THE SUITABILITY OF DIFFERENT ROWANBERRY CULTIVARS FOR PRODUCTION OF FRUIT MARMALADE

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Abstract
The rowanberries (*Sorbus aucuparia* L.) are small orange-red fruits of a rowan tree and belong to the family *Rosaceae*. These berries have been described as an important source of flavonoids, and their antioxidant activity affects reactive oxygen species and lipid peroxidation; therefore they are suitable for production of health-food products. The ripe wild rowanberries have traditionally been used for jellies and jams, but their use as a food ingredient has been less popular because of their bitter taste. Sweeter and less astringent than wild rowanberries are different cultivars of sweet rowanberries and hybrids with other species. The aim of the current research was to determine physical and chemical parameters and sensory properties of rowanberry marmalades. The experiments were carried out in the Faculty of Food Technology of Latvia University of Agriculture. The purees of wild rowanberry and six different rowanberry cultivars were chosen for the production of marmalades. Chemical, physical and sensory indices of the product – moisture, total carotenoids, tannins, colour, hardness and intensity of sensory properties (flavour, colour, bitterness) – were determined as quality indicators. The results showed large variability in the physical and chemical parameters between the marmalades of different rowanberry cultivars and hybrids. The sensory evaluation of marmalades from rowanberry cultivars 'Moravica', 'Mitchurinskaya krasnaya', 'Sorbinka' and hybrid of rowanberry × hawthorn 'Granatnaya' showed that the degree of liking was from "neither like nor dislike" to "like moderately", and marmalades from wild rowanberry, *S. aucuparia* var. *sibirica* and hybrid of rowanberry × pear 'Alaya Krupnaya' – from "dislike moderately" to "dislike slightly".
Key words: Rowanberry marmalade, carotenoids, tannins, colour, hardness, sensory evaluation.

Introduction

The rowanberries (*Sorbus aucuparia* L.) belong to the subfamily *Maloideae* of the family *Rosaceae* and their berries have been promoted as a health-food or can be a source for health-promoting components. The ripe wild rowanberries are picked in the autumn and they are eatable, but very tart in flavour and taste although contain lots of sugar. Rowanberries have been traditionally used to make purees, juices or wine and they make an excellent jelly because of their high amount of pectin, but their use as a food ingredient has been less popular because of their bitter taste (Hukkanen et al., 2006; Poyrazoğlu, 2004; Gough, 2008; Wang, 2007).

Sweeter and less astringent than wild rowanberries are different cultivars of sweet rowanberries and hybrids with other species. The first sweet rowanberry clones were selected in the Sudety mountain area, in the current Czech Republic area in the 19th century. A breeding program for sweet rowanberries was started by Michurin in Russia at the beginning of 20th century, resulting in interesting hybrids of the rowanberry (*Sorbus aucuparia* L.) with the *Aronia, Malus, Mespilus,* or *Pyrus* species. Sweet rowanberries have been bred particularly for northern conditions and have shown excellent winter-hardiness in Russia and Finland (Hukkanen et al., 2006). According to food composition and nutrition tables, sweet rowanberry *S. aucuparia* L. var. *edulis* contains 1600–2420 mg of organic acids per 100 g of edible portion, 98 mg of vitamin C per 100 g, and 2.5 mg of total carotenoids per 100 g (Souci et al., 2008). Comparison of the data obtained to wild rowanberries sugar content indicated that cultivars of the sweet rowanberries were really the sweetest – sugar content in their fruits were considerably 1.2–2.1 times higher (Navys, 2001). The content of reducing sugars (i.e. total amount of glucose and fructose) ranged from 5 to 18 g 100 g^{-1} (Souci et al., 2008, Eder et al., 1991). The content of sorbitol, a sweetening agent that diabetics can tolerate, was high and varied from 3.5 to 12 mg 100 g^{-1} (Eder et al., 1991; Стрельцина et al., 2010).

Sweets constitute the group of food for which human beings have always had some inborn preferences because the majority of sweet fruits or edible parts of plants found in the natural environment are not poisonous. The group of sweets includes honey, candies, jellies and marmalades, candied fruits, sweets made of cacao, and other (Borawska, 2007). Historically, jams and jellies may have originated as an early effort to preserve fruit for consumption in the off-season. Processing of different fruits into juice, marmalade or jam is important for insuring of fruits during all year. Jellies, jams and marmalades are primary distinguished by the form from which their fruit is incorporated. Marmalades are basically jellies with fruit purée and sugar-acid-pectin gel or low-methoxyl pectin-calcium gels. Pectin is traditionally used in a wide range of fruit-based products in which it acts as a thickeners agent (Figuerola, 2007; Grujić et al., 2010; Baker et al., 1996; Willats et al., 2006). Marmalade is a spreadable preparation made from pulp, slurry, juice, aqueous extracts or peels of citrus fruits and sugars. The product has to contain at least 60% by weight of

soluble solids. The addition of fruit pectin and starch syrup is customary. For the production of marmalade, the fresh fruits or intermediary products, such as fruit pulps or slurries, are boiled with the addition of sugar. Other ingredients (gelling agents, starch syrup and acids) are added before the thickening is completed by boiling (Belitz, 2009).

Berries are one of the most suitable fruits for processing into jams and jellies because of their quality, acidity, colour, normally high pectin content, flavour, and aroma. If the fruit does not have enough pectin, commercial pectin has to be used, where a mixture of the required pectin with a similar portion of sugar should be added after the concentration process to avoid heat damage to the pectin molecules. Sugar and other minor ingredients help to develop texture of jams and marmalades because of the formation of a gel between sugars and pectin substances along with fruit acidity. The proportions of fruit and sugar for mixtures should not be less than 45–47 parts by weight of fruit to each 55 parts by weight of sugar (Grujić et al., 2010; Figuerola, 2007).

Acidity of the fruit or its pH value is one of the most important factors in jam process. If the fruit does not have enough acid, a controlled amount of organic acid, such as citric or malic acid, sodium citrate or other is added to reach the required pH to produce gel formation. For gel formation and its stability it is important to insure optimal pH range – 2.5-4.5 (Figuerola, 2007; Javanmard and Endan, 2010; Grujić et al., 2010; Willats et al., 2006).

The purpose of the current research was to determine physical and chemical parameters and sensory properties of fruit marmalades made from sweet rowanberries.

Materials and Methods

Experimental design

The research was carried out at the Faculty of Food Technology, Latvia University of Agriculture, in 2011. The object of the research was fruit marmalade from berries of different rowanberry cultivars grown in Latvia. The rowanberries were picked in the Pure Horticultural Research centre; description of used rowanberry cultivars is given in Table 1. The fruit marmalades were made from rowanberry purees. The rowanberry purees were made from frozen and thawed fruits that were scrubbed through sieve. The mass, mixed with sugar (sucrose – 23.5% from the total amount of product), was heated till 85–90 °C to evaporate part of the water, adding 5.0% pectin (Gen pectin LM-104-AS powder) mixed with part of sugar. The samples of rowanberry marmalade were filled in polypropylene boxes and stored three days at room temperature (22±2 °C) for ripening and thickening. Dimensions of one piece of marmalade on average was 90×70×20 mm, and mass – 100±5 g.

Seven samples of rowanberry marmalades were prepared in this research. Chemical, physical and sensory analyses of the products – moisture content, pH, total carotenoids and tannins, colour L*a*b* values, hardness and intensity of sensory properties (flavour, colour, bitterness) – were determined as quality indicators.

Methods

The moisture content of fruit marmalade was determined with an oven method. The marmalade samples (10 g) were dried at 97 °C overnight (Mattila et al., 2006). For analysis, vacuum drying oven VD53 (Binder) and analytical scales BP-210s (Sartorius)

Table 1

The description of rowanberry cultivars used for research

Rowanberry cultivar	Sort characteristic	Description of fruits
Sorbus aucuparia	Wild rowanberry	Orange or bright red coloured fruits with bitter taste
S. aucuparia var. *sibirica*	Variety of *S. aucuparia*	Orange coloured fruits with bitter taste
'Moravica'	Moravian group variety of *S. aucuparia*	Orange-red coloured fruits with sweet and sour taste
'Sorbinka'	Moravian group variety of *S. aucuparia*	Orange coloured fruits with sweet and sour taste
'Mitchurinskaya krasnaya'	Variety of *S. aucuparia*	Dark red coloured fruits with sweet and sour taste
'Granatnaya'	Hybrid of rowanberry × hawthorn (*Sorbus aucuparia* × *Crataegus sanguinea Pallas)*	Dark red or brown coloured fruits with sweet and sour taste
'Alaya Krupnaya'	Hybrid of rowanberry × pear (*Sorbus aucuparia* × *Pyrus* sp. × *Sorbus aucuparia* var. *moravica*)	Bright red-brown coloured fruits with littlebit bitter taste

were used. Measurements were carried out in three replications.

The pH value was measured by FieldLabpH pH-meter (Schott), using standard method LVS ISO 5542:2010.

The total carotenoids content was analysed by the spectrophotometric method at 440 nm (Ермаков, 1987) extracted with petroleum ether (boiling temperature range – 80–110 °C) and measured with UV-VIS-NIR spectrophotometer UV-3100PC (Shimadzu) in 10 mm cuvettes. A total of 2–3 grams of homogenized marmalade were placed in a conic retort (100 ml) and 96% ethanol (20 ml) was added, and then samples were stirred by a magnetic stirrer for 20 min. Then petroleum ether (25 ml) and water (1 ml) were added, and stirring was continued for one more hour. After 3–4 hours, the top (yellow) layer was used for the detection of total carotenoids. The carotene equivalent (KE) was found, using graduating curve with $K_2Cr_2O_7$. Measurements were carried out in two replications for each sample.

The total tannins content was detected using the traditional method by titration with 0.1 N $KMnO_4$ (Шмыдт, 1960). Measurements were carried out in two replications for each sample.

The colour of rowanberry marmalades was measured in CIE L*a*b* colour system using a *ColorTec-PCM/PSM* (Accuracy Microsensors Inc.). Before measuring, the colorimeter was calibrated using a white reference tile and a light trap (black tile). Ten random areas were measured through the plastic pockets and mean values were reported for each sample. In colour measurement, CIELAB coordinates show the degree of brightness (L), the degree of redness (+a), or greenness (–a), and the degree of yellowness (+b), or blueness (–b), respectively (Coultate, 2002; Chakrborty et al., 2011).

The structure parameter – hardness (cutting force in N) – of the rowanberry marmalades was determined on the Texture Analyser *TA.XT.plus* (Stable Micro Systems Ltd.) and the measuring probe A/BC (butter cutter can be used for soft samples, supplied in association with the Texture Analyser) according to the method described by Muizniece-Brasava et al. (2011). The system was equipped with compression cell of 50 kg and software Texture Exponent 32. Hardness was measured as the maximum penetration force (N) reached during breakage of tissue. Hardness was measured as the maximum penetration force (N) reached during breakage of tissue. The measuring parameters were: pre-test speed – 1 mm s^{-1}; test speed – 1 mm s^{-1}; post-test speed – 10 mm s^{-1}; cutting distance – 10 mm pressing into the sample. The maximum force required for sample compression was calculated as an average of 10 measurements.

Sensory evaluation of the rowanberry marmalades was performed in the Laboratory of Sensory Evaluation at the Faculty of Food Technology of the Latvia University of Agriculture. All rowanberry marmalade samples were evaluated by 25 trained panellists (18 females and 7 males, mean age – 32). Rowanberry marmalade samples were manually divided in 20×20 mm pieces with a knife and presented in three-digit coded containers, and the order of serving was determined by random permutation. The intensity of sensory properties of rowanberry marmalades (colour, flavour and bitterness) was evaluated using line scale, but the degree of liking was evaluated by nine-point hedonic scale (ISO 4121:2003). The obtained data was averaged across panellists. Hedonic scale includes 9 points, which allows evaluating the degree of liking. The points are from “like very much” (9) to “dislike very much” (1) and middle point “neither like nor dislike” (5).

The results represent the mean ± standard deviations. The obtained results were analysed using analysis of variance (ANOVA) and Tukey’s test when significant differences among the rowanberry marmalade samples were found. Statistical differences with *p*-values under 0.05 were considered as significant. Closeness of the relationship between the parameters was determined by analysis of Pearson correlation coefficient.

Table 2

The physical and chemical parameters of rowanberry marmalades

Rowanberry cultivar	pH value	Moisture content, %	Carotenoids, mg 100 g^{-1} DW	Tannins, g 100 g^{-1} DW
‘Granatnaya’	3.33±0.01 ^{c}	36.72±0.07^{c}	2.02±0.14 ^{bc}	0.16±0.02^{c}
‘Moravica’	3.27±0.02^{d}	36.08±0.06^{c}	1.59±0.06 ^{bcd}	0.06±0.02^{d}
Wild rowanberries	3.25±0.02^{d}	38.98±0.16^{b}	2.24±0.19 ^{bc}	0.28±0.04 ^{ab}
S. aucuparia var. *sibirica*	3.46±0.02 ^{a}	39.07±0.14^{b}	3.52±0.68 ^{a}	0.30±0.03 ^{a}
‘Sorbinka’	3.30±0.02 ^{cd}	42.59±0.09^{a}	1.08±0.09^{cd}	0.14±0.01^{cd}
‘Mitchurinskaya krasnaya’	3.40±0.01 ^{b}	43.47±0.12^{a}	2.88±0.04 ^{b}	0.14±0.02^{cd}
‘Alaya krupnaya’	3.15±0.02^{e}	42.98±0.05^{a}	0.43±0.07^{d}	0.21±0.02^{bc}

***** – values, marked with the same superscript letters in a column, are not significantly different (p>0.05).

Results and Discussion

The physical and chemical parameters (pH value, moisture, total tannins and the content of carotenoids) of the samples of rowanberry marmalades are given in Table 2. The moisture content of the mass of raw material varied from 55.42% to 64.79%. It was observed that during preparation of rowanberry marmalades, the moisture decreased on average by 29.5–42.5%.

The results of the statistical analysis indicate that there are significant differences (p=0.000) in the moisture content among the samples of rowanberry marmalade. We can compare our results with moisture content of the rowanberry marmalade and apple-black currant marmalade candies (Berna and Kampuse, 2011; Muizniece-Brasava et al., 2011), where moisture content of marmalade was 26.50–37.92% and 44.78%, respectively. According to these data we can conclude that marmalade can be called as intermediate moisture food similar to jams and jellies, where moisture content of different berries and fruit jams vary between 27.80 and 34.06% (Figuerola, 2007; Ndabikunze et al., 2011).

Based on the fact that the pH is critical to successful gel formation with pectins and low pH increases the percentage of unionized carboxyl groups, the optimum pH for slow-set pectins being about 3.1 and for rapid set pectins 3.4 is recommended (Baker, 1996). Normally fruits used for making jams and jellies have low pH; most have less than pH 4.0 and some have less than pH 3.5. Organic acid (for example, citric acid) stabilizes the relation between pectin and sugar. High acidity, represented by a pH of 3.2 to 3.4, permits an increased number of unionized carboxyl groups in pectin molecules, reducing the electrostatic repulsion between pectin chains (Figuerola, 2007).

The pH values of rowanberry marmalade samples varied from 3.15 to 3.46. The results of the statistical analysis indicate that there were significant differences (p=0.000) in the pH value among the rowanberry marmalade samples. As rowanberries, like other berries, have low pH due to their content of some common organic acids, such as ascorbic, citric, tartaric, and malic acid, then we did not use any of these organic acids for increasing the acidity in fruit marmalade. Similar pH values are reported for thermo-stable marmalades of peach and apples, where pH value varied from 3.16 to 3.58 (Grujić et al., 2010).

The total carotenoids content of all investigated samples is reported in Table 1. The differences in the total carotenoids content between samples of the rowanberry marmalades were significant (p=0.000). The highest total carotenoids content was in the sample made from puree of rowanberry *S. aucuparia* var. *sibirica*, and the least – in the sample made from puree of rowanberry × pear hybrid 'Alaya krupnaya'.

The total tannins content significantly differed between the rowanberry marmalades (p=0.000), and it was between 0.06 and 0.30 g 100 g^{-1} DW (Table 1). Wild rowanberry and *S. aucuparia* var. *sibirica* had the highest content of total tannins, which explains the bitterest taste of marmalade made from these berries compared to marmalades of other rowanberry cultivars and hybrids. We observed that rowanberry marmalades contain less tannins than unprocessed fruits (Kampuss et al., 2009), which could be affected both by the freezing and the processing of the rowanberry puree.

The results of colour L*a*b* measurements of the rowanberry marmalades are shown in Table 3 – colour values significantly differed between rowanberry marmalades (p=0.000). The lightest colour (L* value) was detected to the samples of marmalades from rowanberry cultivars *S. aucuparia* var. *sibirica* and 'Sorbinka', which berries have yellow-orange colour. Whereas the darkest (the lowest L* value) and the reddest marmalade was prepared from rowanberry × hawthorn hybrid 'Granatnaya' and rowanberry cultivar 'Mitchurinskaya krasnaya', which berries are coloured in dark red colour.

Table 3

The average colour L* a* b* values of rowanberry marmalades

Rowanberry cultivar	Colour (L* a* b*) values		
	L*	a*	b*
'Granatnaya'	21.53±1.29^{d}	9.69±0.80^{bc}	10.58±1.90^{b}
'Moravica'	33.80±0.68^{a}	9.45±0.86^{bc}	21.12±1.27^{a}
Wild rowanberries	28.45±1.21^{bc}	18.27±2.13^{a}	20.48±1.44^{a}
S. aucuparia var. *sibirica*	35.78±1.58^{a}	8.47±1.14^{c}	20.04±1.80^{a}
'Sorbinka'	35.03±2.11^{a}	10.89±1.64^{b}	22.68±2.15^{a}
'Mitchurinskaya krasnaya'	24.33±2.38^{cd}	10.35±1.68^{bc}	10.78±1.22^{b}
'Alaya krupnaya'	29.43±2.59^{b}	11.32±1.20^{b}	8.58±1.14^{b}

* – values, marked with the same superscript letters in a column, are not significantly different (p>0.05).

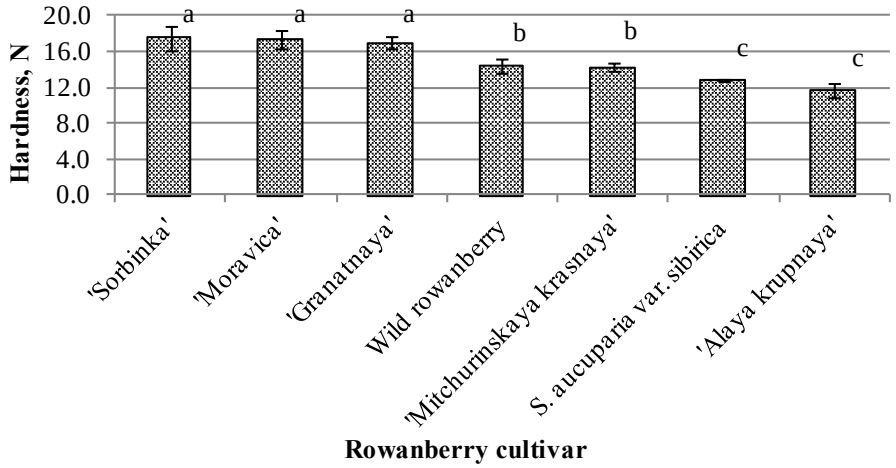

Figure 1. The hardness of the rowanberry marmalades.
* – values, marked with the same superscript letters, are not significantly different (p>0.05).

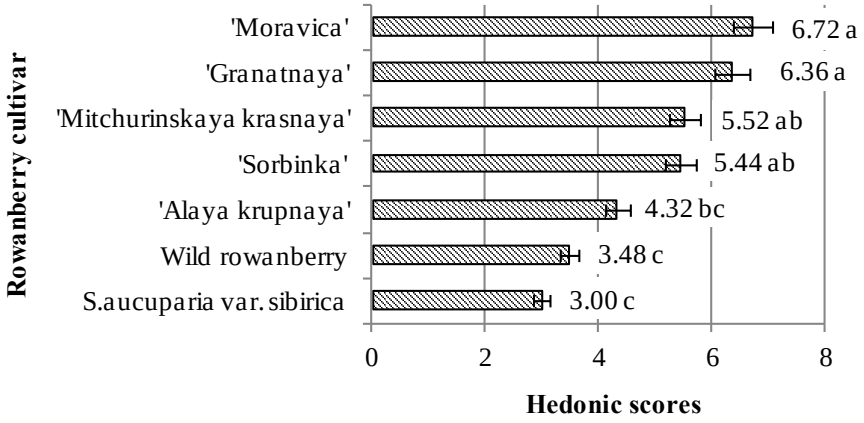

Figure 2. Degree of liking of the rowanberry marmalades.
* – values, marked with the same superscript letters, are not significantly different (p>0.05).

The hardness of the rowanberry marmalades is shown in Figure 1; it varied from 11.6±0.8 to 17.7±1.4 N. We observed that the hardness of the marmalades significantly differed, too (p=0.000).

These values were compared with the hardness results of the rowanberry marmalade made from sweet rowanberry cultivars 'Moravica' and 'Rosina', which hardness was 10.3 and 13.3 N, respectively (Berna and Kampuse, 2011).

The results of hedonic evaluation scores of the rowanberry marmalades are summarized in Figure 2. The results of the analysis of variance (ANOVA) indicate that Fcal = 21.57 > Fcrit = 2.16, which demonstate there are significant differences in the degree of liking among the rowanberry marmalade samples.

According to the hedonic scale, panellists evaluated rowanberry marmalades in the range from 3 (dislike moderately) to 7 (like moderately). The samples with lower bitterness the panellists liked better, and there were no significant differences between the marmalades made from purees of cultivars 'Moravica', 'Granatnaya', 'Mitchurinskaya krasnaya', and 'Sorbinka' (Fig. 2). The marmalade samples made from wild rowanberry and *S. aucuparia* var. *sibirica* the panellists liked the least (p<0.05), because they were too bitter. The marmalade sample made from wild rowanberry did not differ in degree of liking from *S. aucuparia* var. *sibirica* and 'Alaya krupnaya'. The assessment results of the intensity of sensory properties – flavour, colour and bitterness – of the rowanberry marmalades are presented in Table 4.

The marmalades without bitter taste made from sweet rowanberry cultivars 'Granatnaya' and 'Mitchurinskaya krasnaya', which have dark red colour, and cultivars 'Moravica' and 'Sorbinka', which have orange colour were rated as the best for fruit marmalade production by panellists. Several

Table 4

The intensity of sensory properties of rowanberry marmalades

Rowanberry cultivar	Intensity of sensory properties		
	Flavour	Bitterness	Colour
'Granatnaya'	6.7±1.2 [a]	3.8±0.2[bc]	9.6±0.5[a]
'Moravica'	6.4±1.1 [a]	2.7±0.1[c]	7.2±0.4[bc]
Wild rowanberry	6.4±1.2 [a]	9.4±0.5[a]	7.8±0.4[abc]
S. aucuparia var. *sibirica*	7.2±1.2 [a]	9.9±0.5[a]	6.3±0.3[c]
'Sorbinka'	6.0±1.3 [a]	4.0±0.2[bc]	6.8c±0.3[c]
'Mitchurinskaya krasnaya'	6.6±1.1 [a]	4.0±0.2[bc]	9.3±0.5[ab]
'Alaya krupnaya'	6.1±1.4 [a]	5.6±0.3[b]	7.3±0.4[bc]

* – values, marked with the same superscript letters in a column, are not significantly different (p>0.05).

panellists accepted the marmalade made from rowanberry cultivar 'Alaya krupnaya' with a slightly bitter taste as equally good.

The evaluation of the intensity of rowanberry marmalade sensory properties showed that there were no significant differences (p>0.05) in flavour, but there were significant differences in the intensity of colour and bitterness (p<0.05). These results could be explained by the different rowanberry cultivars used for preparation of marmalades – from yellow-orange to dark red coloured fruits and fruits with and without bitter taste.

The panellists considered that the marmalades from the puree of wild rowanberry and *S. aucuparia* var. *sibirica* fruits are unsuitable for nutrition because they were very astringent.

Pearson's correlation analysis was carried out to compare quality indicators of the rowanberry marmalades. A medium positive correlation was determined between the intensity of bitterness and tannin content (p=0.001, r=0.661), as well as a medium negative correlation between the degree of acceptance and tannin content (p=0.009, r=-0.558). Evaluating the correlations it was confirmed that in order to obtain non-bitter marmalades it is necessary to use the rowanberry cultivars with a small tannin content, as well as 'Moravica', hybrid of rowanberry × hawthorn 'Granatnaya', 'Sorbinka' and 'Mitchurinskaya krasnaya'. The rowanberry marmalades made from 'Granatnaya' and 'Mitchurinskaya Krasnaya' had the most intense colour, while the marmalade from *S. aucuparia* var. *sibirica* had the least colour intensity. There was no statistically significant correlation (r=0.215) found between the intensity of colour and carotenoids content.

Conclusions

1. There were significant differences (p<0.01) among the samples of rowanberry marmalades. The moisture content of rowanberry marmalades varied from 36.08 to 43.47%, hardness – 11.6–17.7 N, and carotenoids content – 0.43–3.52 mg 100 g^{-1} DW.
2. The pH of rowanberry marmalades differed between 3.15 and 3.45 and therefore it is not necessary to use any of organic acids for increasing the acidity in fruit marmalade.
3. The marmalade made from puree of wild rowanberry and from *S. aucuparia* var. *sibirica* had the highest tannins content (0.28–0.30 g 100 g^{-1} DW), which explains the most astringent flavour and taste of these marmalades compared to other rowanberry cultivars and hybrids.
4. The sensory evaluation of fruit marmalades from sweet rowanberry cultivars 'Moravica', 'Mitchurinskaya krasnaya', 'Sorbinka' and rowanberry × hawthorn hybrid 'Granatnaya' showed that the degree of liking varied from "neither like nor dislike" to "like moderately".
5. The marmalades from wild rowanberry and *S. aucuparia* var. *sibirica* fruits are unsuitable for nutrition because they are very astringent.
6. There were significant differences (p<0.01) in colour L* a* b* values among the samples of rowanberry marmalades. The colour L* values differed between 21.53 and 35.78, and the darkest marmalade was from rowanberry × hawthorn hybrid 'Granatnaya'.

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