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The Relationship of Anthocyanins with Color of Organically and Conventionally Cultivated Potatoes

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Abstract**—**Many of the compounds present in potato are important because of their beneficial effects on health, therefore, are highly desirable in the human diet. Potato tubers contain significant amounts of anthocyanins. The aim of this research was to determine the content of anthocyanins and its relationship with the colour of organically and conventionally cultivated potato varieties. In the research eight potato samples of three potato varieties were analyzed on anthocyanins, dry matter content and color. Obtained results show that there was no significant influence on amount of anthocyanins between different cultivation environments ($p>0.05$) while between varieties – significant difference ($p<0.05$). Strong correlation between the amount of anthocyanins and color was determined.

Keywords**—**Potato variety, anthocyanins, organic, conventional, dry matter.

I. Introduction

THE research in potato chemistry has established the fact that there is a lot more in potatoes than starch [1]. Many of the compounds present in potato are important because of their beneficial effects on health, therefore, are highly desirable in the human diet [2].

In addition to supplying energy, potatoes contain a number of health promoting phytonutrients such as phenolics, flavonoids, folates, kukoamines, anthocyanins, and carotenoids [3].

Potato tubers contain significant amounts of anthocyanins such as petanin in purple cultivars [4]. Anthocyanins are secondary metabolites of plants, and are the most important subclass of flavonoids [5]. Among flavonoids, anthocyanins are natural pigments, responsible for the red-blue color of many fruits and vegetables. Anthocyanins can impact on the organoleptic characteristics of foods which may influence their technological behavior during food processing and also have implications in the field of human health [6].

A high intake of anthocyanins has been linked to health preventive effects and reduced risks of e.g., certain form of cancer [7], ocular disorders [8] or vascular failures [9].

There are many factors affecting the quality of potatoes. Potato quality varies depending on the growing area, cultivar [10] and aspects of the chemical composition of main crop potato tubers have been shown to depend on the cultivation system as well. The improved qualitative value of organic vs. conventional produce, however, has not been ascertained [11], [12]. Although nutrient content depends on a number of factors, the potato variety is thought to be among the most significant factors [13].

In 2008, the most important arable crop in the EU27 was cereals (44% of the fully converted organic area under arable crops), followed by green fodder (42%), other arable crops such as dried pulses, potatoes, sugar beet, arable seeds and seedlings (7%), fresh vegetables and industrial crops (both 4%) [14]. As a result the interest in organic agriculture and environmentally-friendly agricultural products is increasing, and in particular consumers have made potatoes one of their top organic purchases among fresh vegetables even though organic potatoes carry a price significantly higher than most other vegetables [15].

In this respect, it is not known whether and how different agriculture techniques and/or cultivation systems may affect the nutrients composition of the final product. Comparison of organic and conventional foods in terms of nutritional value, sensorial quality and food safety, has often highlighted controversial results. As a consequence, a clear link between cultivation system and nutritional profile of agricultural products is still missing [16], [17].

The aim of this research was to determine the content of anthocyanins and its relationship with the color of organically and conventionally cultivated potato varieties.

II. Materials and Methods

A. Soil and Climate

The potatoes were planted in the middle of May and harvested in last decades of August or first days of September. Field trials were conducted in three replications. The certified potato seed material was used. Seed tubers were planted in rows; the distance between rows was 0.7m and the distance between tubers 0.3m.

The soil type was sod podzolic (PVv), loamy sand. Organic matter content in soil was 25mg kg^{-1}, pH_{KCl} was 6.3, the availability in soil of K was low and P was medium. The common agronomic practices were used during vegetation period.

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TABLE I
DESCRIPTION OF POTATO VARIETIES

Variety	Shape of tubers	Color of skin and flesh	Maturity	Additional information
Agrie dzeltenie	oval round	skin - russet yellow; flesh - yellow	early	bred at SPPBI*
Imanta	long oval	Skin - yellow with pink eyes; flesh - white	mid-late	bred at SPPBI
Blue Congo	long oval	skin - violet; flesh - violet	mid-late	the Czech Republic Gene bank

* SPPBI- State Priekuli Plant Breeding Institute

The soil type in conventional field was sod-podzolic (PVv), sandy loam. Organic matter content in soil was 27mg kg^{-1}, pH_{KCl} was 5.7, availability of K and P in soil was high. Fertilizer P – 55, K – 90kg ha^{-1} was used in conventional field, two rates of N fertilizer was used N1 – 60kg ha^{-1} and N2 – 120kg ha^{-1}. The common agronomic practices were used during vegetation period. Herbicides in field were used for weed control. The fungicides for restriction fungal diseases were used two times in July.

The weather conditions were warmer than perennial data (PD) with heavily rainfalls occasionally during growing period 2011. The average air temperature in beginning of growing period (end of May and first part of June) exceeded PD for 0.6°C. The weather was hot and dry in rest of June, and the precipitation reached only 46% of PD. During July, the air temperature was similar to the PD. Weather in July was dry (precipitation only 85% of PD), but rainfalls exceeded the PD by 109% in the second decade of August. The infection of late blight started in mid-August when the tubers were mostly developed.

The haulm was cut in last decade of August and the tubers were harvested in the beginning of September.

Potatoes were stored at the State Priekuli Plant Breeding Institute at an air temperature of 4°C and at a relative air humidity of 80 ± 5%.

B. Tubers

In the experiment three potato (*Solanum tuberosum* L.) varieties with white, yellow and violet colored flesh were evaluated, whose seed was obtained in the State Priekuli Plant Breeding Institute (SPPBI) (Latvia) and from abroad. In cooperation with the SPPBI potatoes were grown in organic and conventional field. The characterization of potato varieties is present in Table I.

C. Dry Matter and Anthocyanins

Dry matter (DM) content of potato tubers was determined by ISO 6496:1999 [18]. Anthocyanins were analyzed by spectrophotometric method (with the UV/VIS spectrophotometer Jenway 6705) at 535nm. Initially potato tubers were homogenized, and 30g of potato sample was mixed for a minute with 70ml of ethanol and 1.5M HCl solution (85:15 respectively), afterwards sample was filtrated and then analyzed on spectrophotometer [19].

D. Color Analysis

The color of potato samples was measured by "Color Tec-PCM" device (USA). For evaluation of the color of potato samples, potato slices were cut shortly before measurement in order to avoid formation of melanin pigments in non-enzymatic browning reaction which can affect the accuracy of color measurement. Potato samples were covered by a transparent PP film ("Forpus"), thickness of 25μm, to avoid direct contact between the aperture of the measuring device and the product. The color was measured at least in seven various locations of the sample in order to obtain higher accuracy after calculation of the mean value. For data processing, "ColorSof QCW" software was used.

When a color is expressed in CIELAB, L* defines lightness, a* denotes the red/green value and b* the yellow/blue value.

E. Statistical Analysis

For statistical analysis, the data were processed using the S-PLUS 6.1 Professional Edition software. Data are presented as a mean ± standard deviation (SD). The differences between independent groups were specified by two way analysis of variance (ANOVA), and values of $P < 0.05$ were regarded as statistically significant. In case of establishing statistically significant differences, homogeneous groups were determined by Tukey's multiple comparison test at the level of confidence $\alpha = 0.05$. Relationships between anthocyanins, color and dry matter were made by PCA.

III. RESULTS AND DISCUSSION

Dry matter (DM) content varies from 20.77±0.05% (Blue Congo variety when cultivated conventionally with N supply 60kg ha^{-1}) to 32.45±0.77% (Imanta variety, when cultivated organically) (Fig. 1).

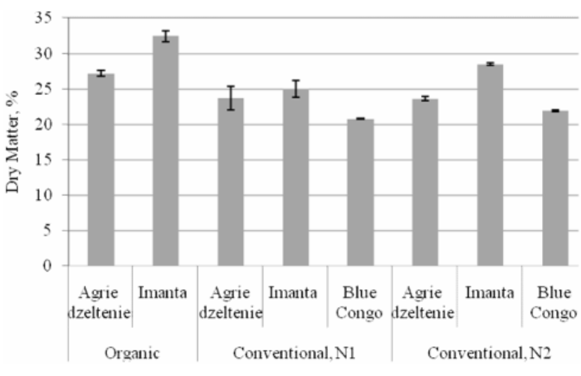

Fig. 1 Dry matter content in potatoes with different flesh color

DM content in Imanta variety was 23% and 12% lower when potatoes were cultivated conventionally with N supply 60 and 120kg ha^{-1} respectively. The difference in DM content was not influenced by the cultivation practice while the factor 'variety' played an important role – there was significant difference in DM content between Imanta and Brasla varieties ($p<0.05$).

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In the previous research reported by Murniece et al. DM content of Imanta variety in the first study year was 24.71% and almost the same value was in the second year – 24.41%. Potatoes were cultivated conventionally with N supply 60kg ha^{-1} [20].

DM was higher in organically cultivated potatoes and comparing with the results of Brazinskiene et al. the tendency was in opposite – DM content was higher in potatoes cultivated conventionally [21]. From the Tein et al. research report is clear that tendency of being higher DM content in organically or conventionally cultivated potatoes is very strongly affected by the season - DM content was found to be different per each research year [22].

In addition to supplying energy, potatoes contain a number of health promoting phytonutrients such as phenolics, flavonoids, folates, kukoamines, anthocyanins, and carotenoids [23]. Anthocyanin levels between 5.5 and 35mg 100g^{-1} FW in potatoes have been reported [24]. Comparing to the results reported by Brown, in the particular research the amount of anthocyanins is found to be lower. The highest amount of anthocyanins was determined in Blue Congo variety i.e. 4.451±0.006mg 100g^{-1} when potatoes cultivated conventionally with N supply 120kg ha^{-1} (Fig. 2).

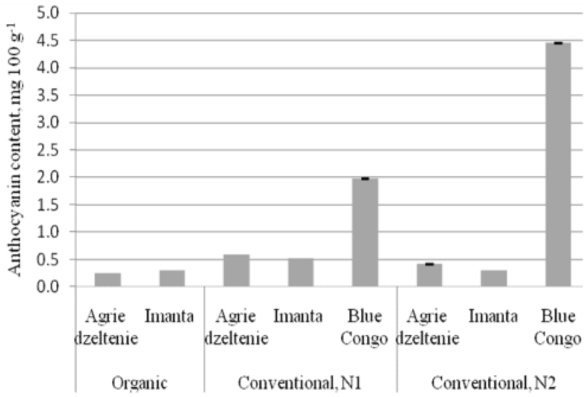

Fig. 2 Dry matter content in potatoes with different flesh color

Blue Congo is variety with flesh in purple color; therefore, results of statistical analysis show significant differences on amount of anthocyanins between varieties ($p<0.001$) while no significant differences between cultivation practice was found ($p>0.05$).

Average intensity of color in white flesh potatoes is L=70.7, yellow flesh potatoes – L=72.9 and potatoes with purple color – L=35.6 (Fig. 3). Significant affect on color intensity L*, color factor a* and b* was found between varieties. In all cases Blue Congo variety showed the difference while in case of color factor b*, the differences was found between each variety. Cultivation practices did not affect significantly on color ($p>0.05$) while slight difference is noticed (Fig. 3).

Colored potatoes have attracted the attention of investigators as well as consumers because of their antioxidant activities, taste and appearance [25]. Colored potatoes have the potential to be one of the richest sources of antioxidants in the human diet.

Anthocyanins correlates with the color of potato flesh and strongest correlation was determined with color factor b* i.e., $R^2=0.691$ while with L* it was $R^2=0.674$ and with a* – $R^2=0.570$.

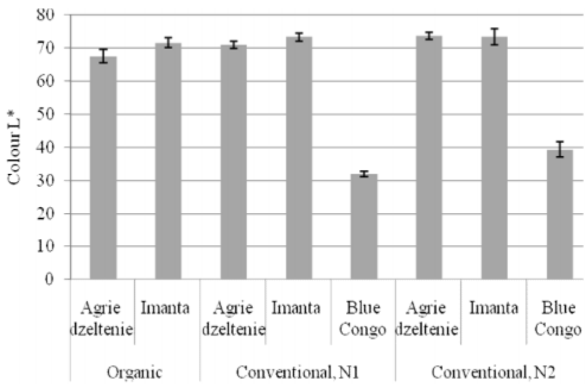

Fig. 3 Color intensity of potato flesh with different flesh color

Principal component analysis (PCA) was used to summarize the relationship between color, DM and anthocyanins (Fig. 4).

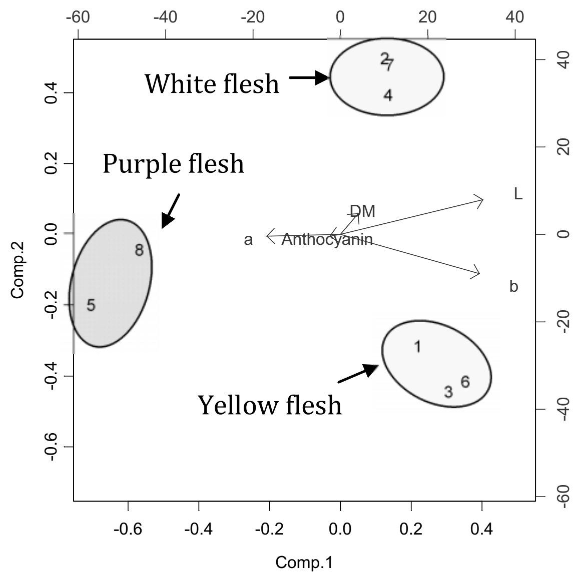

Fig. 4. Principle component analysis. Projection of the analyzed potato samples showing the influence of cultivation type on anthocyanins, color and DM in the space formed by the comp. 1 and comp. 2. Abbreviations used in the figure: 1, 2, 3-Agrie dzeltenie, 2, 4, 7-Imanta, 5, 8-Blue Congo

PCA illustrates that variety with white flesh (#2, 4, 7) is with higher DM content and with higher L* value (L-lightness). Potatoes with purple flesh (# 5, 8) are high in anthocyanins while DM content in these potatoes presented is low. Potatoes with yellow flesh (# 1, 3, 6) presents high b* value which represents yellowness and DM content in these potatoes is lower comparing potatoes with white flesh but higher comparing potatoes with purple flesh.

In the PCA values of white flesh potato variety are much closer comparing with the values of purple flesh and white flesh potato varieties. Due to this fact it might be concluded that in particular research cultivation practice influenced much stronger purple fleshed and yellow flesh potatoes.

IV. Conclusion

Cultivation practise did not affect the amount of anthocyanins while significance was noticed between varieties ($p<0.001$).

Even when the amount of anthocyanins in potatoes was very small strong correlation between amount of anthocyanins and color was found.

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