

Carotenoids and Colour Before and After Storage of Organically and Conventionally Cultivated Potato Genotypes in Latvia

Irisa Murniece, Zanda Kruma, Ilze Skrabule

Abstract—Potatoes are a good source of carotenoids, which are lipophilic compounds synthesized in plastids from isoprenoids. The aim of this research was to determine the content of carotenoids in relationship with the colour of organically and conventionally cultivated potato genotypes before and after period of storage. In cooperation with the State Priekuli Plant Breeding Institute (Latvia), six potato genotypes were studied: 'Agrie dzeltenie', 'Prelma', 'Imanta', 'S-03135-10', 'S-99108-8' and 'S-01063-5'. All the genotypes were cultivated under three different conditions: organically and conventionally (two conditions). The content of carotenoids was determined by using spectrophotometer and the colour – L*a*b* system. The results of current research show that after the period of storage, carotenoid amount has increased and in conventionally cultivated potatoes it varies from 228.514 to 552.434 $\mu\text{g } 100 \text{ g}^{-1}$ while in organically cultivated potato genotypes – from 45.485 to 662.699 $\mu\text{g } 100 \text{ g}^{-1}$ FW. Colour of potato flesh was changing during storage.

Keywords—carotenoids, colour, organic and conventional cultivation, potato genotypes, storage

I. INTRODUCTION

THE potato is a versatile, carbohydrate-rich food consumed worldwide, prepared and served in a variety of ways. The potato appeared in Europe during the last quarter of the sixteenth century [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].

Traditionally, potatoes, which belong to the species *Solanum tuberosum* L. [1], are low in fat and rich in several micronutrients, especially vitamin C. It is also a good source of dietary antioxidants, which may play a part in preventing diseases related to ageing [3]. Carotenoids are isoprenoid molecules that are widespread in nature and have broad range of functions, especially in relation to human health and their role as biological antioxidants [4], [5]. Because of their high carotenoids content potatoes are particularly beneficial for eye health [6], [7]. Lutein, zeaxanthin, violaxanthin and neoxanthin are the major carotenoids present in potatoes and β -carotene is present in trace amounts. The orange and yellow colour of the tuber flesh is due to zeaxanthin and lutein, respectively. Potato cultivars with white flesh contained less carotenoids as compared to cultivars with yellow or orange flesh. Total carotenoids content was reported in the range of 50–350 $\mu\text{g } 100 \text{ g}^{-1}$ FW and 800–2000 $\mu\text{g } 100 \text{ g}^{-1}$ FW, respectively, in white- and yellow-fleshed potato cultivars [8].

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Potato quality varies depending on the growing area, cultivar [9] 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 [10], [11]. Although nutrient content depends on a number of factors, the potato variety is thought to be among the most significant factors [12].

Potato production has high environmental costs. In fact, it requires high inputs of water, fertilisers and pesticides that can cause soil degradation and pollution. In the last years, the demand for high quality foods and the government policies focused on environmentally sustainable agricultural systems have stimulated a rapid expansion of new farming methods. Studies comparing the productivity of organic practices to conventional agriculture provide an excellent example of the wide range of benefits that may result from a conversion to sustainable agricultural methods. Both organic and low-input systems increase the organic carbon content of the soil and the pools of stored nutrients, each of which are critical for long-term fertility maintenance [13]–[15].

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%) [16]. 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 [17]. 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 [18], [19].

The aim of this research was to determine the content of carotenoids in relationship with the colour of organically and conventionally cultivated potato genotypes before and after period of storage.

II. MATERIALS AND METHODS

A. Soil and Climate

The soil type in conventional field was sod-podzolic (PVv), sandy loam. Organic matter content in soil was 27 mg kg^{-1} , pH_{KCl} was 5.7, availability of K and P in soil was high. Fertiliser N –50-60, P – 100, K – 100 kg ha^{-1} was used.

The common agronomic practices were used during vegetation period. Herbicides were used for weed control in field. The fungicides for restriction fungal diseases were used two times in July.

Organic field The soil type was sod-podzolic (PVv), loamy sand. Organic matter content in soil was 33 mg 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.

Weather conditions The potatoes were planted in organic field May 14th, and in conventional field May 17th (second decade of May). The beginning of potato growing season was favourable for potato development, the air temperature exceeded perennial data (PD) for 6.8°C and reached 17.9°C . The precipitation was only 73% of PD. During sprouting the warm conditions and low humidity in soil are preferable. The air temperature during June was close to PD ($14.0 - 16.2^\circ\text{C}$) and the precipitation in two first decades was close to PD as well ($26.8 - 28.9 \text{ mm}$). Those weather conditions were acceptable for potato flowering and beginning of new yield tuber formatting. The air temperature in the second part of vegetation was $3-7^\circ\text{C}$ higher than PD. The precipitation exceeded PD by 24 – 91% in third decade of June and following July and August. The precipitation was mostly like heavy showers, what made soil heavy. Air temperature more than 25°C in some days affected potato tubers formation, tubers could become irregular. The humidity on leaves after rain and lower air temperature during August were favourable for late blight (*Phytophthora infestans*) development. The disease was controlled with fungicides in conventional field. The late blight damaged leaves and interrupted tuber development in organic field in the last decade of August. The haulm was cut in last decade of August. The tubers were harvested in the beginning of September. Too high humidity in soil made tubers more susceptible to mechanical damages. The bacterial pathogens had possibility to contaminate tubers, during storage tuber rooting could appear.

B. Tubers

In cooperation with the State Priekuli Plant Breeding Institute (Latvia), six potato (*Solanum tuberosum* L.) genotypes were grown in organic and conventional field in 2010. The characterisation of potato genotypes: S-03135-10 – early maturity, round tubers, skin light pink with pink eyes, flesh light yellow. S-99108-8 – early maturity, round oval tuber shape, skin light yellow with pink eyes, flesh yellow. S-01063-5 – medium late maturity, oval tuber shape, skin and flesh yellow. ‘Agrie Dzeltenie’ – early maturity, oval round tuber shape, skin russet yellow, flesh yellow. ‘Prelma’ – medium early, oval tubers, skin and flesh yellow. ‘Imanta’ – medium late maturity, tubers oval round, skin light yellow with red eyes, flesh white.

C. Storage

Potatoes were stored at an air temperature of $5 \pm 1^\circ\text{C}$ and at a relative air humidity of $80 \pm 5\%$.

D. Carotenoid Analysis

Carotenoids were analyzed by spectrophotometric method (with the UV/VIS spectrophotometer Jenway 6705) at 440 nm [20]. A sample of 2g of homogenized marmalade sample was placed in 100 ml conic retort and 20 ml 96% ethanol was added. The sample was stirred on magnetic stirrer for 15 min then 25 ml of petrol ether was added and continued to stir for one hour. After 3–4 hours when both layers were completely divided, the top yellow layer was used for further detection of carotenoids at 440 nm. Carotene equivalent (KE) was found, using a graduation curve with $\text{K}_2\text{Cr}_2\text{O}_7$. The content of carotenoids ($\text{mg } 100\text{g}^{-1}$) was calculated by equation (1):

$$X = \frac{12.5 \cdot 100 \cdot KE}{36 \cdot a}, \quad (1)$$

where 12.5 and 36 coefficients for relationship between $\text{K}_2\text{Cr}_2\text{O}_7$ and carotenoids;

KE – carotene equivalent by graduation curve;

a – sample weight, g.

E. Colour Analysis

The colour of potato samples was measured by “Color Tec-PCM” device (USA). For evaluation of the colour 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 colour measurement. Potato samples were covered by a transparent PP film (“Forpus”), thickness of $25 \mu\text{m}$, to avoid direct contact between the aperture of the measuring device and the product. The colour 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 analysis, “ColorSof QCW” software was used.

The colour was defined by three co-ordinates according to the CIE (*Commission Internationale de l'Eclairage*) lab system: L^* (lightness) – the vertical co-ordinate that runs from $L^* = 0$ (black) through grey to $L^* = 100$ (white); a^* (redness) – the horizontal co-ordinate that runs from $-a^*$ (green) through grey to $+a^*$ (red); and b^* (yellowness) – another horizontal co-ordinate that runs from $-b^*$ (blue) through grey to $+b^*$ (yellow) [21].

F. Dry Matter

The moisture content was determined by ISO 6496:1999 standard method. Each sample was heated in an oven at $103^\circ\text{C} \pm 2^\circ\text{C}$ for 4 h. During this period water evaporation corresponded to weight loss.

G. Statistical Analysis

For statistical analysis, the data were processed using the S-PLUS 6.1 Professional Edition software. Data are presented as a mean \pm 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 $\alpha = 0.05$.

III. RESULTS AND DISCUSSION

Carotenoid content in conventionally cultivated potatoes before period of storage varies from 88.433 to 171.930 $\mu\text{g } 100 \text{ g}^{-1}$ FW while organically cultivated – varies from 84.911 to 159.309 $\mu\text{g } 100 \text{ g}^{-1}$ FW (Fig. 1). In both cultivation systems the highest amount of carotenoids was determined in the potato genotype S-01063-5 while the lowest – Imanta.

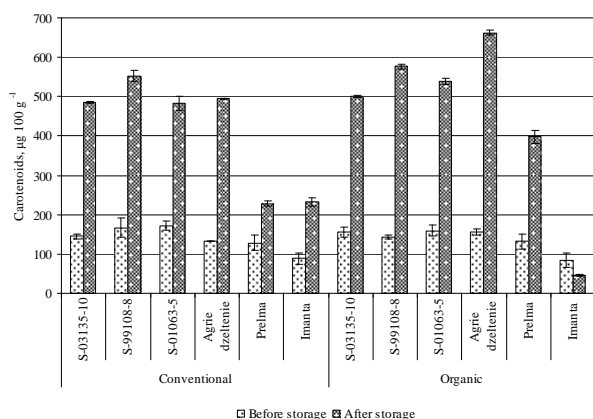


Fig. 1 Carotenoid amount in organically and conventionally cultivated potato genotypes before and after storage

One of the factors might play an important role in the amount of carotenoids is the maturity of potatoes. Katikova et al. and Morris et al. has reported that total carotenoids content was found to be higher in immature tubers and it decreased with tuber maturity [22], [23].

Another factor is storage which affects the nutritional value of potatoes during the period of storage. Blessington et al. has found that carotenoid amount has increased after potatoes were stored in three different storage conditions [24].

The results of current research show that after the period of storage, carotenoid amount has increased and in conventionally cultivated potatoes it varies from 228.514 to 552.434 $\mu\text{g } 100 \text{ g}^{-1}$ while in organically cultivated potato genotypes – from 45.485 to 662.699 $\mu\text{g } 100 \text{ g}^{-1}$ FW. One of the reasons carotenoid content has increase is explained by the changes of the DM content during the period of storage and it varies pre genotype (Fig. 2).

The highest dry matter (DM) content before and after period of storage was found in the genotype Imanta cultivated in both conditions organically and conventionally.

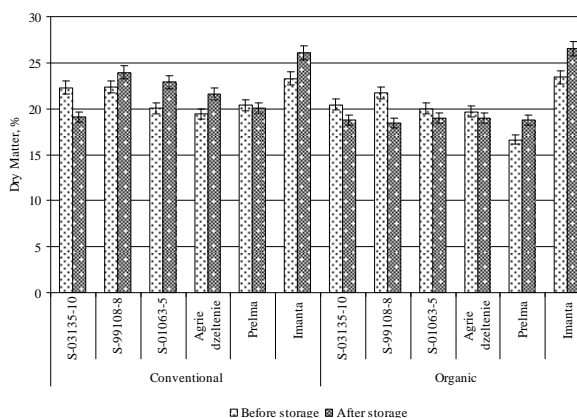


Fig. 2 Dry matter in organically and conventionally cultivated potato genotypes before and after storage

Statistically obtained results show that there was no affect of genotype and cultivation conditions ($p > 0.05$) on the amount of carotenoids while there was affect of storage ($p < 0.001$).

Comparing to other authors' research results, Iwamzik, Tevini, Stute and Hilbert (1983) reported a range of 27-74 $\mu\text{g } 100 \text{ g}^{-1}$ FW for carotenoids in white fleshed potato genotypes [25]. Breithaupt and Bamedi (2002) investigated the carotenoid pattern of four yellow-fleshed and four white-fleshed German potato cultivars (*Solanum tuberosum* L.). The carotenoid pattern was dominated by violaxanthin, antheraxanthin, lutein, and zeaxanthin, which were present in different ratios, whereas neoxanthin, β -cryptoxanthin, and β -carotene were only minor constituents. Antheraxanthin was found to be the only carotenoid epoxide present in native extracts. The total concentration of the four main carotenoids reached 175 $\mu\text{g } 100 \text{ g}^{-1}$ FW [26].

The colour of potato is one of the indicators might predict the amount of carotenoids will be in potatoes. The results of the research show that potato genotype Imanta with the white flesh colour has the lowest amount of carotenoids only after period of storage when it was conventionally cultivated carotenoid amount was higher in Imanta comparing to yellow flesh genotype Prelma.

The correlation between the factor of colour a^* and the amount of carotenoids (results expressed on DW) was found to be closed with the determination coefficient – $R^2 = 0.4522$ (Fig. 3).

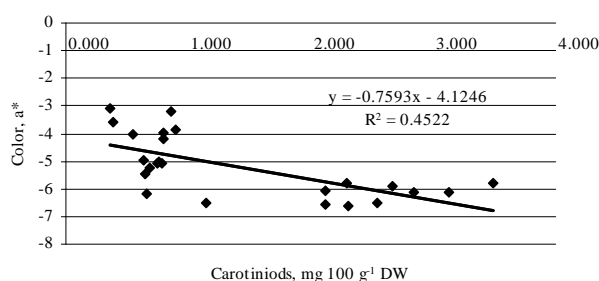


Fig. 3 The correlation between colour a^* and carotenoid amount in organically and conventionally cultivated potato genotypes

TABLE I
THE COLOUR OF POTATO FLESH (CIE LAB SYSTEM)

Genotype	Colour, L*		Colour, a*		Colour, b*	
	Before storage	After storage	Before storage	After storage	Before storage	After storage
Conventional						
S03135-10	67.74	67.97	-5.45	-6.51	33.24	33.9
S99108-8	68.99	66.18	-5.05	-6.64	37.7	36.5
S01063-5	67.26	68.46	-3.19	-6.55	30.49	34.8
Agrie						
dzeltene	67.67	64.48	-5.24	-5.79	33.57	32.03
Prelma	70.6	64.38	-4.97	-6.53	28.04	26.66
Imanta	70.69	68.65	-3.61	-3.86	20.18	16.28
Organical						
S03135-10	68.54	64.88	-5	-5.93	33.87	33.08
S99108-8	71.31	67.1	-6.16	-6.14	37.47	36.07
S01063-5	65.96	68.2	-4.21	-6.12	33.42	35.42
Agrie						
dzeltene	70.39	66.6	-5.05	-5.79	33.57	31.99
Prelma	65.78	65.01	-3.99	-6.05	27.15	29.09
Imanta	71.96	67.91	-3.1	-4.03	17.78	17.82

The results of the colour show that in some genotypes it has been changed with the tendency to decrease in factor L* after period of storage which describes the lightness of the flesh of the potato with the same tendency to decrease of the factor b* which represents the colour from blue to yellow while the factor a* - from green to red has increased in all genotypes after period of storage. Storage time has significantly affected the colour (L* and a*) of the flesh ($p < 0.01$) while genotype has an important role on colour indicator a* ($p < 0.05$) and b* ($p < 0.001$). Changes of the colour mainly could be influence by the loss of moisture. Moisture content determined for potatoes (Fig. 2 dry matter presented) was significantly different at the time of harvesting and after storage, and this can be related to the increase in the transpiration rate of the tubers due to tuber life processes and sprouting [27], [28]. This increase in the evaporation process is due to high permeability of the epidermis of the sprouts and due to the increase in the evaporation surface [27]–[30]. Transpiration causes water loss, and as a consequence increases the content of all the components of the dry matter.

IV. CONCLUSION

From the results of the research can be concluded that carotenoid amount in potato genotypes can be significantly affected by the time of storage ($p < 0.01$) while no significant affect on carotenoid amount was not affected ($p > 0.05$) by genotype and cultivation conditions (organic and conventional). Strong correlation was found between colour and carotenoid amount.

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