Quality changes in black currant berries during ripening

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Black currant ‘Pilėnai’, ‘Vyčiai’, ‘Kriviai’ and ‘Gagatai’ berries of different stages of maturity were studied at the Lithuanian Institute of Horticulture. At technical maturity, black currant ‘Pilėnai’ and ‘Vyčiai’ berries were distinguished for having the greatest masses: 1.54 g and 1.48 g, respectively. When berries overripened, their mass decreased from between 2.9 % (‘Kriviai’) to as much as 38.3 % (‘Gagatai’). During berry ripening, the skin of black currants decreases in firmness. Overripe berries of cvs. ‘Pilėnai’ and ‘Vyčiai’ softened the most: 3.8 times and 3.4 times, respectively. At technical maturity, berries of cvs. ‘Pilėnai’ and ‘Kriviai’ were distinguished for having the most firm skin: 63.09 N cm$^{-2}$ and 53.9 N cm$^{-2}$, respectively. The highest levels of ascorbic acid were found in berries at the beginning of ripening. Overripe berries had the lowest levels of ascorbic acid. Among various cultivars, ‘Pilėnai’ and ‘Gagatai’ berries of differing maturity had the highest levels of ascorbic acid, 152–114 mg 100 g$^{-1}$ and 147–103 mg 100 g$^{-1}$, respectively. With the exception of berries of cvs. ‘Vyčiai’ and ‘Pilėnai’, larger amounts of pigments accumulated in overripe berries. Among all cultivars, mature and overripe berries of cvs. ‘Kriviai’ and ‘Gagatai’ had the highest levels of anthocyanins, at 387.61–450.63 mg 100 g$^{-1}$ and 349.79-393.91 mg 100 g$^{-1}$, respectively. The greatest amounts of dry soluble solids were found in overripe berries. The highest levels were present in the mature and overripe berries of cv. ‘Kriviai’ (14.55–16.95 %). The amount of titratable acidity in black currant berries decreased during ripening. Significantly greater amounts of acids were found in ‘Pilėnai’ berries of various stages of maturity (3.27–2.41 %).

Key words: chemical composition, skin firmness, berry weight, cultivar.

Introduction. Black currants (Ribes nigrum L.) are orchard plants widely grown in Europe, especially in Russia, Poland and Germany. Currant growing in Lithuania was described in studies by J. Strumila in 1820. The Lithuanian Institute of Horticulture has carried out black currant cultivar selection and evaluation of the quality of berries and their products for many years. Most often, the nutritional quality of black currant berries is determined by the amount of ascorbic acid and PP-active substances. Agroclimatic conditions in Lithuania, Latvia, Poland and Byelorussia are favourable for a large accumulation of vitamin C. Black currant cultivars created and grown in these countries exceed Scandinavian cultivars for the amount of ascorbic acid in their berries (Żurawicz et al., 2000; Kampuse et al., 2002; Rubinskienė et al., 2006). Anthocyanin concentrations in berries are mostly determined by the cultivar’s genotype. High concentrations of pigments are found in the berries from Scandinavian
cultivars (350–450 mg 100 g$^{-1}$) (Nes, 1993). According to our research, berries from Lithuanian cultivars accumulate between 274.9 and 499.1 mg 100 g$^{-1}$ of anthocyanins (Rubinskienė, Viškelis, 2002).

Depending on the cultivar, the time-to-ripening for black currant berries can vary by a month or more. In Middle Lithuania, berries of early cultivars ripen by July 5, moderately early berries ripen between July 6–15, and late cultivars begin to ripen during the third week of July. Different agroclimatic conditions influence berry quality and the time-to-ripening for black currants of various cultivars (Bičkauskienė, 1973; Rubinskienė, 2004). Berry quality (firmness, weight) determines the black currant storage potential, transportability and trade appearance. The biochemical composition of the berry shows the specific qualities of various cultivars and the goal for production. Therefore it is very important to choose the optimal harvest time for different cultivars.

The aim of this article is to evaluate berry quality and to investigate the accumulation of bioactive substances and other chemical compounds in black currant berries during ripening, identifying the most suitable harvest time.

**Object, methods and conditions.** For the first time, berries of different stages of maturity of the Lithuanian cultivars ‘Pilėnai’, ‘Gagatai’, ‘Vyčiai’ and ‘Kriviai’ were investigated. They were rated according to a scale composed by the authors: pink (beginning of ripening), dark brown (50 % ripened), black (technical maturity) and overripe berries. Dry soluble solids in black currant berries were established by digital refractometer ATAGO; ascorbic acid content was assessed by titration with 2,6-dichlorophenolindophenol sodium salt solution; titratable acidity (expressed as citric acid) was assessed by titration with a 0.1 N NaOH solution (Ермаков et al., 1987). The total amount of anthocyanins expressed by cyd-3-rut was established spectrophotometrically at a wave length of 544 nm (Wrolstad, 1976). Berry skin firmness was established with a penetrometer ИДП-500, with a probe diameter of 1 mm.

Meteorological conditions have a strong influence on both the biochemical composition of berries and the yield quality. According to data from the Lithuanian Hydrometeorological Station, during the berry ripening period in June 2007, the highest air temperature was 24–27 °C, 1.5–2.8 °C higher than the multiannual average. During that month, there were 298 sunny hours in Middle Lithuania (33 hours longer than average). Most of the precipitation fell during the last days of the month. The conditions were favourable for both early and late cultivars. Air temperature in July was similar to the multiannual average. July 17th was the hottest day, and the air temperature reached 30–34 °C. Rainy weather prevailed; precipitation was 1.5 to 2.5 times the average rainfall. There were 20–50 fewer hours of sunshine than the multiannual average.

**Results.** According to our data, the weight of the average black currant berry depended on the time of ripening and the properties of the cultivar. With the exception of the cultivar ‘Kriviai’, berry weight increased during ripening until the berries reached technical maturity (Fig. 1). Black currant cultivars ‘Pilėnai’ and ‘Vyčiai’ produced the biggest berries, with average weights of 1.54 g and 1.48 g, respectively. From the beginning of ripening, their weights increased 26 % and 45 %. The average weight of black currant ‘Gagatai’ berry at technical maturity increased 34.3 % from the beginning.
of ripening, reaching 1.37 g. It was observed that when berries overripened, their weight decreased. Less weight loss was observed in the berries of ‘Kriviai’ (2.9 %) and ‘Vyčiai’ (7.4 %); the greatest weight loss was seen in ‘Gagatai’ (38.3 %). The weight of overripe berries of the ‘Pilėnai’ cultivar decreased by 14.9 %.

During black currant ripening, the firmness of the berry skin changed. This index depended on both the cultivar’s properties and berry ripeness. The firmest skins of all cultivars were in berries that were just beginning to ripen. The firmness of black currant berry skins ranged from 241.94 N cm$^{-2}$ (‘Pilėnai’) to 150.06 N cm$^{-2}$ (‘Vyčiai’) (Fig. 2).

During ripening, the skin firmness of 50 % ripened berries from cultivars ‘Vyčiai’ and ‘Kriviai’ decreased by 26.9 % and 36.6 %, respectively; firmness of 50 % ripened
berries from the ‘Pilėnai’ and ‘Gagatai’ cultivars decreased by 45.8 % and 56.2 %. A notable softening of the skin was observed in black currant berries of technical maturity. The cultivar ‘Vyčiai’ decreased 69.8 %; skin firmness of the ‘Kriviai’, ‘Gagatai’ and ‘Pilėnai’ cultivars decreased by 56.9 %, 55.8 % and 51.9 %, respectively. At the stage of technical maturity, berries of cultivars ‘Pilėnai’ and ‘Kriviai’ were noted for their firm skin. When berries overripened, the skin of all black currant berries softened. This effect was the greatest for the cultivars ‘Pilėnai’ (3.8 times) and ‘Vyčiai’ (3.4 times) (Fig. 2).

In analyzing the change in ascorbic acid during berry ripening, we observed that changes in ascorbic acid levels in the berries of various cultivars depended on both the physiological properties of cultivars and berry ripeness. In all of the investigated cultivars, greater amounts of ascorbic acid were present in the berries at the beginning of ripening (Fig. 3). Significantly larger amounts of ascorbic acid were observed in the pink berries of ‘Pilėnai’ (152.0 mg 100 g⁻¹) and ‘Gagatai’ (147.0 mg 100 g⁻¹). During ripening in the berries of all cultivars, we observed a decrease in the amount of ascorbic acid. When berries of the above-mentioned cultivars reached technical maturity, ascorbic acid concentrations decreased by 20.7 % and 18.7 %, respectively. The amounts of ascorbic acid in the berries of cultivars ‘Kriviai’ and ‘Vyčiai’ decreased by only 0.85 % and 7.8 %, respectively. The ascorbic acid content of these cultivars further decreased as they became overripe: ‘Kriviai’ berries decreased by 26.2 %, and ‘Vyčiai’ berries decreased by 23.5 %. The amount of ascorbic acid in the berries of the ‘Pilėnai’ and ‘Gagatai’ cultivars decreased from 13.8 % to 5.4 % (Fig. 3).

During ripening, the amount of pigment in the berries noticeably increased, and at technical maturity, there was significantly more pigment in cultivars ‘Kriviai’ (387.61 mg 100 g⁻¹) and ‘Gagatai’ (349.79 mg 100 g⁻¹) (Fig. 3). The berries of cultivars ‘Vyčiai’ and ‘Pilėnai’ accumulated from 246.85 to 267.87 mg 100 g⁻¹ of anthocyanins. It was observed that when berries were overripe, the dynamics of the pigments differed
among cultivars. In the berries of cultivars ‘Kriviai’ and ‘Gagatai,’ the quantity of anthocyanins increased 16.2–12.6 % (up to 450.63 mg 100 g⁻¹ and 393.91 mg 100 g⁻¹, respectively) to produce the highest values overall. In overripe berries of cultivars ‘Vyčiai’ and ‘Pilėnai,’ the concentration of pigments decreased: in berries of ‘Vyčiai’ by 3 %, and in berries of ‘Pilėnai,’ by 34.5 % (Fig. 3).

The quantity of dry soluble solids in berries depended on the properties of the cultivars and the extent of ripeness. During ripening, the amount of dry soluble solids in berries of all cultivars increased. The largest amount of was established in overripe berries of ‘Kriviai’ (16.95 %); the lowest amount was in berries of ‘Pilėnai’ (14.7 %) (Table). The amounts accumulated in berries of cultivars ‘Vyčiai’ and ‘Gagatai’ differed only slightly.

**Table.** Change of biochemical composition in black currant berries during ripening

**Lentelė.** Biocheminės sudėties kitimas juodųjų serbentų uogose nokimo metu

<table>
<thead>
<tr>
<th>Cultivar Žuvislė</th>
<th>Ripeness Sunokimbas</th>
<th>Dry soluble solids Tarpio sausiosios medžiagos (%)</th>
<th>Titratable acidity Titrojamasis rūgštingumas (%)</th>
<th>Dry matter Sausiosios medžiagos (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Kriviai’</td>
<td>Beginning of ripening Nokimo pradžia</td>
<td>12.30</td>
<td>2.45</td>
<td>18.60</td>
</tr>
<tr>
<td>50% ripened berries 50 % sanokusių uogų</td>
<td>12.50</td>
<td>2.54</td>
<td>18.52</td>
<td></td>
</tr>
<tr>
<td>Technical maturity Techninė branda</td>
<td>14.55</td>
<td>2.54</td>
<td>18.71</td>
<td></td>
</tr>
<tr>
<td>Overripe berries Persiprusios uogos</td>
<td>16.95</td>
<td>2.28</td>
<td>20.45</td>
<td></td>
</tr>
<tr>
<td>‘Vyčiai’</td>
<td>Beginning of ripening Nokimo pradžia</td>
<td>11.25</td>
<td>2.71</td>
<td>16.80</td>
</tr>
<tr>
<td>50% ripened berries 50 % sanokusių uogų</td>
<td>13.00</td>
<td>2.50</td>
<td>16.90</td>
<td></td>
</tr>
<tr>
<td>Technical maturity Techninė branda</td>
<td>12.80</td>
<td>2.48</td>
<td>17.61</td>
<td></td>
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<tr>
<td>Overripe berries Persiprusios uogos</td>
<td>15.15</td>
<td>2.26</td>
<td>17.46</td>
<td></td>
</tr>
<tr>
<td>‘Gagatai’</td>
<td>Beginning of ripening Nokimo pradžia</td>
<td>11.30</td>
<td>2.45</td>
<td>17.40</td>
</tr>
<tr>
<td>50% ripened berries 50 % sanokusių uogų</td>
<td>12.70</td>
<td>2.37</td>
<td>17.60</td>
<td></td>
</tr>
<tr>
<td>Technical maturity Techninė branda</td>
<td>13.55</td>
<td>2.23</td>
<td>17.41</td>
<td></td>
</tr>
<tr>
<td>Overripe berries Persiprusios uogos</td>
<td>15.60</td>
<td>2.12</td>
<td>19.30</td>
<td></td>
</tr>
<tr>
<td>‘Pilėnai’</td>
<td>Beginning of ripening Nokimo pradžia</td>
<td>10.70</td>
<td>3.27</td>
<td>15.82</td>
</tr>
<tr>
<td>50% ripened berries 50 % sanokusių uogų</td>
<td>12.30</td>
<td>3.17</td>
<td>16.30</td>
<td></td>
</tr>
<tr>
<td>Technical maturity Techninė branda</td>
<td>12.90</td>
<td>3.01</td>
<td>17.10</td>
<td></td>
</tr>
<tr>
<td>Overripe berries Persiprusios uogos</td>
<td>14.70</td>
<td>2.41</td>
<td>18.28</td>
<td></td>
</tr>
<tr>
<td>LSD₀.₀₅ / R₀.₀₅</td>
<td>0.081</td>
<td>0.059</td>
<td>0.291</td>
<td></td>
</tr>
</tbody>
</table>
Larger amounts of titratable acidity were established in berries of the investigated cultivars at the beginning of ripening. Overripe berries have the lowest amount of organic acids. The berries of cultivar ‘Pilėnai’ were distinguished by having the largest amount of acids (2.41 %); the lowest amounts were in the berries of the cultivar ‘Gagatai’ (2.12 %) (table).

Overripe berries of the cultivar ‘Kriviai’ were notable for having the largest amount of dry soluble solids – 20.45 %. Large amounts (19.3 %) also accumulated in berries of the cultivar ‘Gagatai’ (Table). The lowest amount was found in the berries of cultivar ‘Vyčiai’. When evaluating the properties of cultivars, we observed that during the ripening of cultivar ‘Pilėnai’ the amount of dry soluble solids increased most of all, by 15.5 %.

**Discussion.** Set berries are green. Their unpleasant taste is due to organic acids and fermentation substances. Since they contain large amounts of insoluble propectins and starch, the berries are firm. We noticed that berry firmness depended on the biological properties of cultivars. The black currant cultivars ‘Pilėnai’ and ‘Gagatai’ were distinguished for berry firmness. At the second berry ripening stage, when morphological and biochemical changes took place, their concentration of pectins decreased (during overripening, by as much as 51–57 %) and berries softened (Максименко, 1997). We observed that among the investigated black currant cultivars, the changes in berry skin firmness took place unevenly during ripening. At the stage of 50 % ripeness, skin firmness of ‘Pilėnai’ and ‘Gagatai’ berries decreased by 45.8 % and 56.2 % (Fig. 2). When technical maturity was reached, the softening of ‘Pilėnai’, ‘Gagatai’ and ‘Vyčiai’ berry skins occurred more quickly than in the cultivar ‘Kriviai’. At this maturity stage, the cultivars ‘Pilėnai’ and ‘Kriviai’ were distinguished for berry skin firmness. According to our data, when berries were overripe, skin softening took place quickly.

Studies of the biochemical composition of black currant berries of various ripeness are carried out in Lithuania and as well as in other countries. We observed that the amount of accumulated substances and changes in those levels in berries depends more on the biological properties of the cultivar than on the growth conditions (Brennan, 1996; Viola et al., 2000; Rubinskienė et al., 2006).

The data of the ascorbic acid change confirmed the earlier results obtained by us and by other investigators. Larger amounts of vitamin C are present at the beginning of berry ripening (Fig. 3) (Максименко, 1999; Rubinskienė, Viškelis, 2002).

The quantity of anthocyanins in berries was due to cultivar properties and to the time of ripening. As noted in earlier years of investigation, according chemical analyses, the berries of cultivars ‘Kriviai’ and ‘Gagatai’ were distinguished for having the greatest accumulation of anthocyanins (Fig. 3) (Viškelis, Rubinskienė, Jasutienė, 2001). We observed that overripe berries accumulate greater amounts of anthocyanins (Rubinskienė, 2004). The data showed that pigment concentration did not increase in berries of all the cultivars. The hot weather of July accelerated berry ripening, and abundant precipitation negatively influenced berry quality of the later black currant cultivars. We observed that overripe berries of the cultivars ‘Pilėnai’ and ‘Vyčiai’ were very soft (Fig. 2) and were of sour taste. We think that the process of fermentation (which took place in overripe berries) influenced anthocyanin degradation, and this was the reason why the concentration of these pigments decreased (Fig. 3).
Our results on the dynamics of the changes in titratable acidity and dry soluble solids in berries during ripening do not contradict previously published data. Greater amounts of dry soluble solids are found in overripe berries, and greater amounts of acids are found at the beginning of ripening (Максименко, 1997; Rubinskienė et al., 2006). At the second stage of ripening, when the amounts of anthocyanins and dry soluble solids significantly increase, titratable acidity starts to decrease in berries (Fig. 3, Table).

**Conclusions.** 1. At the stage of technical maturity, berries of the cultivars ‘Pilėnai’ and ‘Vyčiai’ were distinguished for the largest weights: 1.54 g and 1.48 g, respectively. When berries became overripe, their weight decreased by between 2.9 % (‘Kriviai’) to 38.3 % (‘Gagatai’).

2. During black currant ripening, skin firmness decreases. Overripe berries of cultivars ‘Pilėnai’ and ‘Vyčiai’ soften most of all: 3.8 and 3.4 times. At the stage of technical maturity, the berries of cultivars ‘Pilėnai’ (63.09 N cm⁻²) and ‘Kriviai’ (53.9 N cm⁻²) had firm skin.

3. Greater amounts of ascorbic acid were present in berries at the beginning of ripening. Overripe berries were the least vitaminous. At various stages of maturity, berries of the cultivars ‘Pilėnai’ and ‘Gagatai’ were notable for ascorbic acid content: 152–114 mg 100 g⁻¹ and 147–103 mg 100 g⁻¹, respectively. With the exception of the berries of cultivars ‘Vyčiai’ and ‘Pilėnai’, greater amounts of pigment accumulate in overripe berries. Berries of technical maturity and overripe berries of cultivars ‘Kriviai’ and ‘Gagatai’ were observed to have significantly greater quantities of anthocyanin: 387.61–450.63 mg 100 g⁻¹ and 349.79–393.91 mg 100 g⁻¹, respectively. Larger amounts of dry soluble solids were found in overripe berries. Larger quantities were present in berries of technical maturity and in overripe berries of cultivar ‘Kriviai’ (14.55–16.95 %). During ripening of the berries of black currants, the amount of titratable acidity decreases. Significantly greater amounts of acids were found in the berries of cultivar ‘Pilėnai’ of varying maturity (3.27–2.41 %).

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**References**

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Mažiausiu vitamingumu pasižymi persirpusios uogos. Tarp veisių askorbo rūgšties kiekiu išskiria įvairios brandos ‘Pilėnų’ (152–114 mg 100 g⁻¹) ir ‘Gagatų’ (147–103 mg 100 g⁻¹) uogos. Išskyrus ‘Vyčių’ ir ‘Pilėnų’ serbentus, gausesni pigmentų kiekiai susikaupia persirpusiose uogose. Tarp veisių patikimai didesniu antocianinų kiekiu pasižymi techninės brandos ir persirpusios ‘Krivų’ (387,61–450,63 mg 100 g⁻¹) bei ‘Gagatų’(349,79–393,91 mg 100 g⁻¹) uogos. Didesni tirpių sausųjų medžiagų kiekių yra persirpusiose uogose. Daugiau jų nustatyta techninės brandos ir persirpusiose ‘Krivų’ (14,55–16,95 %) uogose. Nokimo metu juodųjų serbentų uogose sumažėja titruojamojo rūgštingumo kiekis. Patikimai didesni rūgščių kiekiai rasti įvairios brandos ‘Pilėnų’ uogose (3,27–2,41 %).

Reikšminiai žodžiai: cheminė sudėtis, odelės tvirtumas, uogos masė, veislė.