

CHEMICAL COMPOSITION AND QUALITY OF CULTIVATED AND NATURAL BLUEBERRY FRUIT IN ESTONIA

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Summary

Nutrition studies suggest that blueberries help keep us healthy and these possible health benefits may be due to the antioxidant capacity as well as other natural compounds in blueberry fruit. Different taxa of *Vaccinium* species (Bilberry - *Vaccinium myrtillus* L.; lowbush blueberry - *Vaccinium angustifolium* Ait.; half-highbush blueberry - *Vaccinium corymbosum* x *Vaccinium angustifolium* 'Northblue' and 'Northcountry') were analyzed for surface color, size, sugars, titratable acidity, soluble solids, fat, protein, vitamins and anthocyanin content. The blueberry fruit were harvested from three commercial blueberry plantations and from one natural habitat in 2003. The fruit of *V. angustifolium* were collected from two different areas: one plantation was located on mineral soil and the other on peat soil (abandoned peat pits). The anthocyanin content ranged from 125 to 405 mg·100 g⁻¹ of fresh berry in different species and cultivars. Half-highbush blueberry 'Northblue' had the largest berry size but ascorbic acid and anthocyanin contents were low. *V. myrtillus* had the lowest total energy value, but the highest anthocyanin content. Glucose and fructose content was higher in fruit of *V. angustifolium* compared with the other species. The soil type (mineral or peat soil) did not affect anthocyanin and ascorbic acid content of *V. angustifolium* fruit but titratable acids and moisture content was higher in fruit of *V. angustifolium* grown on peat soil, compared with mineral soil.

key words: bilberry, vitamin, surface color, sugars, titratable acids, soluble solids, and anthocyanin

INTRODUCTION

Nutrition information studies suggest that wild blueberries help keep us healthy and may even thwart the effects of aging, particularly with respect to loss of memory and motor skills. The possible health benefits of blueberries

may be related to the antioxidant capacity of the blue pigments (anthocyanins), as well as other natural compounds. Blueberries have more antioxidant capacity than 40 other fruits and vegetables tested. There is evidence that the blue in the berries may have cancer-fighting properties and protect against heart disease (Kalt & Dufour 1997). Blueberries contain a number of phytochemicals that may make a positive contribution to human health (Prior *et al.* 1998). These include: antioxidants, anthocyanins, bacterial inhibitors, folic acid, vitamins A and C, carotenoids, ellagic acid, and dietary fibers. Their caloric value is low and they contain no fat (Kalt & Dufour 1997, Salvayre *et al.* 1981).

The wild lowbush blueberry (*Vaccinium angustifolium* Ait.) is an important successional species of cleared woodland and abandoned farmland of northeastern North America where commercial, managed blueberry fields have been developed. Lowbush blueberries are a widely-grown fruit crop in the USA and Canada. These berries are noted for their small size and sweet taste.

The cultivated highbush blueberry (*V. corymbosum* L.) is a multiseed berry, with small, soft seeds. The dark blue berries are three times larger than lowbush blueberry. Highbush blueberries are cultivated mainly in USA, Canada, Australia, Argentina, Chile, New Zealand, the Netherlands, Poland, Japan, Spain and France (Strik 2005).

In North European countries such as Norway, Sweden, Finland and Estonia, the cultivation of blueberries is being considered. The climate conditions of North Europe are suitable for the lowbush and half-highbush (*Vaccinium corymbosum* L. x *Vaccinium angustifolium* Ait.) blueberry cultivation (Bläsing 1989, Haffner & Vestheim 1994, Karp *et al.* 2000, Paasisalo *et al.* 1994, Starast *et al.* 2002). Bilberry (*V. myrtillus* L.) is widespread in Estonian nature and historical traditions use the fresh berries, plant leaves and dried berries as a herbal plant (Pogen 1977).

The aim of the study was to compare the chemical composition of different blueberry taxa from both natural and cultivated sites.

METHODS

The following taxa were used in the trial: bilberry; lowbush blueberry; and half-highbush blueberry cultivars 'Northblue' and 'Northcountry'. The bilberry fruit were harvested from a natural habitat situated in South Estonia in Voru county (57° 37'N and 27° 4'E). The lowbush blueberry fruit were collected from two different areas: one plantation was located on mineral soil (Voru county in South Estonia 57° 37'N and 27° 4'E) and the other on peat (abandoned peat pits) soil (Harju county in North Estonia 59° 9'N and 25° 19'E). Half-highbush blueberry fruit were collected from a commercial farm in Tartu county, South Estonia (58° 12'N, 26° 41'E). The blueberry fruit were harvested on 5, 6, 7 August 2003.

100 berries from each taxon were weighed and the diameter measured using calipers. The average berry weight (g) and diameter were calculated.

Dry matter (DM) was determined using a 10 ± 1 g sample and drying in a thermostat (Co. Memmert) at 105°C to a constant weight. Fruit moisture was calculated on a dry weight and fresh weight basis.

The titratable acidity was measured by neutralizing 0.1 M NaOH solution (automatic titrator, Mettler Toledo DL 50 Randolino). Titratable acids were expressed as citric acid ($\text{g} \cdot 100 \text{ g}^{-1}$).

Soluble solids were analyzed using a Pocket Pal-1 refractometer (Co. Atago).

For the determination of anthocyanins, 10 whole fruit were crushed and 10 g of the crushed fruit were soaked in an extracting solution containing HCl (0.1M): $\text{C}_2\text{H}_5\text{OH}$ (96%) = 15: 85 (v/v). Solutions were shaken and held at 5°C for 24 h. After settling, 2 x 2 ml of the clear supernatant was pipetted into 50 ml volumetric flasks and made up to volume with extracting solution. The anthocyanins were determined using the modified pH differential method of Francis (1982) and Fuleki & Francis (1968). The Thermo Spectronic Helios β spectrophotometer was used for measuring the absorbance. The extinction coefficient of malvidin-3-glycoside (28 000) was used (Wrolstad 1976).

The content ($\text{mg} \cdot 100 \text{ g}^{-1}$) of thiamin (vitamin B1), riboflavin (vitamin B2, vitamin G), nicotinic acid (a form of vitamin B3, vitamin PP), nicotinamide (a form of vitamin B3, vitamin PP), pyridoxine (a form of vitamin B6), pyridoxal (a form of vitamin B6) and folic acid (vitamin B9) was analyzed at the Laboratory of Department of Food Processing (Tallinn University of Technology) using standard methods (Water Soluble Vitamins 2003). The content of fat ($\text{g} \cdot 100 \text{ g}^{-1}$), protein ($\text{g} \cdot 100 \text{ g}^{-1}$), glucose ($\text{g} \cdot 100 \text{ g}^{-1}$), fructose ($\text{g} \cdot 100 \text{ g}^{-1}$) and the total energy value ($\text{kcal} \cdot 100 \text{ g}^{-1}$) was determined by standard AOAC (AOAC 1990) methods at the Veterinary and Food Laboratory.

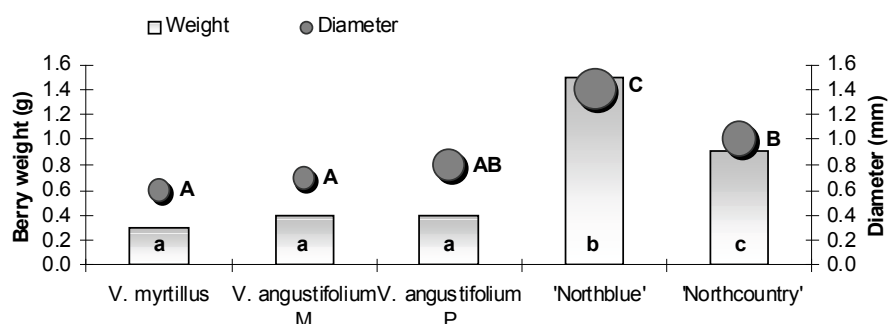
For the determination of vitamin C, 10 g of crushed fruit were taken for analysis. As described by Paim & Reis (2000), 60 ml of metaphosphoric and acetic acid (3% HPO_3 + 8% CH_3COOH) was added immediately to the fruit to avoid vitamin C breakdown in the air. The slurry was shaken in 125 ml plastic bottles with leakproof screwcaps for one hour using a reciprocating shaker at $190\text{--}200 \text{ rpm min}^{-1}$. Vitamin C was titrated iodometrically using an automatic titrator (Mettler Toledo DL 50).

Surface color of fresh blueberries was measured with a reflectance colorimeter (Model CR-400, Minolta Co., Ltd.). In each replication ten fruit were measured. The mean of three color readings for each berry was calculated. Color of the fruit was expressed as L^* (lightness; black = 0, white = 100), a^* (redness, red = +60, green = -60), b^* (yellowness, yellow = +60, blue = -60), C^* (chroma, saturation, vividness), and h (hue angle).

All measurements and analyses were made in three replications. One-way analysis of variance (ANOVA) was conducted to compare average values of different blueberries. Different letters indicate significant differences at $P < 0.05$ on Figures and Tables. Unless noted otherwise, only results significant at $P < 0.05$ will be discussed.

RESULTS AND DISCUSSION

The half-highbush blueberry cultivar 'Northblue' produced the largest berries (Fig. 1). There was no significant difference in berry weight between bilberry and lowbush blueberry grown in different soil. Berries of 'Northblue' were three times heavier and berry diameter was twice as large as the diameter of bilberry and lowbush blueberry. An average berry weight of 'Northcountry' was 0.9 g with a diameter of 1.0 cm. Both 'Northblue' and 'Northcountry' are hybrids of a lowbush and a highbush blueberry (Lubi *et al.* 1989). 'Northblue' resembles highbush blueberries while 'Northcountry' is more like the lowbush blueberry.



Note: M – berries were harvested from plantation on mineral soil

P – berries were harvested from plantation on peat soil

Different letters indicate significant differences at $P < 0.05$

Fig. 1. Berry weight and diameter of different blueberries.

The growing environment significantly influenced berry moisture content. Dry matter content was higher in berries of 'Northcountry' and lowbush blueberry grown on mineral soil (Table 1). The berries of bilberry and lowbush blueberry, grown in peat soil, contained more water. The amount of fat and protein was lower in berries of 'Northblue'. Protein content was the highest in bilberry berries. The titratable acidity was significantly different among taxa. It was highest in berries of bilberry and lowest in 'Northcountry'. The berries of lowbush blueberry, grown in peat soil, had significantly higher protein and titratable acidity, compared with berries harvested from mineral soil. The berries of rabbiteye blueberry (*V. ashei* Read.) are more acidic than cultivars of highbush and lowbush blueberries (Prior *et al.* 1998). It was found in this study that the highest titratable acidity was in berries of bilberry ($1.52 \text{ mequiv} \cdot \text{g}^{-1}$ of DM).

Soluble solids content is relatively high in blueberries (Bushway *et al.* 1983). In this experiment it ranged from 10.0 to $14.9 \text{ g} \cdot 100 \text{ g}^{-1}$, with berries of bilberry having the lowest value (Table 1). Prior *et al.* (1998) indicated the soluble solids content in lowbush blueberries is 14.3% which is comparable to the results of our study.

Table 1. Nutrient composition in different blueberries

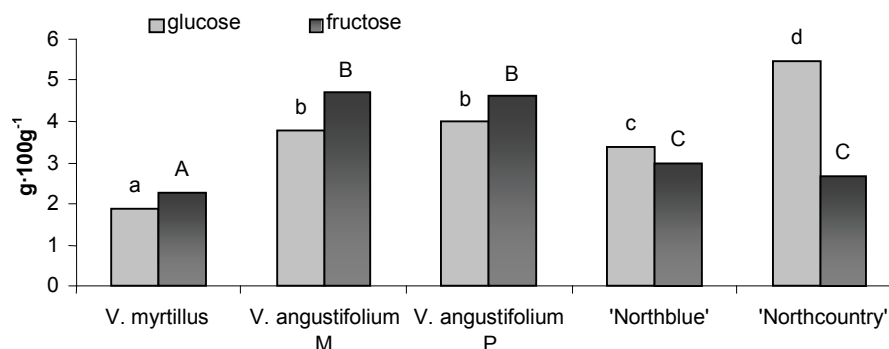
Taxon	Dry matter	Moisture content	Fat	Protein	Titrateable acidity	Soluble solids
	(g·100 g ⁻¹)					
<i>V. myrtillus</i>	11.0a	89.0a	0.66a	0.67a	3.8a	10.0a
<i>V. angustifolium</i> M	15.8b	84.2b	0.67a	0.41b	0.5b	14.0b
<i>V. angustifolium</i> P	9.8a	90.2a	0.68a	0.56c	1.1c	14.5bc
'Northblue'	12.9c	87.1c	0.46b	0.30d	2.3d	11.5d
'Northcountry'	16.5b	83.5b	0.63a	0.46b	0.2e	14.9c

M – berries were harvested from plantation on mineral soil

P – berries were harvested from plantation on peat soil

Different letters indicate significant differences at $P < 0.05$

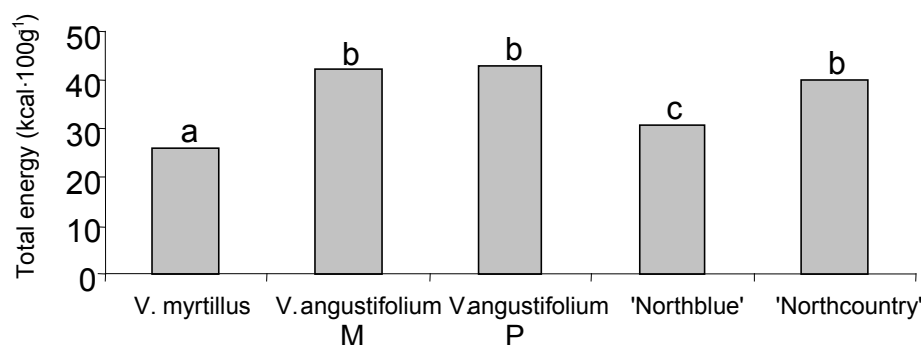
Because glucose and fructose account for essentially all the sugar in low-bush blueberries (Barker *et al.* 1963), only glucose and fructose were measured in this study. The average glucose content was 3.7 g·100 g⁻¹ and the average fructose content was 3.5 g·100 g⁻¹ (Fig. 2). The berries of bilberry contained the lowest level of glucose and fructose. Glucose content was highest in berries of 'Northcountry' while the fructose content was highest in lowbush blueberry. Free sugars, organic acids and amino acids are natural components of many fruits and vegetables and they play important roles in maintaining fruit quality and determining nutritive value. Acids and sugars are important components in a number of food products. This is especially true of fruit juices (Ashoor & Knox 1982). The nature and the concentration of these constituents in fruits have been of interest because of their important influence on organoleptic properties. Consequently, food analysts and plant physiologists have been interested in changes in the nature and amounts of the various chemical components occurring during ripening in the edible parts of fruits because of their effect on the market quality of the food product (Wrolstad 1981).



Note: see Fig. 1

Fig. 2. Glucose and fructose content in different blueberries

The total energy values of the five blueberries ranged from 26 kcal·100 g⁻¹ to 43 kcal·100 g⁻¹ (Fig. 3). The berries of bilberry had the lowest total energy values. This value was higher in berries of lowbush blueberry and 'Northcountry'. Usui *et al.* (1994) suggested the total energy value of lowbush blueberry is 52.5 kcal·100 g⁻¹ and carbohydrate is the major contributor to this value whereas fat and protein content do not influence the total energy value.



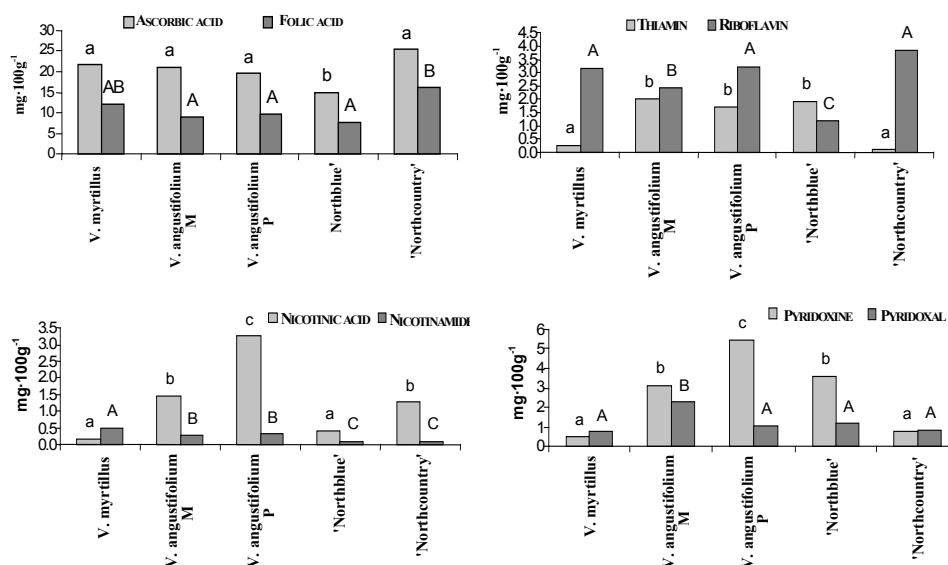
Note: see Fig. 1

Fig. 3. Total energy value of different blueberries

Fruits and vegetables contain different antioxidant compounds, such as vitamin C, vitamin E and carotenoids, whose activities have been established in recent years. These compounds are not the only ones contributing to the antioxidant activity of fruit and vegetables. Additionally these works show that the presence of polyphenol compounds, such as flavonoids also contribute beneficial effects of this group of foods (Bors *et al.* 1990, Cao *et al.* 1996, Hertog *et al.* 1993, Hertog *et al.* 1995, Wang *et al.* 1996). Apart from their biological properties, flavonoids are also of interest in the food, cosmetic, and pharmaceutical industries, as they can be used as substitutes for synthetic antioxidants (Moure *et al.* 2001). In our study the content of vitamins showed a significant variation between cultivars and species. Ascorbic acid concentration was between 15 and 25 mg·100 g⁻¹ (Fig. 4). The ascorbic acid content was significantly lower in berries of the half-highbush blueberry 'Northblue' compared with the other cultivars. However, Prior *et al.* (1998) have shown that highbush blueberry (7.2 mg·100 g⁻¹) has higher levels of ascorbate than lowbush blueberry (5.5 mg·100 g⁻¹) and bilberry (1.3 mg·100 g⁻¹). They observed during the course of the study that if the skin of the blueberry is broken, ascorbate may be oxidized and the concentration may be significantly reduced. In our experiment the content of ascorbic acid was higher than in the Prior *et al.* (1998) study.

The average folic acid concentration of berries was higher in 'Northcountry' (Fig. 4). Thiamin and pyridoxine content were lower in bilberry and 'Northcountry'. The average riboflavine concentration was 2.8 mg·100 g⁻¹ and higher level had bilberry, lowbush blueberry from peat soil and 'Northcountry'. The highest content of nicotinic acid was found in lowbush blueberry from peat

soil and the lowest level was found in berries of bilberry and ‘Northblue’. However bilberry had higher content ($0.5 \text{ mg} \cdot 100 \text{ g}^{-1}$) of nicotinamide. Also Bushway *et al.* (1983) suggested lowbush blueberry fruit are an excellent source of niacin (also called nicotinic acid) and vitamin C.



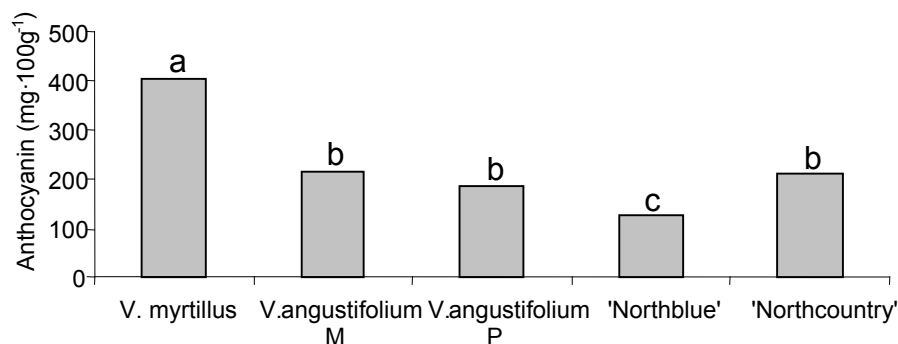
Note: see Fig. 1.

Fig. 4. Content of vitamins in different blueberries

The 3-glucoside(s) and 3-galactoside(s) of delphinidin, malvidin, petunidin, cyanidin, and peonidin are the primary anthocyanins that have been identified in blueberries (Mazza & Miniati 1993, Gao & Mazza 1994). In our experiment an average content of anthocyanins was $229 \text{ mg} \cdot 100 \text{ g}^{-1}$ (Fig. 5). The lowest content was found in ‘Northblue’ berries and the highest in bilberry, respectively. Prior *et al.* (1998) reported blueberries (*Vaccinium* sp.) to be one of the richest sources of antioxidant phytonutrients, and found a linear relationship between oxygen radical absorbing capacity of four *Vaccinium* species and anthocyanin or total phenolic content. However, it was observed that the antioxidant capacity in *Vaccinium* species and diverse small fruits is more highly correlated to total phenolics than to anthocyanins (Moyer *et al.* 2002), with lowbush blueberries having higher antioxidant capacity than highbush blueberries (Kalt *et al.* 2001).

The actual color of blueberries is a deep purple-black, but is masked by a glaucous covering that gives the fruit a characteristic bluish color (Darrow & Camp 1945), which is responsible for the lightness or darkness of the blue color of the berry. Light blue color is the desired marketing characteristic (Galleta 1975). Surface color of bilberry was the darkest and less red (Table 2). The ber-

ries of lowbush blueberry from peat soil were darker than from mineral soil. The cultivar 'Northblue' had the bluest fruit, compared with the other taxa. The color was more saturated on bilberry than the other species and cultivars. The value of hue angle (h) was higher in berries of bilberry and lower in 'Northblue'. Austin & Bondari (1993) indicated the color of berries depended on cultivar and it varied in different years.



Note: see Fig. 1.

Fig. 5. Anthocyanin content in different blueberries

Table 2. Surface color of fruits from different blueberry taxa

Taxon	Color measurement				
	L*	a*	b*	C*	h
<i>V. myrtillus</i>	19.6 a	4.2 a	0.8 a	4.3 a	11.2° a
<i>V. angustifolium</i> M	20.1 b	6.4 b	0.8 a	6.5 b	7.5° bd
<i>V. angustifolium</i> P	20.8 c	6.1 b	0.9 a	6.1 c	8.5° c
'Northblue'	20.1 b	4.9 c	0.6 b	4.9 d	6.8° d
'Northcountry'	20.6 c	6.4 b	0.9 a	6.5 b	8.1° bc

M – berries were harvested from plantation on mineral soil

P – berries were harvested from plantation on peat soil

Different letters indicate significant differences at $P < 0.05$

Considering the results of the study we can characterize different taxa as follows. The berries of bilberry were dark-blue color with acid taste. These fruit contained more anthocyanin and total energy value was very low. 'Northblue' half-highbush blueberry had big, light-blue berries with a low level of fat, protein, anthocyanin and vitamins. The berries of 'Northcountry' were medium size, sweet-tasting and contained more folic acid and riboflavin. The lowbush blueberry had small size, sweet berries. The cultivation environment influenced the chemical composition of these fruits. The cultivation on peat soil increased the content of moisture, protein, titratable acidity, riboflavin, nicotinic acid and pyridoxine. However, pyridoxal content decreased on the peat soil.

Acknowledgements

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SKŁAD CHEMICZNY I JAKOŚĆ BORÓWKI POCHODZĄCEJ Z PLANTACJI UPRAWNEJ I Z WARUNKÓW NATURALNYCH

Streszczenie

Badania dotyczące dietetycznych właściwości borówki wskazują na prozdrowotny wpływ spożycia owoców na zdrowie człowieka ze względu na właściwości antyoksydacyjne oraz obecność innych naturalnych składników w owocach. Różne obiekty *Vaccinium* (czarna jagoda – *Vaccinium myrtillus* L.; borówka amerykańska niska – *Vaccinium angustifolium* AIT.; borówka amerykańska średniowysoka – *Vaccinium corymbosum* x *Vaccinium angustifolium* 'Nortblue' i 'Nortcountry') wzięto do oceny koloru powierzchni owocu, jego wielkości, zawartości cukrów, substancji nierozpuszczalnych,

tłuszczy, białek witamin, antocyjanów oraz kwasowości miareczkowej. Owoce borówki były zbierane na plantacjach uprawnych i w warunkach naturalnych w 2003 roku. Owoce *V. angustifolium* zbierano na dwóch plantacjach: jedna była założona na glebie mineralnej a druga na torfowej. Zawartości antocyjanów wynosiła od 125 do 405 mg·100 g⁻¹ świeżej masy w owocach różnych obiektów. Borówka amerykańska średniowysoka ‘Nortblue’ miała większe owoce lecz zawartość kwasu askorbinowego i antocyjanów była mniejsza. *V. Myrtillus* miała niższą wartość energetyczną lecz wyższą zawartość antocyjanów. Zawartość glukozy i fruktozy w owocach *V. angustifolium* była porównywalna z innymi obiektami. Rodzaj gleby (mineralna lub torfowa) nie miał wpływu na zawartość antocyjanów i kwasu askorbinowego w owocach *V. angustifolium* lecz zawartość kwasów i wody była wyższa w owocach *V. angustitolium* uprawianej na glebie torfowej w porównaniu z glebą mineralną.