid and the 2.45 mM potassium persulfate. In order to terminate the reaction and to stabilize the ABTS cation-radical the solution was kept overnight in the dark at ambient temperature. Prior to analysis the radical solution was diluted with phosphate buffer saline (pH 7.4) in such a way that allowed for obtaining the final absorbance of $A=0.70\pm 0.02$ (ABTS_{0.7}) measured at 734 nm.

Fruits were freeze-dried and were extracted with 80 % methanol (0.5 g in 25 mL). One hundred-microlitre aliquots of diluted samples of extracts, wines, liquors or Trolox solution (concentrate 1–10 mg/100 mL) were added to 1 mL of ABTS_{0.7}, and the absorbance was measured 6 min after mixing (spectrophotometer BECKMAN DU 650, USA). Antioxidant capacity was calculated using a standard curve obtained by measuring the absorbance of solutions of water-soluble analog of vitamin E (Trolox, SIGMA-Aldrich) and expressed in μ M of Trolox/100 g of fruits or μ M of Trolox/100 mL of wines and liquors.

Estimation of total content of polyphenols

An amount of 5 mL of 80 % methanol fruits extract (0.5 g in 25 mL) or wines or liquors was dissolved in 45 mL of redistilled water. Then the 5 mL of this solution was added to 0.25 mL of Folin-Ciocalteu reagent (water dissolved 1:1 v/v) and 0.5 mL of 7 % Na₂CO₃. The mixture was left for 30 min in the dark. Then the absorbance was measured on a spectrophotometer (spectrophotometer BECKMAN DU 650, $\lambda=760$ nm). The obtained results of total polyphenol content were expressed as mg catechin equivalents/100 g of fruits or mg catechin equivalents/100 mL of wines and liquors, based on the standard plot.

Sensory evaluation

The sensory assessment of wines, liquors was performed using the point method (PN-64/A-04022 1964). A panel (25 persons) assessed each of the sensory descriptors (clarity, color, taste and aroma), rating according to a 10-point scale (1 = bad to 10 = very good). The following coefficients of importance were used: taste—0.4, aroma—0.3, clarity—0.15 and color—0.15.

Statistical analysis

There were a minimum of three replications of the whole analysis. The results are shown as the arithmetic mean ($\pm$ standard deviation). The Kolmogorov-Smirnov test was applied to assess the normality of distribution. Single-factor analysis of variance (ANOVA) with *post hoc* Tukey test was applied to assess the differences between means (InStat, Version 3.01, GraphPad Software, Inc., San Diego, CA).

Results and discussion

Fruits

The Japanese quince, cornelian cherry and black mulberry fruits were characterized for their chemical composition (Table 1).

Among the analyzed fruits, the cornelian cherry was characterized by the highest amount of dry weight, extract and sugars. The acidity was the highest for Japanese quince, whereas the black mulberry fruit stood out for its very low acidity level. The obtained results present the typical level of assessed parameters for cornelian cherry and Japanese quince (Lesińska 1987; Demir and Kalyoncu 2003). In contrast, significant differences were noted for dry weight content in ripe black mulberry fruit, which according to other authors should be at the level of 20 to 30 % (Ercisli and Orhan 2007). The results obtained in this work were much lower and were caused, most probably, by unfavorable weather conditions during ripening, mainly because of heavy rainfall, and premature harvest. The high acidity of Japanese quince and cornelian cherry and unfavorable ratio of acids to sugars exclude their consumption in a raw state (Yilmaz et al. 2008). Among the assessed fruits only the black mulberry fruit was suitable for direct consumption. Based on antioxidant activity and total polyphenol content (Table 1) the assessed fruits can be assigned to fruit raw material of a very high antiradical potential (Rumpunen 2002; Gasik and Mitek 2008). The products obtained from them also should be characterized by high antioxidant properties.

Wines

The results of the analysis of wines are presented in Table 2.

Taking into account the results of extract and reducing sugars content the obtained wines can be classified as dry (PN-A-79121 1998). The largest amount of residual sugars was found in Japanese quince wine. Their presence was probably connected to decomposition of dextrans, which were present in not fully matured fruit. The high total extract was also in accordance with the norm, which defines only the lower limit of extract content—15 g/L for white wines and 16 g/L for red wines.

The ethanol content of wines obtained in this work was in accordance with the Polish Norm (from 9 % to 18 %). The lower concentration of ethanol found in Japanese quince wines correlated with the high amount of residual sugars. Darias-Martin et al. (2003) showed that not sweetening of black mulberry musts caused that the concentration of ethanol in obtained wines did not achieve 8 %, whereas the addition of saccharose syrup raised the strength up to 11.5 %. It should be underlined that the authors (Darias-Martin et al. 2003) obtained those levels with *Saccharomyces cerevisiae* yeast fermentation. Fermentation with the native microflora did not give a satisfactory effect.

The total acidity expressed as malic acid for wines of cornelian cherry was higher than that set by the Polish Norm (above 9 g/L) and was the result of high raw material acidity. The lowering of that value would demand greater dilution of must, application of deacidifying components or coupage with wines with much lower acidity. The rest of the wines achieved acidity in the range described by the norm, but the black mulberry wine was acidified. The total acidity of wines obtained from black mulberry wines examined by Darias-Martin et al. (2003) reached 20.4 g/L (calculated as malic acid). The volatile acidity of all analyzed wines ranged from 0.4 to 1.13 g of acetic acid per liter. That value for black mulberry wines was the highest, but in accordance with requirements set in the Polish Norm (up to 1.4 g/L). Much lower values of volatile acidity were measured by Darias-Martin et al. (2003) for wines produced from black mulberry (lower than 0.6 g/L).

Table 1 Chemical composition and antioxidant activity of Japanese quince, Cornelian cherry and Black mulberry fruits

Parameters	Japanese quince	Cornelian cherry	Black mulberry
Dry weight [%]	12.9 $\pm$ 0.43 ^a	20.3 $\pm$ 0.47 ^b	12.5 $\pm$ 0.70 ^a
Extract [%]	9.4 $\pm$ 0.72 ^a	15.0 $\pm$ 0.00 ^b	5.6 $\pm$ 0.72 ^c
Fructose [%]	0.5 $\pm$ 0.01 ^a	3.7 $\pm$ 0.04 ^b	1.4 $\pm$ 0.02 ^c
Glucose [%]	1.6 $\pm$ 0.01 ^a	5.4 $\pm$ 0.05 ^b	0.99 $\pm$ 0.085 ^c
Total acidity (as malic acid) [g/100 g]	4.1 $\pm$ 0.02 ^a	3.9 $\pm$ 0.02 ^b	0.39 $\pm$ 0.000 ^c
Antioxidant activity [μ M Trolox/100 g]	10512.0 $\pm$ 37.05 ^a	7123.0 $\pm$ 14.62 ^b	7449.0 $\pm$ 21.34 ^c
Total polyphenol contents [mg catechin equivalents/100 g]	924.0 $\pm$ 11.71 ^a	611.0 $\pm$ 8.11 ^b	674.0 $\pm$ 1.02 ^c

^{a,b,c}The same letters mean no significant differences for analysed parameters, $p < 0.05$; the experiments were done in triplicate

Table 2 Chemical composition, antioxidant activity and sensory overall acceptability quality of wines produced of Japanese quince, Cornelian cherry and Black mulberry fruits

Parameters	Wine		
	Japanese quince	Cornelian cherry	Black mulberry
Ethanol content [%v/v]	10.1±0.12 ^a	11.8±0.33 ^a	11.4±0.21 ^a
Extract [g/L]	60.0±2.01 ^a	31.1±1.02 ^b	39.0±1.03 ^c
Glycerol [g/L]	4.8±0.19 ^a	5.7±0.12 ^b	6.2±0.64 ^b
Fructose [mg/100 mL]	0.00±0.00 ^a	141.9±0.65 ^b	14.2±2.36 ^c
Glucose [mg/100 mL]	465.7±4.20 ^a	40.3±0.26 ^b	44.4±2.49 ^c
Total acidity (as malic acid) [g/L]	8.4±0.34 ^a	10.3±0.04 ^b	6.4±0.16 ^c
Volatile acidity (as acetic acid) [g/L]	0.46±0.022 ^a	0.40±0.074 ^a	1.1±0.20 ^b
Antioxidant activity [μ M Trolox/100 mL]	2356.2±182.29 ^a	731.2±26.99 ^b	1049.8±67.55 ^c
Total polyphenol content [mg catechin equivalents/100 mL]	194.4±5.54 ^a	74.8±11.84 ^b	119.6±6.94 ^c
Volatile components [mg/L]			
2-Phenylethanol	38.0±3.69 ^a	49.7±6.83 ^b	44.8±6.05 ^c
Acetaldehyde	45.0±6.61 ^a	21.0±2.51 ^b	18.6±1.34 ^b
Acetone	11.3±0.50 ^a	11.4±0.65 ^a	10.0±0.52 ^b
Isoamyl alcohols	239.1±20.00 ^a	437.7±46.97 ^b	223.6±13.03 ^a
Isobutanol	98.8±9.99 ^a	143.9±19.12 ^b	141.2±11.12 ^b
Methanol	30.5±0.44 ^a	32.5±1.51 ^b	35.5±1.12 ^c
Ethyl acetate	63.9±5.57 ^a	39.6±1.54 ^b	111.0±19.45 ^c
Propanol	32.8±10.82 ^a	35.1±5.85 ^a	53.9±21.33 ^b
Sensory overall acceptability score [pt]	8.3±1.33 ^a	7.01±1.46 ^a	7.1±1.10 ^a

^{a,b,c}The same letters mean no significant differences for analysed parameters, $p < 0.05$; the experiments were done in triplicate

Glycerol, which is one of the basic side-products of fermentation by yeast, gives the wines a rich aroma and mellow taste during consumption. In grape wines it is present mostly in the amount of about 4 g/L, and the highest concentration which advantageously influences taste was stated as 26 g/L (Sehovic et al. 2004). In this work, contents of glycerol obtained in wines ranged from 4.7 to 6.2 g/L.

As expected, the total polyphenols content in the assessed wines depended on the raw material used. The highest levels were measured for Japanese quince wines and the smallest for cornelian cherry, although both musts were considerably diluted by water. The obtained values were strictly correlated with antioxidant activity ($R^2=0.98$). The cornelian cherry wine obtained in this work showed antioxidant properties close to cherry wines, whereas wines from Japanese quince and black mulberry contained higher polyphenols than most grape wines, fruit wines and ciders analyzed in our previous study (Tarko et al. 2008). Minussia et al. (2003) reported levels of polyphenols in white grape wines at 21–85 mg of gallic acid/100 mL of wines, and Satora et al. (2008), in wines of different apple varieties, assessed it ranging from 23 to 64 mg of gallic acid/100 mL. The Japanese quince wines can be compared in the range of polyphenols content to blackcurrant wines (at about 210 mg/100 mL of wine). It should be mentioned that grape wines are produced commonly from non-diluted must, so the real values assessed for Japanese quince and cornelian cherry musts were much higher

than for grape ones. The wines obtained from the assessed fruits seem to be an interesting proposal showing antioxidant activity at levels allowing for their classification as products with high scavenging abilities. The differences in antioxidant activity of wines originate from differences in raw material composition. The highest antioxidant ability and at the same time the biggest positive influence on human health are shown by the high molecular weight flavonoids tannins. The flavonoids are present mostly as glycosides characterized by lower antioxidant potential than aglycones. In black mulberry fruit, cyanidin-3-glucoside constitutes over 70 % of anthocyanins. There is also observed a large proportion of cyanidin-3-rutinoside (Thomas-Barberan and Espin 2001; Pérez-Gregorio et al. 2011). The cornelian cherry fruit contains the largest amounts of cyanidin-3-galactoside, delphinidin-3-galactoside, and pelargonidin-3-galactoside (Seeram et al. 2002). Strong antioxidant characteristics are also shown by trans-resveratrol, belonging to the stilbenes group, present in considerable amounts in black mulberry fruits (Thomas-Barberan and Espin 2001). For comparison, among the anthocyanins in red grapes malvidin derivatives dominate and they constitute more than 60 % of total anthocyanins (Figueiredo-González et al. 2012).

Total scores obtained in sensory assessment tests for examined wines differed slightly (no statistically significant differences were noted). The Japanese quince wine obtained the highest scores for almost every category, with the exception of

clarity (slightly opalescent, possible to eliminate during clarification). The cornelian cherry wine obtained a relatively low total score mainly because of acid taste (which was confirmed by total acidity analysis results) and less intensive color. That suggested that in the recipe the maceration of the whole fruits should be considered in order to extract dyes, which are present mainly in peels. The lowered scores of sensory assessment of black mulberry wines were mainly the result of contradictions against taste, which was described as not typical for the raw material used. Negative impressions, in the case of cornelian cherry wine, could also have been influenced by the high content of isoamyl alcohol and other higher alcohols (above 500 mg/L). According to Vidrich and Hribar (1999) the content of fusels in wines below 300 mg/L strengthened the desired aroma, whereas the level above 400 mg/L is assessed negatively.

Table 2 presents the results of assessment of selected volatile components in wines.

Among obtained compounds the isoamyl alcohols dominated, and the cornelian cherry wine contained as much as twice the amount (438 mg/L) of the other wines. High concentrations of isobutanol were shown mainly in black mulberry and cornelian cherry wines (at about 140 mg/L), and ethyl acetate with a sweet, strong aroma was the third, in proportion, volatile component of Japanese quince and black mulberry wines. A considerable concentration of acetaldehyde was measured in Japanese quince wine (45 mg/L). There were also detected, in smaller amounts, methanol, propanol, 2-phenylethanol and acetone. The rest of the assessed compounds (1,3-propandiol, 3-hydroxy-2-butanone, butanol, ethyl butyrate, 2,3-butanedione, hexanol, ethyl isovalerate, pentanol) was present in the concentrations lower than the detection level of the applied method.

The volatile compounds assessed in the examined wines are also present in wines obtained from other fruits, including grapes (Selli et al. 2004). The concentration of isoamyl alcohols in wines of Japanese quince and black mulberry was comparable to that for grape wines (Minussia et al. 2003). The concentration of propanol was five times lower in wine of cornelian cherry than in other cherry products (154 mg/L) (Minussia et al. 2003). Also the isobutanol in

cherry wine was present in larger amounts than products examined in this study. In Japanese quince and cornelian cherry wines, obtained amounts of ethyl acetate were comparable to results measured for grape wines, and black mulberry wines could be compared (for that parameter) to cherry ones (Minussia et al. 2003). The profile of volatile compounds in cornelian cherry wines was close to results obtained by Tesević et al. (2009), who analyzed distillates of fermented cornelian cherry fruit—“Drenji”. The authors identified acetaldehyde, ethyl acetate, methanol, propanol, butanol, isoamyl alcohols and 2-phenylethanol.

The aroma and compounds creating it in wine depend not only on the variety of fruits used but also on climate and weather conditions during ripening. In different regions of the world, fruit of the same variety can be characterized by different composition of volatile compounds (Alves and Franco 2003). The yeasts used have also an important influence on the content of volatile compounds in wines. Stashenko et al. (1992) found that the largest amount of volatile compounds was generated on the third day of fermentation and from this point their production falls considerably.

The obtained wines met the requirements of the norm for most parameters. They can be used as single component wines and also as coupage wines, especially as the acidifying components for wine with too low acidity. They would add to the final compositions taste and aroma elements uncommon in other fruits, enriching the spectrum of fruit wines.

Liquors

Liquors are obtained as the macerates of fruit with ethyl alcohol, with possible sugar addition, and have ethanol concentration of at least 25 % (PN-A-79530 1995). The chemical analyses of prepared liquors were carried out and their antioxidant properties were assessed. The obtained results are presented in Table 3.

Based on measured parameters the experimental liquors can be classified (because of extract) between semisweet and sweet vodkas. It is interesting that the ethanol concentration of Japanese quince and black mulberry liquors was

Table 3 Chemical composition and sensory overall acceptability quality of Japanese quince, Cornelian cherry and Black mulberry liquors

Parameters	Liquors		
	Japanese quince	Cornelian cherry	Black mulberry
Ethanol content [% v/v]	27.3±1.02 ^a	26.1±0.82 ^b	28.2±0.21 ^a
Extract [g/L]	202.2±1.04 ^a	229.0±6.01 ^b	248.2±4.01 ^c
Total acidity (as malic acid) [g/L]	46.8±2.00 ^a	52.3±0.52 ^b	5.5±0.20 ^c
Antioxidant activity [μM Trolox/100 mL]	6289.4±173.07 ^a	5064.2±248.94 ^b	1374.9±33.84 ^c
Total polyphenol content [mg catechin equivalents/100 mL]	310.7±15.64 ^a	153.5±15.39 ^b	134.3±3.26 ^c
Sensory overall acceptability score [pt]	9.0±0.94 ^a	9.1±0.86 ^a	8.5±1.20 ^a

^{a,b,c}The same letters mean no significant differences for analysed parameters, $p<0.05$; the experiments were done in triplicate

similar, although for their production 40 and 60 % ethyl alcohol was used, respectively. The black mulberry liquors showed the highest concentration of extract (248 g/L), statistically higher than in other products. Taking into account the fact that proportions of raw material used for liquors production were the same, the differences should be the result of diversity in raw materials. However, black mulberry was characterized by the lowest extract among the assessed fruits, and the dry weight did not differ statistically between Japanese quince and black mulberry. Such results may suggest better extractivity of black mulberry components than of Japanese quince. The acidity of assessed liquors was rather high, but originated only from macerated raw fruit. There were not found data concerning the ethanol concentration, extract and acidity of assessed liquors. The research focused more on pro-health and sensory values of those alcoholic products.

The content of polyphenol assessed in the experimental liquors was much higher than in wines obtained from the same raw materials. The biggest difference was measured for cornelian cherry liquors because of maceration of fruits with stones and peels, which are a rich source of polyphenols. It was found that stones and peels of fruit contain about 90 % of all fruit polyphenols (Tarko et al. 2009). The results obtained in this work can be compared to results obtained by Sokół-Łętowska et al. (2009) for liquors of black rose, black chokeberry, blackcurrant and strawberry. The values reported by researchers ranged from 150 mg of gallic acid/100 mL (strawberry liquors) to 1,300 mg/100 mL (black rose). It was also found (Sokół-Łętowska et al. 2009) that the highest concentrations of polyphenol compounds in liquors were present 9 months after production. Liquors in this work ripened considerably sooner (6 weeks).

The antioxidant activity of Japanese quince and cornelian cherry liquors was significantly higher than that for the respective wines (from 2.5 to 7.0 times). The obtained values arise from the affinity of antioxidant compounds, mainly of polyphenols, to ethyl alcohol (Peschel et al. 2006). Pinelo et al. (2004) observed that the solvent used influenced not only the amounts of extracted compounds but also their activity. Ethanol was found to be one of the most effective solvents and it can be used for food production. In the assessed liquors the ethanol content was 2–3 times higher than in analogue wines, which can explain the higher antioxidant potential of those products. It was also found that improper choice of extractor could favor the decomposition of polyphenols, e.g. of proanthocyanidins to compounds of lower antioxidant activity. Peschel et al. (2006) demonstrated that polyphenol compounds dissolve in 50 % aqueous solution of ethanol in the best way.

Based on the sensory test data analyses it can be concluded that liquors were assessed higher than the respective wines. Especially high marks (Table 3) were obtained by

cornelian cherry and Japanese quince liquors. They can be classified as products with high economic potential and it can be assumed that prospective customers will accept such products. The obtained liquors can also be recognized as good sources of antioxidants. The liquors produced as in the described recipes can be introduced as such to the market with a great probability of success. The fruits used seem to be a very good raw material for production of liquors, which may be attractive for consumers because of their original sensory characteristics as well as their health promoting properties.

Summary

All examined fruits showed considerable antioxidant activity (7,122–10,512 μ M Trolox/100 g) and high polyphenol content (611–924 mg catechin equivalents/100 g). The studied fruits had a specific flavor and aroma, described as attractive and desirable. The obtained results suggest that all the fruits could be used for fruit processing. Results of the sensory analysis showed high commercial potential of the examined fruits. This is very important because, due to inappropriate acid to sugar ratio, Japanese quince and cornelian cherry are unfit for direct consumption. Considering the data obtained from chemical and sensory evaluation it was concluded that the best way to process the examined fruits is production of liquors and fruit wines as a component of multicomponent fruit wines (also homogeneous wines in the case of Japanese quince).

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