

# Impact of Cultivar on Profile and Concentration of Lipophilic Bioactive Compounds in Kernel Oils Recovered from Sweet Cherry (*Prunus avium* L.) by-Products

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**Abstract** Lipophilic bioactive compounds in oils recovered from the kernels of seven sweet cherry (*Prunus avium* L.) cultivars, harvested at single location in 2013, were studied. Oil yield in sweet cherry ranged between 30.3–40.3 % (w/w) dw. The main fatty acids were oleic acid (39.62–49.92 %), linoleic acid (31.13–38.81 %),  $\alpha$ -eleostearic acid (7.23–10.73 %) and palmitic acid (5.59–7.10 %), all four represented approximately 95 % of the total detected fatty acids. The ranges of total tocopherols and sterols were between 83.1–111.1 and 233.6–419.4 mg/100 g of oil, respectively. Regardless of the cultivar, the  $\gamma$ -tocopherol and  $\beta$ -sitosterol were the main lipophilic minor bioactive compounds. The content of the carotenoids and squalene were between 0.38–0.62 and 60.9–127.7 mg/100 g of oil, respectively. Three significant correlations were found between oil yield and total contents of sterols ( $r = -0.852$ ), tocopherols ( $r = -0.880$ ) and carotenoids ( $r = -0.698$ ) in sweet cherry kernel oils. The oil yield, as well as the content of lipophilic bioactive compounds in oil was significantly affected by the cultivar.

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## Abbreviations

DW	Dry weight basis
T	Tocopherol
T3	Tocotrienol
RP-HPLC/FLD	Reverse-phase high-performance liquid chromatography/fluorescence detector

## Introduction

The global production of sweet cherries (*Prunus avium* L.) continues to increase with demands from the fruit and food industry, and in 2012 amounted to 2.3 million tons [1]. Sweet and sour cherries are not only consumed in fresh form, but also in large scales to be processed into juice, jams and candied fruits, consequently generating vast amounts of by-products (e.g., fruit pits) with limited utilization. Fruit kernels are valuable sources of oils that are rich in functional bioactive compounds such as essential fatty acids, tocopherols, carotenoids, phytosterols and squalene [2–8].

Fatty acids are concentrated sources of energy, however some fatty acids, for instance  $\alpha$ -eleostearic acid have been reported to possess antitumor activity in cancer cells [9].

Tocopherols and tocotrienols (vitamin E) are synthesized only by photosynthetic organisms and their content in the plant tissue ranges from below 1  $\mu\text{g/g}$  to above 1 mg/g dry weight basis in different vegetative parts [10]. Tocopherols have reported unique physicochemical activity in model and biological [11–15] systems.

Carotenoids are natural isoprenoid pigments synthesized mainly in photosynthetic, but also in some non-photosynthetic organisms such as fungi and bacteria, with over 700 different known compounds, some of which have pro-vitamin A activity [16]. Certain plasma carotenoids and tocopherols were inversely related to prostate-specific antigen levels at various points of time, suggesting that greater intake of foods containing these micronutrients could benefit men with prostate-specific antigen-defined recurrence of prostate cancer [17].

Phytosterols belong to the group of cholesterol analogues which occur in plants and vary with the carbon side chains.  $\beta$ -Sitosterol along with stigmasterol and campesterol are the most common forms of phytosterols in the plant world with the ability to reduce levels of cholesterol in blood serum, which contributed to the rapid application in numerous food stuffs as a functional ingredient [18].

Squalene is a 30 carbon isoprenoid, precursor of steroid hormones, vitamin D and cholesterol. Squalene has reported antioxidant activity against oxidative destruction of DNA and consequently damage of mammary epithelial cells in humans [19].

Since the cultivar is often associated with the significant different concentrations of bioactive compounds [20, 21], the present study has focused on the oil yield and its composition of lipophilic compounds (fatty acids, tocopherols, carotenoids, sterols, squalene) recovered from selected cultivars of sweet cherry kernels.

## Materials and Methods

### Reagents

Methanol, 2-propanol, *tert*-butyl methyl ether, *n*-hexane (HPLC grade) and 5 $\alpha$ -cholestane ( $\geq 97$  %, GC) were purchased from Sigma-Aldrich (Steinheim, Germany). Tocopherol and tocotrienol homologues ( $\alpha$ ,  $\beta$ ,  $\gamma$  and  $\delta$ ) ( $> 95$  %, HPLC) were obtained from Merck (Darmstadt, Germany) and LGC Standards (Teddington, Middlesex, UK), respectively. The Sylon BTZ and fatty acid methyl ester mix were received from Supelco (Bellefonte, PA, USA) and (Steinheim, Germany), respectively.

### Plant Material

The kernels were recovered from fruit pits (by removing the outer shells) of seven cultivars of mature sweet cherries (*Prunus avium* L.) harvested in July 2013 in Dobeles, at the Latvia State Institute of Fruit-Growing. Undamaged kernels were frozen and subsequently freeze dried using a FreeZone freeze-dry system (Labconco, Kansas City, MO, USA) at a temperature of  $-51 \pm 1$  °C under vacuum of 0.055–0.065

mBar for 48 h. Kernels were selected (~20 g) and milled with a Knifetec™ 1095 universal laboratory mill (Foss, Höganäs, Sweden) to pass through a sieve of 0.75 mm mesh size to finally obtain a powder. Dry weight basis (dw) in the studied samples was measured gravimetrically.

### Oil Extraction

Oil was extracted according to an earlier introduced method [3].

### Fatty Acid, Sterols and Squalene Composition

The fatty acids, sterols and squalene were determined according to a method previously described [20].

### Tocopherol and Tocotrienol Homologues Determination

The oils samples were diluted in 2-propanol as was described by Górnas [22] and determined by RP-HPLC/FLD according to the method previously developed and validated [23].

### Total Carotenoids Determination

Total carotenoids were estimated according to Górnas *et al.* [20].

### Statistical Analysis

The results were presented as means  $\pm$  standard deviation ( $n = 3$ ) from three batches of ground kernels. The  $p$ -value  $\leq 0.05$  was used to denote significant differences between mean values determined by one-way analysis of variance (ANOVA). The Bonferroni *post-hoc* test was used to denote statistically significant values at  $p \leq 0.05$ . The association between analysed variables was assessed by Pearson's correlation coefficient. Its significance was evaluated by Student's *t*-test. Linear regression model ( $y = ax + b$ ) was calculated additionally for the analysis of significant relationships between parameters. All analyses were performed with the assistance of Statistica 10.0 (StatSoft, Tulsa, OK, USA) software.

## Results and Discussion

The cultivar selection was found to significantly impact the recovered oil yield for crab, cider and dessert apple seeds [3, 4]. The investigated kernels of different sweet cherry cultivars resulted in the oil yield ranging from 30.3 to 40.3 % (w/w) dw in cvs. 'Krupnoplodnaya' and 'Tyutchevka', respectively (Table 1). With the exception of the lowest oil yield cv. 'Krupnoplodnaya', the oil yield was comparable for the

**Table 1** Oil yields (% w/w dw) recovered from the kernels of seven sweet cherry cultivars and fatty acid composition (%)

Cultivar	Oil yield	Fatty acid								
		C16:0	C16:1	C18:0	C18:1	C18:2	$\alpha$ -C18:3	$\alpha$ -ESA C18:3	C20:0	C20:1
Bryanskaya Rozovaya	39.6 <i>0.5<sup>cd</sup></i>	5.59 <i>0.13<sup>a</sup></i>	0.33 <i>0.02<sup>a</sup></i>	2.94 <i>0.04<sup>cd</sup></i>	49.92 <i>0.33<sup>c</sup></i>	31.13 <i>0.25<sup>a</sup></i>	0.09 <i>0.01<sup>a</sup></i>	8.49 <i>0.05<sup>b</sup></i>	1.08 <i>0.02<sup>de</sup></i>	0.43 <i>0.03<sup>b</sup></i>
Gårdebo	38.5 <i>0.6<sup>bcd</sup></i>	5.74 <i>0.15<sup>a</sup></i>	0.37 <i>0.02<sup>ab</sup></i>	3.24 <i>0.04<sup>e</sup></i>	48.87 <i>0.31<sup>de</sup></i>	31.71 <i>0.33<sup>a</sup></i>	0.07 <i>0.01<sup>a</sup></i>	8.76 <i>0.12<sup>b</sup></i>	0.91 <i>0.03<sup>ab</sup></i>	0.33 <i>0.02<sup>a</sup></i>
Iedzenu Dzeltenais	39.5 <i>0.6<sup>cd</sup></i>	6.34 <i>0.07<sup>b</sup></i>	0.38 <i>0.02<sup>ab</sup></i>	2.82 <i>0.03<sup>bc</sup></i>	48.35 <i>0.40<sup>d</sup></i>	32.95 <i>0.25<sup>b</sup></i>	0.08 <i>0.01<sup>a</sup></i>	7.59 <i>0.12<sup>a</sup></i>	1.09 <i>0.04<sup>f</sup></i>	0.41 <i>0.03<sup>b</sup></i>
Krupnoplodnaya	30.2 <i>0.4<sup>a</sup></i>	6.76 <i>0.06<sup>c</sup></i>	0.41 <i>0.01<sup>bc</sup></i>	2.43 <i>0.05<sup>a</sup></i>	39.62 <i>0.44<sup>a</sup></i>	38.81 <i>0.52<sup>d</sup></i>	0.14 <i>0.01<sup>b</sup></i>	10.43 <i>0.06<sup>c</sup></i>	0.88 <i>0.02<sup>a</sup></i>	0.58 <i>0.03<sup>c</sup></i>
Lapins	38.2 <i>0.7<sup>bc</sup></i>	6.30 <i>0.11<sup>b</sup></i>	0.53 <i>0.02<sup>d</sup></i>	2.79 <i>0.07<sup>b</sup></i>	41.80 <i>0.45<sup>b</sup></i>	36.67 <i>0.46<sup>c</sup></i>	0.13 <i>0.01<sup>b</sup></i>	10.29 <i>0.15<sup>c</sup></i>	1.04 <i>0.03<sup>cde</sup></i>	0.44 <i>0.02<sup>b</sup></i>
Tyutchevka	40.3 <i>0.7<sup>d</sup></i>	7.10 <i>0.08<sup>d</sup></i>	0.52 <i>0.03<sup>d</sup></i>	2.97 <i>0.04<sup>d</sup></i>	43.63 <i>0.36<sup>c</sup></i>	33.73 <i>0.36<sup>b</sup></i>	0.09 <i>0.01<sup>a</sup></i>	10.73 <i>0.15<sup>d</sup></i>	0.96 <i>0.04<sup>abc</sup></i>	0.27 <i>0.03<sup>a</sup></i>
Vytenu Juodoji	37.5 <i>0.8<sup>b</sup></i>	6.13 <i>0.09<sup>b</sup></i>	0.46 <i>0.01<sup>c</sup></i>	3.41 <i>0.04<sup>f</sup></i>	47.92 <i>0.37<sup>d</sup></i>	33.36 <i>0.29<sup>b</sup></i>	0.07 <i>0.01<sup>a</sup></i>	7.23 <i>0.10<sup>a</sup></i>	0.99 <i>0.04<sup>bcd</sup></i>	0.42 <i>0.01<sup>b</sup></i>

Italic values correspond to standard deviations ( $n = 3$ ). Different letters in the same column indicate statistically significant differences at  $p \leq 0.05$ . *nd* not detected;  $\alpha$ -ESA  $\alpha$ -eleostearic acid

majority of studied samples (37.5–40.3 % (w/w) dw) and in most cases were statistically insignificant ( $p \leq 0.05$ ). The average oil yield in seven tested samples amounted to 37.7 % (w/w) dw. A previous study included the impact of the cultivar on the oil yield for four Iranian cultivars extracted with petroleum ether in Soxhlet apparatus, the reported oil yields were between 22.2–37.9 % [24], comparable to the results obtained in the present study, however with a wider range. Another study by Bernardo-Gil *et al.* [25] quantified a low 9 % oil yield in sweet cherry seeds (fruit shell and kernel) extracted with supercritical carbon dioxide. Non-varietal factors such as growing conditions, horticultural practice and climate may also account for the differences among the same cultivars [4]. Nonetheless, previous studies have clearly indicated that genetic factors have a greater impact on oil yield and quality

than environmental ones, for instance in corn (*Zea mays* L.). It has been highlighted that the oil yield and its composition can vary considerably from location to location as well as year to year, however the relative rank of genotype will be similar under various environmental conditions [26]. Additionally, the influence of external factors may have different impacts for each crop [27].

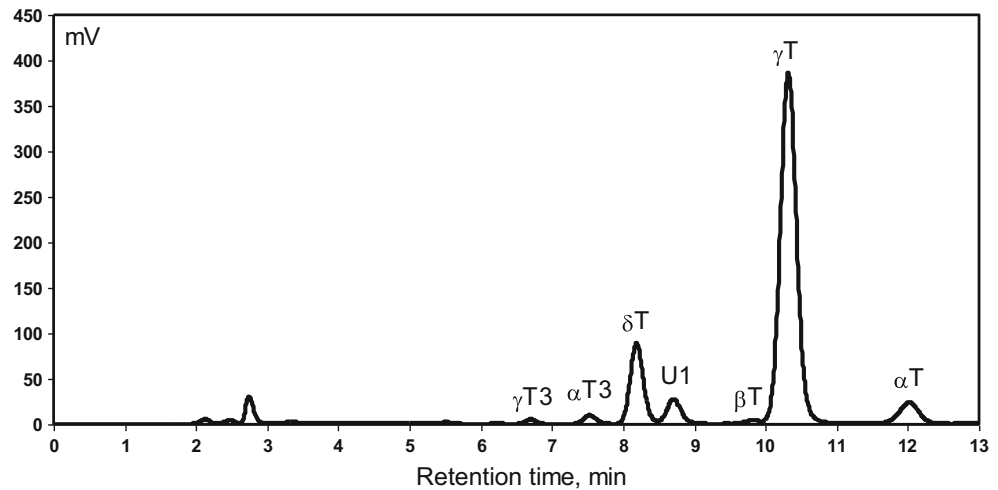
The composition of fatty acids in kernel oils recovered from seven sweet cherry cultivars was significantly different ( $p \leq 0.05$ ) in most cases (Table 1). From nine identified fatty acids, the oleic (C18:1) (39.62–49.92 %), linoleic (C18:2) (31.13–38.81 %),  $\alpha$ -eleostearic ( $\alpha$ -ESA C18:3) (7.23–10.73 %) and palmitic (C16:0) (5.59–7.10 %) acid together represented approximately 95 % of the total detected fatty acids. Levels over 1 % were detected for stearic (C18:0)

**Table 2** Sum of SFA, MUFA and PUFA (%) and fatty acids ratios of kernel oils recovered from seven sweet cherry cultivars

Cultivar	$\Sigma$ SFA	$\Sigma$ MUFA	$\Sigma$ PUFA	Fatty acids ratio	
				$\Sigma$ UFA/ $\Sigma$ SFA	$\Sigma$ PUFA/( $\Sigma$ SFA + $\Sigma$ MUFA)
Bryanskaya Rozovaya	9.6	50.7	39.7	9.4	0.7
Gårdebo	9.9	49.6	40.5	9.1	0.7
Iedzenu Dzeltenais	10.3	49.1	40.6	8.8	0.7
Krupnoplodnaya	10.1	40.6	49.4	8.9	1.0
Lapins	10.1	42.8	47.1	8.9	0.9
Tyutchevka	11.0	44.4	44.6	8.1	0.8
Vytenu Juodoji	10.5	48.8	40.7	8.5	0.7

$\Sigma$ SFA sum of saturated fatty acids,  $\Sigma$ MUFA sum of monounsaturated fatty acids,  $\Sigma$ PUFA sum of polyunsaturated fatty acids,  $\Sigma$ UFA sum of unsaturated fatty acids

**Fig. 1** Chromatogram of the tocopherols separation via RP-HPLC/FLD in sweet cherry kernel oil cv. ‘Tyutchevka’  $\alpha$ T3,  $\gamma$ T3,  $\alpha$ T,  $\beta$ T,  $\gamma$ T and  $\delta$ T – tocotrienol (T3) and tocopherol (T) homologues; U1 – unidentified compound 1



(2.43–3.41 %) and arachidic (C20:0) (0.88–1.09 %) acid. Values below 1 % were recorded for palmitoleic (C16:1) (0.33–0.53 %),  $\alpha$ -linolenic ( $\alpha$ -C18:3) (0.07–0.14 %) and gondoic (C20:1) (0.27–0.58 %) acid (Table 1). Similar identification and concentration of fatty acids in sweet cherry kernel oils in three cultivars grown in Slovenia and Norway, where the cultivar factor had higher statistical significance on the variability of fatty acids profile than location, was reported previously [28]. The range and average (%) of the different types of fatty acids in kernel oils recovered from various sweet cherry cultivars were as follows: saturated (9.6–11.0, 10.2 %), monounsaturated (40.6–50.7, 46.6 %) and polyunsaturated (39.7–49.4, 43.2 %). The sum of unsaturated/saturated fatty acids ( $\Sigma$ UFA/ $\Sigma$ SFA) ratios in sweet cherry kernel oils were in the range of 8.1–9.4. The fatty acids  $\Sigma$ PUFA/( $\Sigma$ SFA +  $\Sigma$ MUFA) ratios in sweet cherry kernel oils were in the range of 0.7–1.0. The  $\Sigma$ PUFA/( $\Sigma$ SFA +  $\Sigma$ MUFA) ratios shows a majority of the  $\Sigma$ SFA +  $\Sigma$ MUFA were found in all the studied samples, with the exception of the oil sample ‘Krupnoplodnaya’, in which the amount of  $\Sigma$ PUFA and  $\Sigma$ SFA +  $\Sigma$ MUFA was equal (Table 2).

Four homologues of tocopherol ( $\alpha$ ,  $\beta$ ,  $\gamma$  and  $\delta$ ) and two of tocotrienol ( $\alpha$  and  $\gamma$ ) were detected in all studied samples (Fig. 1, Table 3).  $\gamma$ -T was a predominant tocopherol with the concentration between 73.7–97.4 mg/100 g oil in cvs. ‘Bryanskaya Rozovaya’ and ‘Krupnoplodnaya’, respectively, and consisted of 86–89 % of all determined tocopherols in the analysed samples of oil.  $\gamma$ -T was reported to be a predominant homologue of tocopherols in other fruit seeds and kernels of plants belonging to the Rosaceae family, where the impact of the cultivar on the tocopherols concentration was taken into consideration: plums (*Prunus domestica* L. and *Prunus cerasifera* Ehrh.) 78–89 % [29], apricots (*Prunus armeniaca* L.) 91–95 % [30] and pears (*Pyrus communis* L.) 84–88 % [31]. However, some exceptions were reported, for instance in the apple seeds (*Malus domestica* Borkh.) [22] and in Japanese quince seed oil (*Chaenomeles japonica* (Thunb.) Lindl. ex Spach) [32] where the  $\gamma$ -T consisted of a low percentage of the total detected tocopherols (1–24 % and 2 %, respectively). Significantly lower concentrations in sweet cherry kernel oils were noted for  $\alpha$ -T and  $\delta$ -T (5.2–8.1 and 3.1–5.3 mg/100 g oil,

**Table 3** Content of tocopherols and total carotenoids (mg/100 g oil) in kernel oils recovered from seven sweet cherry cultivars

Cultivar	Tocopherols							Total carotenoids
	$\alpha$ -T	$\beta$ -T	$\gamma$ -T	$\delta$ -T	$\alpha$ -T3	$\gamma$ -T3	Total	
Bryanskaya Rozovaya	5.2 ± 0.1 <sup>a</sup>	0.1 ± 0.0 <sup>a</sup>	73.7 ± 0.6 <sup>a</sup>	3.5 ± 0.1 <sup>b</sup>	0.5 ± 0.0 <sup>bc</sup>	0.2 ± 0.0 <sup>b</sup>	83.1 ± 0.9 <sup>a</sup>	0.38 ± 0.01 <sup>a</sup>
Gårdebo	5.7 ± 0.1 <sup>b</sup>	0.1 ± 0.0 <sup>a</sup>	80.4 ± 0.7 <sup>c</sup>	4.1 ± 0.1 <sup>c</sup>	0.5 ± 0.0 <sup>bc</sup>	0.2 ± 0.0 <sup>b</sup>	91.1 ± 0.9 <sup>c</sup>	0.56 ± 0.02 <sup>d</sup>
Iedzenu Dzeltēnais	7.3 ± 0.2 <sup>d</sup>	0.2 ± 0.0 <sup>a</sup>	81.4 ± 0.6 <sup>c</sup>	4.7 ± 0.1 <sup>d</sup>	0.8 ± 0.0 <sup>d</sup>	0.2 ± 0.0 <sup>b</sup>	94.6 ± 0.8 <sup>d</sup>	0.36 ± 0.02 <sup>a</sup>
Krupnoplodnaya	8.1 ± 0.2 <sup>c</sup>	0.1 ± 0.0 <sup>a</sup>	97.4 ± 1.1 <sup>e</sup>	4.2 ± 0.1 <sup>c</sup>	1.2 ± 0.0 <sup>e</sup>	0.1 ± 0.0 <sup>a</sup>	111.1 ± 1.4 <sup>f</sup>	0.62 ± 0.03 <sup>e</sup>
Lapins	5.7 ± 0.1 <sup>b</sup>	0.1 ± 0.0 <sup>a</sup>	81.6 ± 0.9 <sup>c</sup>	3.1 ± 0.1 <sup>a</sup>	0.6 ± 0.0 <sup>c</sup>	0.3 ± 0.1 <sup>b</sup>	91.3 ± 0.9 <sup>c</sup>	0.45 ± 0.02 <sup>b</sup>
Tyutchevka	5.2 ± 0.1 <sup>a</sup>	0.1 ± 0.0 <sup>a</sup>	77.0 ± 0.7 <sup>b</sup>	4.2 ± 0.1 <sup>c</sup>	0.4 ± 0.0 <sup>a</sup>	0.2 ± 0.0 <sup>b</sup>	87.0 ± 0.7 <sup>b</sup>	0.50 ± 0.03 <sup>c</sup>
Výtenu Juodoji	6.2 ± 0.2 <sup>c</sup>	0.1 ± 0.0 <sup>a</sup>	89.5 ± 0.9 <sup>d</sup>	5.3 ± 0.2 <sup>e</sup>	0.5 ± 0.0 <sup>bc</sup>	0.1 ± 0.0 <sup>a</sup>	101.8 ± 1.1 <sup>e</sup>	0.43 ± 0.02 <sup>b</sup>

Values are expressed as the mean ± standard deviation ( $n = 3$ ). Different letters in the same column indicate statistically significant difference at  $p \leq 0.05$ . T tocopherol, T3 tocotrienol

respectively). Very low levels were noted for  $\alpha$ -T3 (0.4–1.2 mg/100 g oil) and only minor amounts for  $\beta$ -T and  $\gamma$ -T3 (0.1–0.2 and 0.1–0.3 mg/100 g oil, respectively) (Table 3). The amount of total tocopherols in sweet cherry kernel oils was in the range of 83.1–111.1 mg/100 g oil, comparable to levels reported for grape (*Vitis vinifera* L.) and watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai) seed oils (97.49 and 117.87 mg/100 g oil, respectively) [7]. To the best of our knowledge this is the first report of the tocopherols and tocotrienols composition in kernel oils of different sweet cherry cultivars. In the previous studies, tocopherols were determined in sweet cherry kernels, but not in their extracted oils [33].

The content of carotenoids in sweet cherry kernel oils ranged from 0.36 to 0.62 mg/100 g oil (in cvs. 'Iedzenu Dzeltenais' and 'Krupnoplodnaya', respectively). A comparable range of carotenoids concentrations (0.10–1.58 mg/100 g oil) was reported previously in seed oils recovered from six apples cultivars [8].

Nine sterols (campesterol,  $\beta$ -sitosterol,  $\Delta$ 5-avenasterol, 24-methylene-cycloartanol, cholesterol, gramisterol,  $\Delta$ 7-stigmasterol,  $\Delta$ 7-avenasterol and citrostadienol) were identified in sweet cherry kernel oils (Table 4). The  $\beta$ -sitosterol was the predominant phytosterol in each studied cultivar (201.5–333.1 mg/100 g oil) and consisted of 75–86 % of the total detected sterols. A similar composition of sterols for sweet cherry kernel oil was reported previously, however the impact of the cultivar was not taken into consideration [25]. The percentage of  $\beta$ -sitosterol in oils recovered from different plant cultivars varied considerably, for instance in apple seed oils the levels ranged from 51 to 94 % [3]. For the other detected sterols, the concentrations were in the range of 0.0–32.5 mg/100 g oil (Table 4). The total amount of sterols ranged from 233.6–419.4 mg/100 g oil in cvs. 'Tyutchevka' and 'Krupnoplodnaya', respectively. A comparable range of total sterols was noted in seed oils recovered from six crab and five dessert apple cultivars (113–314 and 182–780 mg/100 g oil, respectively) [3].

The content of squalene in sweet cherry kernel oils ranged from 60.9 to 127.7 mg/100 g oil (in cvs. 'Gårdebo' and 'Iedzenu Dzeltenais', respectively). Squalene concentrations in sweet cherry kernel oils are significantly higher to those reported in dessert apple seed oils (9.0–34.0 mg/100 g oil) [3] and comparable to reported levels in pumpkin seeds (89.0 mg/100 g) [34] and pomegranate seed oil (82.8–144.9 mg/100 g) [35]. To the best of our knowledge this is the first report about the carotenoids and squalene concentration in sweet cherry kernel oils and therefore, direct comparison was not possible.

Three significant correlations between oil yield in seeds of different sweet cherry cultivars and the total content of sterols ( $r = -0.852$ ,  $p \leq 0.05$ ), tocopherols ( $r = -0.880$ ,  $p \leq 0.01$ ) and carotenoids ( $r = -0.698$ ,  $p \leq 0.1$ ) were found (Electronic supplementary material). Demonstrating that a higher oil yield

**Table 4** Sterols and squalene content (mg/100 g oil) in kernel oils recovered from seven sweet cherry cultivars

Cultivar	Sterols										Squalene
	Campe-sterol	$\beta$ -Sito-sterol	$\Delta$ 5-Avena-sterol	24-Methylene-cyclo-artanol	Chole-sterol	Grami-sterol	$\Delta$ 7-Stigma-sterol	$\Delta$ 7-Avena-sterol	Citro-stadienol	Total	
Bryanskaya Rozovaya	7.5 0.4 <sup>ab</sup>	236.9 8.6 <sup>b</sup>	11.9 0.6 <sup>bc</sup>	18.7 0.5 <sup>a</sup>	10.9 0.5 <sup>a</sup>	3.9 0.2 <sup>a</sup>	2.1 0.1 <sup>ab</sup>	2.2 0.1 <sup>a</sup>	2.8 0.2 <sup>b</sup>	297.0 8.7 <sup>b</sup>	78.7 0.7 <sup>bc</sup>
Gårdebo	8.1 0.4 <sup>bc</sup>	219.8 6.6 <sup>ab</sup>	8.5 1.2 <sup>a</sup>	23.3 0.6 <sup>b</sup>	13.7 0.9 <sup>abd</sup>	11.3 0.4 <sup>c</sup>	1.6 0.2 <sup>a</sup>	3.2 0.4 <sup>b</sup>	3.2 0.3 <sup>bc</sup>	292.7 7.2 <sup>b</sup>	60.9 1.4 <sup>d</sup>
Iedzenu Dzeltenais	8.7 0.2 <sup>c</sup>	264.1 9.3 <sup>c</sup>	10.2 0.7 <sup>ab</sup>	32.5 1.1 <sup>d</sup>	12.3 0.9 <sup>ab</sup>	6.9 0.4 <sup>c</sup>	2.2 0.2 <sup>ab</sup>	2.1 0.3 <sup>a</sup>	3.4 0.2 <sup>c</sup>	342.3 11.3 <sup>c</sup>	127.7 3.9 <sup>c</sup>
Krupnoplodnaya	8.9 0.5 <sup>c</sup>	333.1 10.2 <sup>d</sup>	16.3 0.6 <sup>d</sup>	27.6 0.6 <sup>c</sup>	14.2 0.3 <sup>cd</sup>	10.0 0.3 <sup>d</sup>	2.5 0.2 <sup>b</sup>	3.6 0.4 <sup>bc</sup>	3.2 0.1 <sup>bc</sup>	419.4 11.0 <sup>d</sup>	82.0 2.5 <sup>c</sup>
Lapins	7.0 0.4 <sup>b</sup>	242.1 8.0 <sup>bc</sup>	8.5 0.6 <sup>b</sup>	20.4 0.7 <sup>b</sup>	12.5 0.8 <sup>abc</sup>	12.5 0.3 <sup>c</sup>	2.5 0.2 <sup>b</sup>	4.1 0.1 <sup>c</sup>	3.0 0.3 <sup>bc</sup>	312.6 8.0 <sup>b</sup>	78.1 1.6 <sup>bc</sup>
Tyutchevka	0.0	201.5 6.5 <sup>a</sup>	0.0	0.0	12.3 0.1 <sup>ab</sup>	5.5 0.3 <sup>b</sup>	2.7 0.3 <sup>b</sup>	11.6 0.3 <sup>d</sup>	0.0	233.6 6.8 <sup>a</sup>	74.1 3.2 <sup>b</sup>
Vytenu Juodoji	0.0	238.9 9.2 <sup>bc</sup>	12.5 0.4 <sup>c</sup>	22.7 0.6 <sup>b</sup>	15.6 0.6 <sup>d</sup>	5.3 0.2 <sup>b</sup>	2.2 0.3 <sup>ab</sup>	2.3 0.1 <sup>a</sup>	1.9 0.2 <sup>a</sup>	301.4 9.1 <sup>b</sup>	98.5 3.3 <sup>d</sup>

Italic values correspond to standard deviations ( $n = 3$ ). Different letters in the same column indicate statistically significant differences at  $p \leq 0.05$



in sweet cherry kernels results in a lower concentration of minor lipophilic bioactive compounds. These phenomena can provide valuable information as preliminary estimates of the total concentration of sterols, tocochromanols and carotenoids, based on known oil yields in sweet cherry kernels. A similar observation was reported previously in cases that focused on seed oils recovered from different cultivars of crab and dessert apples, recording two negative correlations between the oil yield and the content of  $\beta$ -sitosterol ( $r = -0.931$ ) and total sterols ( $r = -0.901$ ) [3]. Nevertheless, as was stated previously, a larger amount of different cultivars is required to confirm this phenomenon.

## Conclusion

The oils recovered from sweet cherry cultivars are rich sources of lipophilic compounds, namely, tocopherols, carotenoids, phytosterols, and essential fatty acids. Our findings have demonstrated that the content of bioactive molecules in sweet cherry kernel oils is significantly affected by the cultivar, since the abiotic factors were the same for all studied varieties. Correlations between oil yield in sweet cherry kernels and the amount of minor lipophilic compounds were observed, cv. ‘Krupnoplodnaya’ had the highest total content of tocochromanols, carotenoids and sterols, and the lowest oil yield. Hence, in recovered oils from different sweet cherry cultivars, the oil content may be considered as a preliminary indicator of the concentration of lipophilic bioactive molecules. The impact of multiple non-varietal factors, which were not the subject of the present study, should be also taken into consideration, since the oil yield and its composition for the same cultivar grown even in the same location, year to year, can have a tendency to variability.

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**Compliance with Ethical Standards**

**Conflict of Interest** None.

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